Putting community health workers on the map: Toward a geography of community health workers

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DECLARATION

I declare that "***Putting community health workers on the map: Toward a geography of community health workers***" is my original work, and that it has not been submitted for any degree in this or any other university. I declare that all sources cited or quoted have been indicated and acknowledged by complete references.

Nicholas Oliphant

Signature: *Nicholas Oliphant*

DEDICATION

This is dedicated to my wife, Michael Crook, my best friend, and forever partner. You are an endless well of support. I hope I am as much for you.

To my children, William and Henry, who were born early in this journey. When I see your smiling faces, the glint in your eyes, I am reminded of why I do what I do. Thank you.

To all community health workers everywhere.

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I wish to express my most heartfelt gratitude and sincere thanks to all the people that have helped me on this journey. In particular:

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My supervisor, Prof. David Sanders, who inspired me and countless others to fight injustice, to be better allies, and always question the solution. David, I know you are somewhere fishing in a quiet stream, the guide laughing at one of your dirty jokes. Rest in peace my friend.

Prof. John Mason, my first academic mentor, who took me under his wing until I could fly. John, my wings will never be as big as yours, but I promise to pay it forward with what I have. I'll see you again one day. Rest in peace my friend. Corinne Carolissen and the administrative officials in the School of Public Health at the University of Western Cape for their patience, guidance, and support.

Linda and Paul Oliphant, my parents. Linda, who started her career as a public health nurse serving the poorest barrios of El Paso and worked forty-six years in the service of health for all. Paul, a social worker, who spent a lifetime defending the poor from the vagaries of our human systems, fighting for justice and greater equity. You both instilled in me the importance of caring for others, hard work, and fighting injustice. You were my first public health mentors; you opened my eyes to this path. Thank you.

Thanks to all community health workers everywhere.

#CHWsCount #CountCHWs #PayCHWs

ACRONYMS/ABBREVIATIONS

ASC	Community health agent, full-time paid type of CHW in Mali and Niger (French acronym)
CHW	Community health worker
CS	Health post (French acronym)
CSCom	Community health centre (French acronym)
CSI	Integrated health centre (French acronym)
CSRef	Referral health facility (French acronym)
EPOC	Effective Practice and Organization of Care
GFF	Global Financing Facility
GIS	Geographic information systems
GRADE	Grading of Recommendations, Assessment, Development, and Evaluation
HIV	Human immunodeficiency virus
HLMA	Health Labour Market Assessment
HR	Hazard ratio
HRH	Human resources for health
iCCM	Integrated community case management
ILO	International Labour Organization
IMCI	Integrated management of childhood illness
ITSA	Interrupted time series analysis
LMIC	Low- and middle-income countries
MOHS	Ministry of Health and Sanitation
MOPH	Ministry of Public Health
MSDS	Ministry of Health and Social Development
MSH	Management Sciences for Health
Pf	*Plasmodium falciparum*
PHC	Primary health care
RC	Community relay, volunteer type of CHW in Mali and Niger (French acronym)
RR	Risk ratio
SDG	Sustainable Development Goal
SPHC	Selective primary health care
U5	Under-five
UHC	Universal health coverage
UNICEF	United Nations Children's Fund
USD	United States dollar
VHW	Village health worker
WHO	World Health Organization

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ABSTRACT

Background

In many contexts community health workers (CHWs) are intended to expand the geographical accessibility of integrated primary health care (PHC) services at community level, including prevention, promotive, and curative health services such as integrated community case management (iCCM). However, there is little empirical evidence of the contribution of CHWs to geographical accessibility of integrated PHC services at community level, and approaches for optimising the scale and deployment of CHWs to maximize the geographical accessibility of integrated PHC services in low- and middle-income countries (LMICs). Similarly, there is little understanding of the effect of iCCM, given geographical accessibility to a CHW providing iCCM, on intervention coverage and mortality among children younger than five years of age in LMICs.

Aim

To improve understanding of the contribution of existing CHWs networks to geographical accessibility of integrated PHC services at community level, including iCCM, approaches for optimizing the scale and deployment of CHWs to maximize geographical accessibility of integrated PHC services at community level, and the effectiveness of iCCM with the aim of informing health policy and planning.

Methods

This study was based on geospatial analyses in Niger, Sierra Leone, and Mali, and a systematic review of iCCM in LMICs. Four studies were conducted. Studies 1-3 used geospatial analysis to estimate the contribution of CHWs to geographical accessibility of integrated PHC services at community level, including iCCM. They also explored approaches for optimizing the scale and deployment of CHWs to maximize geographical accessibility of integrated PHC services. Study 4 used a systematic review to assess the effects of iCCM on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events, and coverage of careseeking for children younger than five years of age in LMICs.

Results

In Niger, the percent of the population within 60 minutes walking to the nearest community

health post with a CHW increased from 0.0% to 17.5% between 2000 and 2013. Optimal deployment of 7 741 additional CHWs could increase geographical coverage of the health facility plus CHW network from 41.5% to 82.9%. Hypothetical optimized CHW networks were more efficiently deployed than existing networks by 32.3%–47.1%, depending on targeting metric.

In Sierra Leone, the percent of the population within 30 minutes walking to the nearest CHW with pre-service training increased from 16.1% to 80.4% between 2000-2015. Ministry of Health and Sanitation-defined easy-to-reach and hard-to-reach areas that should have been targeted for CHW deployment, were less well covered, with 19.2% and 34.6% of the population in 2015 beyond a 30-minute walk to a CHW, respectively. Hypothetical optimized CHW networks in these areas were more efficiently deployed than existing networks by 22.4%-71.9%, depending on targeting metric.

In Mali, a hypothetical optimized network of 15 843 ASC would ensure that 77.3% of the population beyond 5 km of the CSCom (community health centre) and CSRef (referral health facility) network would be within a 30-minute walk of an ASC. The same optimized network would cover an estimated 59.5% of U5 deaths and 58.5% of *Plasmodium falciparum* (*Pf*) malaria cases. There were no important differences in geographic coverage of the estimated population, U5 deaths, and *Pf* malaria cases when prioritizing/targeting CHW deployment based on the estimated population, U5 deaths, or *Pf* malaria cases, indicating equivalence in geographic coverage for these outcomes across approaches for optimizing the scale and deployment of CHWs.

In the systematic review of iCCM in LMICs, based on a comparison with usual facility care, we concluded we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness (RR 0.96, 95% CI 0.77 to 1.19; 2 CBA studies, 5 898 children; very low-certainty evidence); iCCM may have little to no effect on neonatal mortality (HR 1.01, 95% 0.73 to 1.28; 2 trials, 65 209 children; low-certainty evidence); we are uncertain of the effect of iCCM on infant mortality (HR 1.02, 95% CI 0.83 to 1.26; 2 trials, 60,480 children; very low-certainty evidence) and under-five mortality (HR 1.18, 95% CI 1.01 to 1.37; 1 trial, 4 729 children; very low-certainty evidence); iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness by 68% (RR 1.68, 95% CI 1.24 to 2.27; 2 trials, 9 853 children; moderate-certainty evidence). None of the studies reported quality of care,

severity of illness or adverse events for this comparison.

Conclusion

CHWs make important contributions to geographical accessibility of integrated PHC services at community level, including iCCM, in Niger, Sierra Leone, and Mali however the scale and deployment of CHWs has not been optimized and gender inequalities in CHW employment persist in Niger and Sierra Leone. In Mali, the equivalence of geographic coverage across outcomes of interest and approaches for optimizing the scale and deployment of CHWs may provide policy makers and planners with confidence that trade-offs between the approaches are negligible and that any of the approaches assessed in the study will perform equally well across outcomes. When compared to usual facility services, iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness. However, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness. iCCM may have little or no effect on neonatal mortality and we are uncertain of the effect on infant mortality or under- five mortality. Given the very low- to moderate-certainty evidence for all reported outcomes in the systematic review, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, evidence was not reported for three primary outcomes: quality of care, case load or severity of illness at health facilities, and adverse events – research is needed on these outcomes.

The evidence presented in this thesis highlights important inefficiencies in the scale and deployment of CHWs, , and weaknesses across health policy and systems needed for CHWs to effectively deliver integrated PHC services such as iCCM. It builds on existing conceptual frameworks and normative guidance, underscoring the value of integrating geospatial and gender analyses into planning for the scale-up and deployment of CHWs in the context of broader health and care workforce planning, along with assessments of health policy and systems, for maximizing geographical accessibility, care seeking, utilization, and quality of integrated PHC services, enhancing gender equality of the CHW workforce, and securing decent work for CHWs everywhere. It also underscores the need for moving beyond piecemeal, short-term approaches to investment in PHC, focused mostly on training health and care workers on discrete interventions, toward more comprehensive health policy and systems strengthening efforts in alignment with WHO and UNICEF normative guidance.

Further research should be undertaken in additional contexts using geospatial analysis to estimate the contribution of CHWs to geographical accessibility at national scale and approaches for optimizing the scale and deployment of CHWs. Further research assessing the effects of iCCM, and effect modifiers is also needed.

CHAPTER ONE: INTRODUCTION

This introduction provides an overview of the research in the context of the literature on primary health care (PHC) and the health care workforce, including a section on community health workers (CHWs). This is followed by conceptualizations of geographical accessibility and iCCM. The evidence on the contribution of CHWs to the geographical accessibility of integrated PHC services and the effect of iCCM are also reviewed. The chapter concludes by presenting the study setting, problem statement, aim and objectives, and provides an overview of the structure of the thesis.

Background

Renewed focus on primary health care

It has been forty-five years since the Alma-Ata Declaration in 1978. The concept of PHC has been defined and redefined over the years from the Alma-Ata Declaration in 1978 to the Astana Declaration in 2018 (WHO and UNICEF, 2020). In the last fifteen years, the mainstream global health community has called for a renewed focus on PHC and for a reorientation of health systems around PHC as a means to achieve universal health coverage (UHC) (WHO, 2008; Walley *et al*., 2008; Frenk, 2009; Rohde *et al*., 2008; Balabanova *et al*., 2013; WHO and UNICEF, 2018; Ghebreyesus *et al*., 2018; Kluge *et al*., 2018; The Lancet, 2018; Watkins *et al*., 2018; WHO and UNICEF, 2018a; WHO and UNICEF, 2018b; WHO and UNICEF, 2020; Rasanathan *et al*., 2020; Ferigato *et al*., 2020; Usuelli *et al*., 2020; Hanson *et al*., 2022). The Declaration of Astana envisioned "Primary health care and health services that are high quality, safe, comprehensive, integrated, accessible, available and affordable for everyone and everywhere, provided with compassion, respect and dignity by health professionals who are well-trained, skilled, motivated and committed" (WHO and UNICEF, 2018a). As part of the Astana Declaration, WHO and UNICEF developed "A vision for primary health care in the 21st century: Towards universal health coverage and the Sustainable Development Goals" which defines PHC as "A whole-of-society approach to health that aims to maximize the level and distribution of health and well-being through three components: (a) primary care and essential public health functions as the core of integrated health services; (b) multisectoral policy and action; and (c) empowered people and communities" (WHO and UNICEF, 2018b).

Others have called for a bolder PHC agenda, aligned to calls in the Alma-Ata Declaration not only for a reorientation of health systems within the existing economic, political, and social order but the establishment of a new international economic order addressing the colonial and

neoliberal economic roots of health inequity and for addressing the social determinants of health beyond the health sector (e.g., food and nutrition, gender equality, water and sanitation, economic inequality, vulnerability to environmental hazards and climate change) (Sanders *et* al., 2019; Sanders *et al*., 2011; Sanders *et al*., 1985; Baum *et al*., 1995; Kallon, 2020).

WHO and UNICEF's vision for PHC is further described in an "Operational framework for primary health care: Transforming vision into action" (WHO and UNICEF, 2020). In the operational framework for PHC, WHO and UNICEF provide a theory of change whereby the three components of the "PHC Approach" are operationalized through fourteen "PHC levers" and effect "PHC Results", including improved access, utilization and quality, improved participation, health literacy and care seeking, and improved determinants of health (see Figure 1 below).

The features of PHC from the Declaration of Astana (WHO and UNICEF, 2018b) and the WHO and UNICEF operational framework (WHO and UNICEF, 2020) outlined above were also central to the PHC approach as defined by WHO and UNICEF (WHO and UNICEF, 2020). This was also true of PHC as defined in the Alma-Ata Declaration, where universal geographical accessibility to PHC services – with workers at all levels trained both "socially and technically" (Sanders D. *et al*., 2019) -- was an explicit feature: "Primary health care is essential health care…made universally accessible to individuals and families in the community…bringing health care as close as possible to where people live and work" (WHO, 1978). This conceptualization of PHC included the "principles of equitable provision of services, comprehensive care, intersectoral action, community involvement and appropriate technology" (Sanders *et al*., 2011). Improving health inequity (e.g., addressing systematic, socially produced (and thereby avoidable) differences in health by reaching populations with the greatest needs first) was central to the vision of *how* PHC and its call for universal geographical accessibility should be implemented (Braverman *et al*., 2003; Sanders *et al*., 2011; WHO and UNICEF, 2020, Kallon, 2020).

Despite wide recognition of the centrality of access to integrated PHC services to the PHC approach, WHO has estimated that roughly half of the world's population lacks access to PHC services and research suggests geographical accessibility of PHC services remains inequitable, particularly in LMICs but also in middle- and high-income countries (WHO *et al*., 2017; Noor *et al*., 2006; Gabrysch *et al*., 2009; Blanford *et al*., 2012; Huerta Munoz *et al*., 2012; Oosterveer *et al*., 2015; McGrail *et al*., 2015; Tanser *et al*., 2006; Crooks *et al*.,

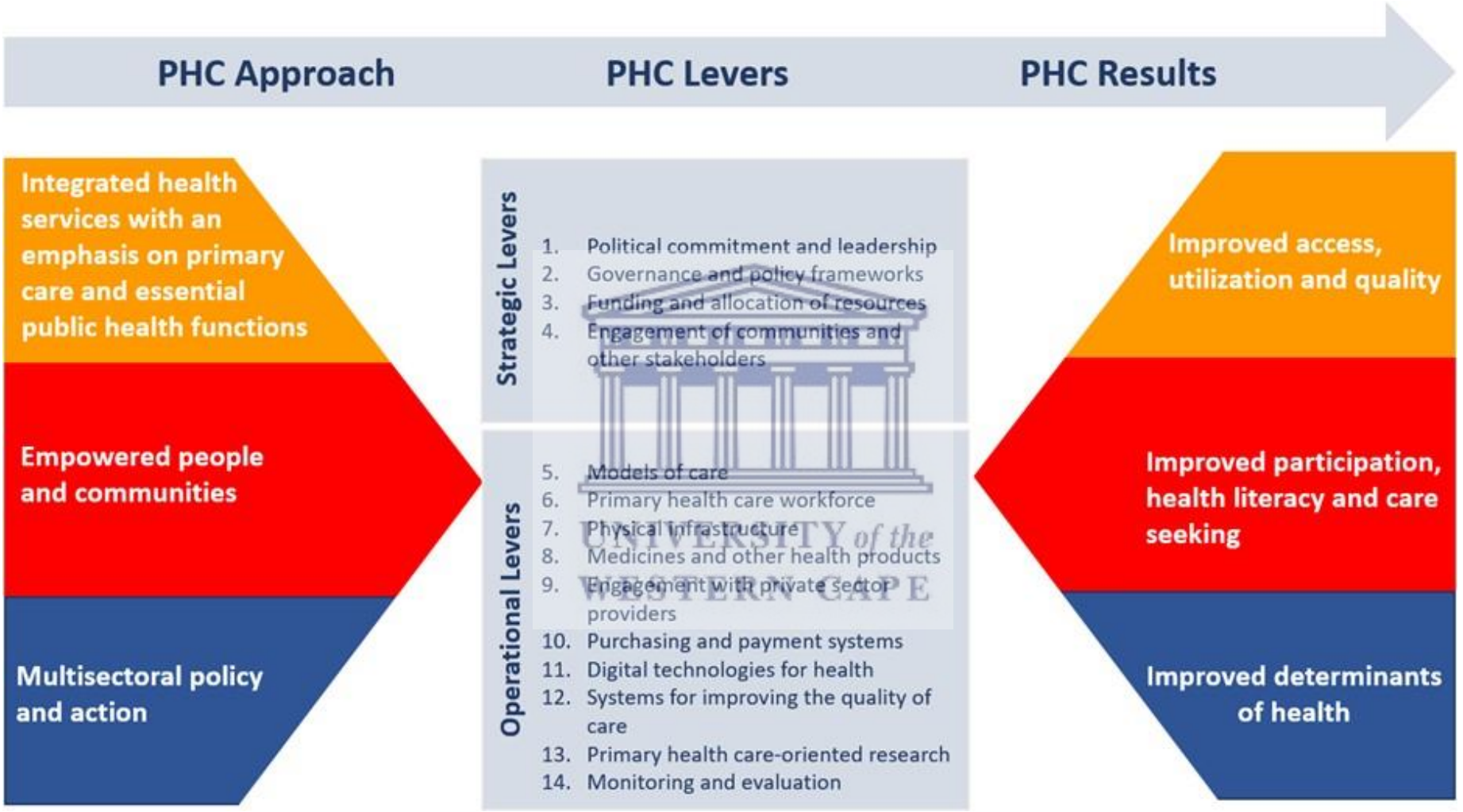
2012). The latest refocus on PHC provides an opportunity to move beyond the selective PHC of the past and rethink strategic and operational levers of PHC, such as models of care, PHC workforce planning, and multidisciplinary PHC teams to expand geographical accessibility of PHC services to populations most in need while also addressing social determinants of health such as gender inequality and poverty (Cueto, 2004; Doherty *et al*., 2010; WHO and UNICEF, 2020; WHO, 2022; Dahn *et al*, 2015).

Focus on Children - Integrated community case management

High mortality rates among children under-five years of age (i.e., 0-59 months) have persisted in many LMICs (Perin J *et al*., 2021). Lower respiratory infections, diarrhoea, malaria, and newborn sepsis have consistently been among the leading causes of under-five deaths in these contexts (Perin J *et al*., 2021). Prevention and treatment of the major causes of child death are important components of PHC for children.

In the 2000s, the WHO and UNICEF, in collaboration with other development partners, developed an approach – now known as integrated community case management (iCCM) – to bring treatment services for children 'closer to home' and advocated for LMICs to adopt it (Bennett *et* al., 2015; Diaz *et* al., 2014; WHO/UNICEF 2012). iCCM is an extension of IMCI – providing treatment services outside the healthcare facility at community level (Bennett et al., 2015; Gera et al., 2016); and c-IMCI – the original community-based component of IMCI which focused on promoting key family and community practices for improving child health (WHO, 1997). iCCM is an approach to providing integrated case management services for two or more illnesses – including diarrhoea, pneumonia, and malaria (the latter in malaria- affected countries) – among children under-five at community level by lay health workers (also called community health workers (CHW)) where there is limited access to health facility-based case management services (WHO/UNICEF 2012). Case management services as defined here include assessment, treatment, and referral services, following locally adapted WHO/UNICEF guidelines (WHO/UNICEF, 2012; WHO, 2011). In some contexts, iCCM may also include case management services for acute malnutrition and newborn illness (Rasanathan 2014; WHO 2007; WHO, 2011). iCCM is considered an equity-focused approach in that it is primarily implemented in rural and hard-to-reach areas with limited access to facility-based case management services (WHO/UNICEF 2012). The transfer of iCCM policy from the global level to national levels has been complex, characterised by "early" and "later" adopters and variation in the role of international organisations and policy transfer strategies used (Bennett *et al*., 2015). Overall,

Figure 1. WHO and UNICEF Primary health care theory of change



Source: Figure 2 in WHO and UNICEF, 2018.

the adoption of iCCM and its adaptation to national contexts by ministries of health has been rapid, particularly in SSA where most countries have some form of written policy to enable implementation of iCCM (Rasanathan *et al*., 2014).

Renewed focus on the health and care workforce

Linked to the refocus on PHC, has been a refocus on the health and care workforce (WHO, 2016a; WHO and UNICEF, 2020; WHO, 2022; Women in Global Health, 2022). In its Working for Health Action Plan 2022-2030, the WHO defines health and care workers as "all of those who are engaged in actions with the primary intent of enhancing health. This includes all of those who provide direct personal care services in the home, in health care and residential settings, assisting with routine tasks of daily life, and performing a variety of other similar routine tasks" (WHO, 2022). The WHO has positioned the health and care workforce, also known as human resources for health (HRH) as vital to the achievement of a range of Sustainable Development Goals (SDGs), including SDG 3 (good health and well-being) through service delivery, SDG 1(end poverty) through better health of populations and employment, SDG 4 (quality education) through better health of populations, including students and teachers, and education of health and care workers, SDG 5 (gender equality) through addressing health inequity and gender inequality in the health and care workforce (WHO estimates that women make up 67% of the health and care workforce), and SDG 8 (decent work and economic growth) through employment of health and care workers and improved health of populations (WHO, 2022; WHO, 2016b; WHO, 2020; Global Health Workforce Network and WHO, 2020; Boniol *et al*., 2019; Wiskow, 2017; OECD, 2021; Bourgeault *et al*., 2020; Haldane *et al*., 2021; Legido-Quigley *et al*., 2020; Ballard *et al*., 2021a).

The WHO has projected a shortfall of 18 million health workers by 2030, primarily in LMICs, with the largest deficit in the Africa region (WHO, 2016a). The WHO estimated the needs-based shortage of health workers in the Africa region will increase by 45% from 4.2 million in 2013 to 6.1 million in 2030 (WHO, 2016a).

Challenges facing the health and care workforce have been identified, most notably

> labour market failures, health emergencies [such as the HIV epidemic, the COVID-19 pandemic], health and demographic trends [increasing demand for health and care workers for PHC, in particular], gender inequality and substantial under-investment…difficulties in attracting and retaining workers…shortages [and

> maldistribution], which paradoxically exist side by side with workforce underutilization and unemployment (especially among young workers)…suboptimal [and unsafe] working conditions and neglect of labour protection and rights, contribute to the international mobility of and attrition of workers, which further exacerbate worker shortages. Furthermore, pervasive inequalities in the workforce,
> particularly among women and youth [making up the largest segments of the informal and unpaid health and care workforce]…[Challenges] underpinned by limited health system capacity, budgetary constraints and inadequate and/or inefficient planning and investment (WHO, 2022).

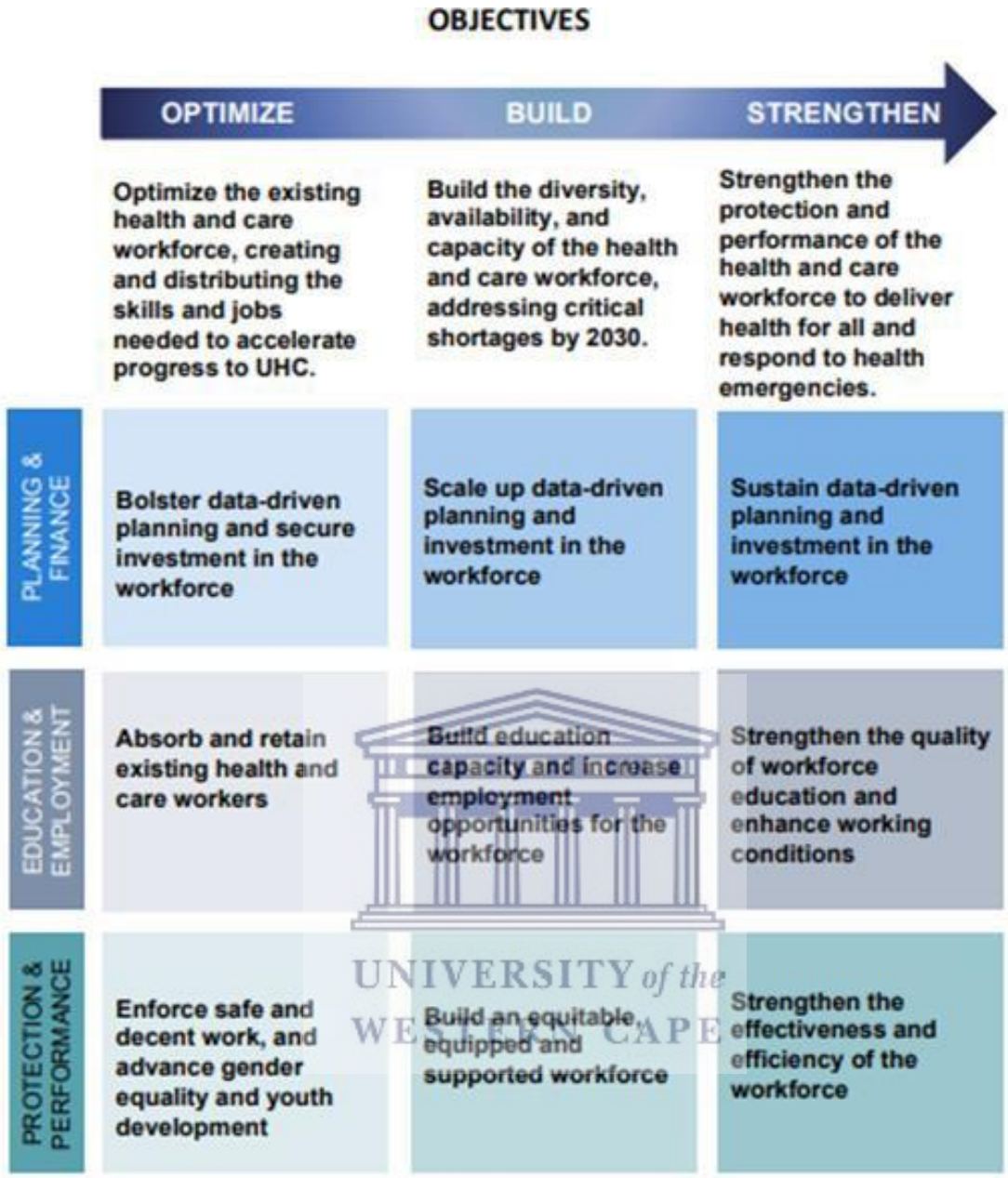
The causes of the health and care workforce crisis in LMICs include those noted above, with root causes linked to factors noted in the analysis by Sanders *et al.* (2019) in their riposte to the optimism of the Astana Declaration, such as colonial histories, the harsh effects of neoliberal economic policies, the debt crisis of the 1980s and structural adjustment programs that followed, including austerity measures such as public sector wage bill ceilings imposed by the IMF and multilateral development banks as conditions for loans, caps on out-migration to high-income countries (i.e., inadequate regulation of the health labour market), the disproportionate effects of the HIV epidemic, Ebola epidemic, and now the COVID-19 pandemic (Sanders *et al*, 2019; Chen *et al*., 2004; Crisp *et al*., 2014; Lewin *et al*., 2008; Evans *et al*., 2015; World Health Assembly, 2021; WHO, 2022b). Also of note, the for-profit private health sector has little incentive to extend access to poor and remote populations that cannot pay for services (Gwatkin *et al*., 2004; World Bank, 1993).

To respond to the World Health Assembly Resolution 74.14, which called for "a clear set of actions for accelerating investments in health and care worker education, skills, employment, safeguarding and protection to 2030", the WHO developed a "Working for Health progression model" with three objectives (Optimize, Build, and Strengthen) across three areas of application (Planning and Finance, Education and Employment, and Protection and Performance) shown in Figure 2 below (WHO, 2022).

Renewed focus on CHWs

CHWs have existed in some form since at least the 1950s (Lehmann *et al*., 2007). Early examples include the Chinese barefoot doctors and Thai village health volunteers (Zhu *et al*., 1989; Hsiao, 1984; Sidel, 1972; Shi, 1993; Kaufmann *et al*., 1997; Sringernyuang *et al*., 1995). Early experiences in Africa include the village health workers (VHWs) in Maradi,

Figure 2. WHO Working for Health progression model



Source: Figure 1 in Working for Health progression model. WHO, 2022

Niger in the 1960s and later the VHW initiatives in Tanzania and Zimbabwe, the latter arising in the context of political struggle and decolonization (Fournier *et al*., 1975; Lehmann *et al*., 2007). These early experiences helped situate CHWs as a prominent feature within the concept of PHC declared at Alma-Ata and subsequent government health efforts to implement PHC in the 1970s and early 1980s (Lehmann *et al*., 2007; Fournier *et al*., 1975; Aye *et* al., 2018; World Bank, 1993). National CHW programs (as they were often called) collapsed in the 1980s due to fiscal pressures from the debt crisis and the structural adjustment programs and austerity measures that followed (as noted above for the broader health and care workforce), the shift in the predominant global health paradigm away from PHC toward selective PHC (SPHC), and challenges with scaling and sustaining effective programs (Lehmann *et al*., 2007; Gilson *et al*., 1989; Aye *et al*., 2018). In the 1990s the support for CHWs continued to wane and was exacerbated further with the emergence of the Global Health Initiatives and renewed enthusiasm for vertical programs (Haines *et al*., 2007; Doherty *et al*., 2010; Baum *et al*., 1995). The small-scale CHW programs that remained were re-aligned to fit the dominant paradigm of SPHC (Lehmann *et al*., 2008; Cueto, 2004). Roles of CHWs increasingly focused narrowly on providing selected cost-effective interventions of known efficacy, sometimes becoming specialized, single disease-focused (e.g., malaria, HIV, tuberculosis) CHWs for vertical programs versus broader PHC needs and serving as agents of community change (Lehmann *et al*., 2008; Cueto, 2004; Doherty *et al*., 2010). Their availability to the community declined and their accountability shifted to the health system and funders (Lehmann *et al*., 2008; World Bank, 1993).

Over the last fifteen years, within and concurrent to the calls for renewed focus on PHC and the health and care workforce, the global health discourse has called for renewed focus on CHWs (Lewin *et al*., 2010; Kane *et al*., 2010; Herman, 2011; Christopher *et al*., 2011; Tulenko *et al*., 2013; Vaughan *et al*., 2015; Kok *et al*., 2015; McCollum *et al*., 2016; Nkonki *et al*., 2017; Kok *et al*., 2017; Ballard *et al*., 2017; Scott *et al*., 2018; WHO 2016a; WHO 2016b; WHO, 2018; WHO, 2020; WHO, 2022; WHO and UNICEF, 2018; WHO and UNICEF, 2020; Ballard *et al*., 2020, Ballard *et al*., 2021a; Ballard *et al*., 2022a; Gichaga *et al*., 2021; Zulu *et al*., 2021; Ballard *et al*., 2022b). The renewed focus on CHWs has arisen, in part, out of increasing recognition by policymakers, planners, and the mainstream global health community that community health work is work and CHWs are workers (CHWs have been recognized as an occupational unit group by the International Labour Organization of

the United Nations and the WHO since at least 2012) (ILO, 2012; WHO, 2018). CHWs themselves have played an important role in this shift through organizing (e.g., forming CHW associations and unions or joining existing unions), mobilizing, advocating, and making demands, striking, and engaging in social dialogue (Shoba, 2019; Public Services International, 2020; CHW Advocates, 2021). The WHO, in its "Working For Health Action Plan", singles out CHWs and home-based caregivers, who are predominantly women, for particular attention with regard to social protection, working conditions, and safety as these workers are disproportionately vulnerable to exploitation and precarious work conditions through informal or unpaid health work (WHO, 2022; Women in Global Health, 2022; Nepomnyashchiy *et al*., 2020; Ballard *et al*., 2021a; Aye Baba *et al*., 2018; Kallon, 2020; Alperstein, 2020; Public Services International, 2020, Public Services International, 2021). WHO argues that recognizing community health work as work and CHWs as workers per the ILO International Standard Classification of Occupations and formalizing the employment of CHWs within the formal health sector has strong potential for improving gender equality, reducing poverty, especially for women, and improving inclusive economic growth (WHO, 2022, WHO, 2018, ILO, 2012).

The renewed focus on CHWs is also due to increased evidence (and recognition of this evidence by the policymakers, planners, and the mainstream global health community before and since the COVID-19 pandemic) on the important contributions CHWs can make to the health of populations, to increasing access to high quality, integrated PHC services, to pandemic preparedness, and to the strength and resilience of health systems and communities, particularly when they are well-supported following WHO normative guidance (WHO, 2018; WHO, 2020; WHO, 2022; WHO and UNICEF, 2018; WHO and UNICEF, 2020; Ballard *et al*., 2022a). The "WHO Guideline on health policy and systems support to optimize community health worker programming" summarizes the state-of-the-art evidence on CHWs (in all their forms and variations) and provides recommendations "of relevance to health systems of countries at all levels of socioeconomic development" (WHO, 2018). The WHO guidelines highlight the potential of CHWs as part of the broader health and care workforce, working as members of inter-professional, multidisciplinary PHC teams (WHO, 2018). This focus is reinforced in the WHO and UNICEF PHC framework and WHO's Working for Health Action Plan (WHO and UNICEF, 2020; WHO, 2022). Together with actions along the strategic and operational levers of PHC, such as more efficient expansion of physical infrastructure (e.g., health facilities) and re-designed models of care aiming to

expand geographic accessibility to and equity of PHC health services at community level, there is strong potential for CHWs to make important contributions to multiple SDGs as noted above for the broader health and care workforce (WHO, 2018; WHO and UNICEF, 2020; WHO, 2022).

Tools and approaches for PHC planning

The WHO and UNICEF Operational Framework for PHC and WHO Working for Health 2022-2030 Action Plan refer to several tools and resources for health sector planning with a focus on PHC (WHO and UNICEF, 2020; WHO, 2022). Most relevant to this thesis are the tools and resources for planning physical infrastructure e.g., Accessmod (Accessmod, 2021) and the health and care workforce e.g., Health Labour Market Analysis or HLMA (WHO, 2022b), Workload Indicators of Staffing Need (WISN) (WHO, 2010), and the Community Health Planning and Costing Tool (UNICEF, 2020).

Accessmod is a free and open-source WHO tool for modelling physical accessibility of health services, including estimating travel times to/from health service delivery locations given topography, constraints to movement, and modes of transportation, estimating the population covered with a given travel time (with or without consideration of maximum population capacity of the health facility and/or constraints such as availability of trained health and care workers, and necessary equipment and commodities), estimating referral times and distances between health facilities, and optimizing scale-up scenarios (Ray *et al.*, 2008; Accessmod, 2021). Accessmod has been endorsed by the WHO and UNICEF as a tool for integrating robust geospatial analysis into health sector planning, particularly for health infrastructure such as health facilities (WHO and UNICEF, 2020). It has been used in numerous countries for planning health facility-based services and at least fourteen peer reviewed articles using Accessmod have been published (Accessmod, 2021). Although Accessmod has the functionality required, assuming the availability of the requisite input data and robust assumptions, to accurately estimate the number of CHWs needed at national scale, where the CHWs should be deployed, and in which order the CHWs should be deployed to maximize their contribution to geographical accessibility, previous applications and research have not used Accessmod (or other geospatial modelling software) for these purposes.

The HLMA is a WHO tool for assessing and planning the health and care workforce (WHO, 2022b; WHO, 2022a). The HLMA is useful for achieving

> a better understanding of the forces that drive health worker shortages and surpluses, skills mix and geographical imbalances, and suboptimal performance, and to develop effective policies to address these issues…[it] provides reliable information on the main dimensions of the performance of the health workforce, for example, its availability, accessibility, acceptability and quality. An HLMA can raise policy- and decision-makers' awareness of how and why their country's health labour market changes, and can help them answer important questions in relation to some of its dysfunctions and challenges and formulate appropriate responses (WHO, 2022b).

The HLMA includes basic analysis of the geographical distribution of the health and care workforce e.g., as densities of workers per population across administrative areas and by types of workers to estimate the skills mix and whether efficiency gains can be achieved by altering the skills mix (WHO, 2022b). However, the HLMA lacks the geographical granularity afforded with geospatial analysis tools such as Accessmod. For example, unlike Accesmod, the HLMA cannot accurately estimate how many CHWs are needed, in which communities the CHWs are needed, and in which order they should be deployed to maximize the efficiency of CHW deployment. Hence there is scope for using the HLMA in conjunction with Accessmod to complement each other (as was done in Sierra Leone as part of this research in study 2). Additionally few applications of the HLMA have included CHWs (personal communication from WHO) e.g., Burkina Faso as illustrated in the HLMA guidebook (WHO, 2022b) and Sierra Leone (unpublished draft HLMA report). Lastly, the HLMA shares important data dependencies with Accessmod if CHW analysis is to be included, such as having an up-to-date national georeferenced CHW master list (Liu *et al*., 2021).

WISN is a WHO tool for health and care workforce needs assessment and planning (WHO, 2010). WISN helps planners and managers to assess the workload for a particular health facility, network of facilities of a given type, or network of different types of health facilities, and estimate how many health workers of a particular type are required in each health facility, or across a health facility network or by facility type (WHO, 2010). WISN has been used in numerous countries and peer reviewed publications (Kunjumen T *et al*., 2022). However, WISN has not been adapted for estimating CHW needs and has not been used for doing so. Like the HLMA, WISN lacks the fine-scale geospatial granularity afforded by geospatial analysis tools such as Accessmod. The WISN cannot estimate how

many CHWs are needed, in which communities the CHWs are needed, and in which order the CHWs should be deployed to maximize the efficiency of CHW deployment.

The Community Health Planning and Costing Tool is a UNICEF tool developed by Management Sciences for Health (MSH) to cost and plan community health services (UNICEF, 2020). Although the Community Health Planning and Costing Tool allows for the costing and planning of services provided by CHWs, like the HLMA and WISN it lacks the fine-scale geospatial granularity and optimization functionality of geospatial tools such as Accessmod and could be applied in conjunction with Accessmod to optimize costing scenarios. For example, the assumptions for "scale-up" in the data inputs of the Community Health Planning and Costing Tool could be informed by the outputs of CHW scale-up analysis using Accessmod to ensure costed scenarios are based on optimized scale and deployment.

Given the strengths and limitations of the above tools for planning integrated PHC services at community level, there is scope for using them together as a package of tools for planning. This has been done, at least in part, in Sierra Leone where the HLMA, Accessmod analysis, and an assessment of the CHW program complemented each other and jointly informed the development of a new national community health strategy, as indicated in study 2.

Geographical accessibility

In addressing geographical accessibility, community-based interventions tend to be more pro- poor than facility-based interventions (Barros *et al*., 2012). The inverse equity hypothesis, which postulates that better-off socioeconomic groups tend to benefit first from the introduction or scale-up of new public health interventions (Victora *et al*., 2000), has been widely documented in the literature (Victora *et al*., 2000; WHO, 2005; WHO, 2008; Boerma *et al*., 2008). In contrast countries that have emphasized equity, i.e., targeted the poorest, most marginalized, rural, remote populations first, have tended to achieve the most rapid gains in intervention coverage and have done so more cost-effectively than less equity-focused approaches (Victora *et* al., 2012; Barros *et al*., 2005; Frenk *et al*., 2006; Carrera *et al*., 2012). To accelerate progress on child mortality in LMICs and achieve the broader targets of the health SDGs, governments and partners will need to take equity-focused actions (Marmot *et al*., 2008; Rasanathan *et al*., 2009; Chopra *et al*., 2012). Filling gaps in geographical accessibility of integrated PHC services as part of a progressive path to

universal health coverage should be among these actions (Ray *et al*., 2008; WHO and UNICEF 2018; WHO and UNICEF, 2020).

While countries strive to increase financing for health sector development, including for the construction and maintenance of health facilities and other health infrastructure as well as the health and care workers needed to provide services, concurrent efforts are needed to optimize the impact and efficiency of available funding through rightsizing the scale and improving the efficiency and equitable deployment of health facilities and health and care workers.

Geospatial analysis using geographic information systems (GIS) can be powerful for health sector planning in this regard. However use of GIS and geospatial analysis within the health sector in LMICs – as well as conceptualizations and research exploring these topics – has primarily focused on single diseases or vertical programs (e.g., Cheney *et al*., 2020; GAVI *et al*., 2021; Brinjnath *et al*., 2012; Aimone *et al*., 2013; Valamparampil *et al*., 2018) and less frequently on their application to broad health sector planning, service delivery platforms for integrated PHC services (e.g., tiers of the health system and referral networks between them, or platforms for integrated reproductive, maternal, newborn, child, and adolescent health), or the health and care workforce (e.g., Molla *et al*., 2017; Makanga *et al*., 2016; Ahmadian *et al*., 2020; Ebener *et al*., 2015; Ebener *et al*., 2019; van Duinen *et al*., 2020). This reflects a missed opportunity to use GIS and geospatial analysis to inform broader health sector planning, address inefficiencies and inequities in geographical accessibility of integrated PHC services and distribution of the health and care workforce, and more effectively and efficiently geo-enable health system planning (Ebener *et al*., 2018).

The concept of distance as a determinant of accessibility and use of health care services came to prominence in the medical geography literature of the 1960s (Hopkins *et al*., 1968; Shannon *et al*., 1969). Distance decay in health care seeking behaviour was identified by researchers as early as 1968 (Hopkins *et al*., 1968). In the 1970s travel distance and travel time were proposed by researchers as measures of geographic accessibility to health care services (Shannon *et al*., 1973). Later researchers would support travel time as the more robust and comparable measure of geographic accessibility (Tsay, 1985; Roxero-Bixby, 2004; Guargliardo, 2004; Noor *et al*., 2006; Ray *et al*., 2008). Location theory, spatial analysis, and location-allocation methods became prominent in the private sector in the 1960s and were adopted in the 1970s-1980s in the public sector considering reduced public

sector budgets, calls for greater efficiency, and growing inequity both in high income countries and LMICs (Cooper, 1963; Dear, 1974; Mohan, 1983; Rushton, 1984).

In the early 2000s researchers incorporated new technology in the form of GIS to analyse spatial patterns of primary health care usage in rural South Africa (Tanser *et al*., 2001; Tsoka *et al*., 2004). Previous studies have estimated geographical accessibility (as travel time) to public sector health facilities, excluding CHWs from the analysis, at global level, and national and subnational levels in LMICs (Weiss *et al*., 2020; Blanford et al., 2012; Huerta Munoz *et al*., 2012; Noor *et al*., 2006).

Geographical accessibility and CHWs

No study prior to this research has explored the contribution of CHWs to geographical accessibility (as travel time) to integrated PHC services at national level or approaches for optimizing the scale-up and deployment of CHWs to maximize geographical accessibility of integrated PHC services at national scale. Previous studies have explored the contribution of CHWs to geographical accessibility (as travel time) for subnational areas (Ihantamalala et al., 2020; Brunie et al, 2020). The efficiency of placement of health service locations has been assessed for hospitals in low-income and middle-income countries, but this did not include community health posts or CHWs (Wong *et al*., 2019). Previous studies have explored the efficiency of deployment of existing CHW networks and/or optimizing the scale-up and efficiency of deployment of CHWs at subnational level (Pratt *et al*., 2014; Cherkesly *et al*., 2019; Ihantamalala *et al*., 2020; Brunie *et al*., 2020). These studies used the conceptualizations of availability of health services and geographic accessibility of health services put forward by Peters *et al*., (2008) which built on earlier conceptualizations (Aday *et al*., 1974; Penchansky *et al*., 1981), and applied the methods for modelling geographic accessibility by Ray *et al*., (2008). Saint Fermin *et al*., (2021) used a Euclidean distance- based approach (not travel time) to explore the cost-efficiency of CHW deployment at national scale in Mali (Saint-Firmin *et al*., 2021). Champagne *et al*., 2022 (published after Study 1 and at the same time as publication of Study 2 and submission of Study 3) explored optimization of CHW scale-up and deployment at national scale in Haiti.

Problem statement

Previous research has focused on the use of geospatial analysis to assess the geographical accessibility of health facilities, the contribution of CHW networks to geographical accessibility of health services for subnational areas, and/or the efficiency of CHW deployment for subnational areas. No studies have assessed the contribution of CHW

networks to geographical accessibility of integrated PHC services at national scale, and approaches for optimizing the scale-up and deployment of CHWs at national scale to maximize their contribution to such services. The WHO and UNICEF PHC framework and WHO Working for Health 2022-2030 Action Plan call for optimizing the distribution of the health and care workforce and geographical accessibility to integrated PHC services, but the tools and resources referenced in these documents (e.g., Accessmod, HLMA, WISN, and the Community Health Costing and Planning Tool) have not been used to explore optimization of the scale and deployment of CHWs.

Additionally, there has been no systematic review on the effects of iCCM, a core component of integrated PHC services for children provided by CHWs in LMICs, and the scale-up of iCCM has preceded without robust consideration of its effects and the conditions under which it may be effective.

Aim

The aim of this research was to contribute to improved understanding of the contribution of CHWs to geographical accessibility of integrated PHC services at community level, including iCCM, explore geospatial approaches for optimizing the scale and deployment of CHWs to maximize geographical accessibility of integrated PHC services at community level, and assess the effectiveness of iCCM in LMICs with the aim of informing health policy and planning.

Objectives

Studies 1 and 2: To estimate the contribution of CHWs to geographical accessibility of integrated PHC services at national scale in Niger and Sierra Leone;

Studies 1-3: To explore geospatial approaches for optimizing the scale and deployment of CHWs for maximizing geographical accessibility of integrated PHC services at community level in Niger, Sierra Leone, and Mali;

Study 4: To assess the effects of iCCM on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, and adverse events for children younger than five years of age in LMICs.

Overview of the thesis

This is a thesis by publication. The thesis is presented in four chapters. Chapter One presents a literature review of relevant background on PHC, iCCM, health and care

workers, CHWs, and geographical accessibility. This is followed by a description of the problem statement, aim of the research, objectives, and overview of the thesis. Chapter Two presents the methods, including conceptual framework, study setting, design, and ethical considerations. Chapter Three presents the findings in the form of the four peer-reviewed, published (or submitted) journal articles:

1. Oliphant, N. P., Ray, N., Bensaid, K., Ouedraogo, A.., Gali, A. Y., Habi, O. et al. (2021). Optimising geographical accessibility to primary health care: a geospatial analysis of community health posts and community health workers in Niger. BMJ Global Health 6:e005238.doi:10.1136/bmjgh-2021-005238
2. Oliphant, N. P., Ray, N., Curtis, A., Musa, E., Sesay, M., Kandeh, J. (2022a). Optimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis. BMJ Global Health [In press].doi:10.1136/ bmjgh-2021-008141
3. Oliphant, N.P., Sy, Z., Koné, B., Berthé B., Beebe, M., Samaké, M., Diabaté, M., Tounkara, S., Diarra, B., Diarra, A. B., Diawara, C. H., Yakimova, T., Florisse, S., Jackson, D., Ray, N., Doherty, T. (2022b). Improving the efficiency of scale-up and deployment of community health workers in Mali. [Submitted for peer review]
4. Oliphant, N. P., Daniels, K., Odendaal, W. A., Besada, D., Manda, S., Kinney, M., et al. (2017). Integrated community case management of childhood illness in low- and middle-income countries. Cochrane Database of Systematic Reviews 11(CD012882).doi:10.1002/14651858.CD012882

The PhD candidate was responsible for the overall conceptualization, methodology, data curation, analysis, data visualisation, and writing the manuscript under the guidance of all supervisors, who contributed verbally and in writing. During the time of the PhD studies, the candidate worked at UNICEF (2010-2016) and was responsible for supporting operational research on CHWs in the three focus countries. From 2017, he moved to the Global Fund to Fight AIDS, Tuberculosis, and Malaria where he supports strategic thinking and advisement on investment in CHWs and health systems strengthening, including support to the focus countries of the thesis through the Global Fund Secretariat. All co-author contributions are provided in each publication and in the introductory notes for each paper in Chapter Three.

CHAPTER TWO: METHODS

Chapter Two provides an overview of the methods used in this thesis. The chapter begins by presenting the conceptual framework for the thesis (Figure 3). This is followed by a summary of the study settings, study designs, study populations and sampling techniques, data collection procedures, data cleaning procedures, data analysis, and limitations of the data (Table 1). The chapter closes with a summary of the ethical considerations.

Conceptual framework

The conceptual framework for this thesis situates the research within existing conceptual frameworks and normative guidance on PHC and the health and care workforce (WHO and UNICEF, 2020; WHO, 2018; WHO, 2022a). This was a deliberate choice, understanding that it made sense to use the existing frameworks and normative guidance (which are used by countries) as scaffolding on which to build and extend concepts and that this may increase use of the research for informing health policy and planning – one of the main aims of the research. The conceptual framework progresses through five steps, highlighted in red numbers. Red boxes situate each step within the broader conceptual frameworks. The red arrows and red text "zoom-in" to each step, providing detail.

The main propositions of the conceptual framework are that geospatial analysis can complement other data sources and analyses (e.g., HLMA) for optimizing planning of CHW scale and deployment in the context of broader health sector and health and care workforce planning, providing estimates of the contribution of CHWs to geographical accessibility, estimates of the efficiency of CHW deployment, and optimized scenarios for future scale-up and deployment of CHWs to maximize geographical accessibility to integrated PHC services (steps 1-3). Adding geospatial analysis to such planning builds on the scaffolding of the Working for Health theory of change and contributes to the "Optimize, Build, Strengthen" objectives of the Working for Health progression model (WHO, 2022). Optimizing CHW scale and deployment using geospatial analysis results in efficiencies and cost-savings. These savings may unlock opportunities for sustainable financing pathways (including through domestic financing) and re-investing cost-savings for further strengthening the health policy and systems needed for CHWs to improve access, care seeking, utilization, and quality of integrated PHC services, including iCCM. Stronger health policy and systems and progress toward sustainable financing will also improve decent working conditions for CHWs, and contribute to greater impact on

population health, improved health security, and more equitable societies (steps 4-5), building on the Working for Health theory of change, the WHO guideline on health policy and system support to optimize CHW programmes, and the PHC theory of change (WHO, 2022; WHO, 2018; WHO and UNICEF, 2020). Studies 1-3 of this thesis explore steps 1-3. Study 4 explores steps 4-5 by assessing the effect of iCCM in LMICs, highlighting opportunities for improving health policy and practice in alignment with the conceptual framework.

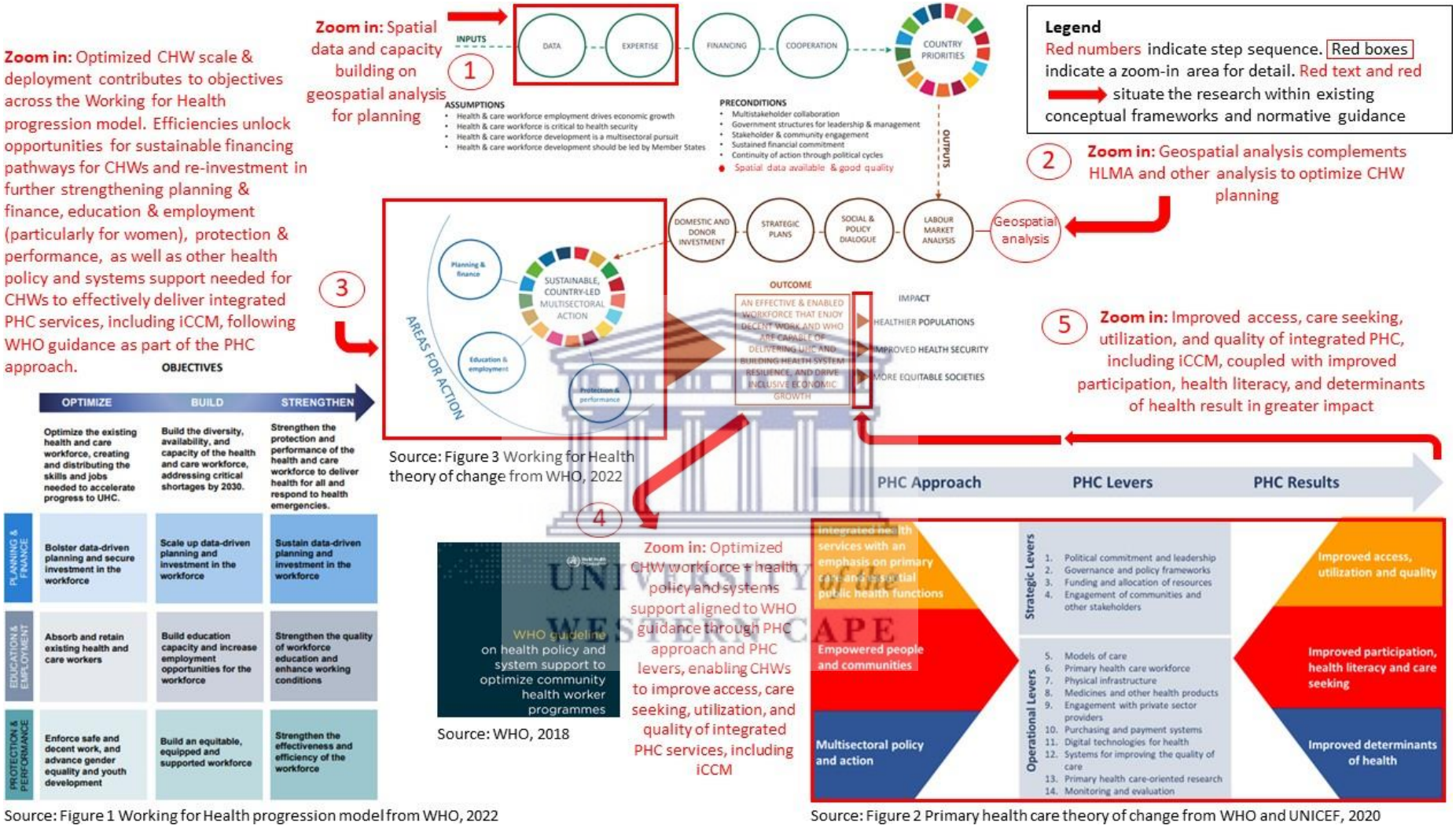
Study setting

Studies 1-3 (geospatial analysis) concern Niger, Sierra Leone, and Mali. Study 4 (systematic review of iCCM) concerns all LMICs, however, included studies were from Burkina Faso, Guinea-Bissau, India, Liberia, Sierra Leone, and Uganda. Table 1 below summarizes information on CHWs in each country.

Study 1: Niger

Niger is a landlocked country covering an area of 1.2 million square kilometres (km) in the Sahel region of Africa (Ministère de la Santé Publique, 2013). In 2013, the estimated population was 18.1 million (WorldPop, 2018). The estimated under-five mortality rate was 126 deaths per 1 000 live births in 2012 (Institute for Health Metrics and Evaluation, 2019). In 2013, an estimated 66% of the population lived within a 60 minute-walk of a referral health facility or community health post (Oliphant *et al*., 2021). During the period of focus of study 1 (2000-2013), the health system of Niger consisted of a public and private sector organized in a decentralized, pyramidal structure with three administrative levels overseen by the Ministry of Public Health (MOPH). This PhD analysis focused on the first level (periphery) of the public sector, which is central to PHC at community level. The first level of the public sector is made up of referral facilities called *centre de santé intégré* (CSI) and community health posts called *case de santé* (CS). As of December 2012, there were 856 CSI offering a minimum package of services, focused on PHC, referral from and counter-referral to the CS, and supervision of the CS (Ministère de la Santé Publique, 2013). CSI were typically staffed by nurses – and in certain urban communities by a generalist doctor and midwives (Ministère de la Santé Publique, 2013). CS were intended to be situated 5 km beyond a supervising CSI and provided a minimum package of services, focused on PHC at community level, including prevention services health promotion services, and services for reproductive, maternal, newborn and child health, including iCCM (Ministère de la Santé Publique et de la Lutte contre les Endémies,

Figure 3. Thesis conceptual framework



Source: Figure 1 Working for Health progression model from WHO, 2022

Source: Figure 2 Primary health care theory of change from WHO and UNICEF, 2020

2006). CS were typically staffed by a cadre of paid, full-time CHWs called agent de santé communautaire (ASC) and/or, in some cases, a nurse (Ministère de la Santé Publique et de la Lutte contre les Endémies, 2006). CS and ASC were scaled up between 2000 and 2013—a period of considerable progress on under-5 mortality (Besada *et al*., 2016; Amouzou *et al*., 2012). Some CS were supported by one or more volunteer CHWs called relais communautaire (RC), providing health promotion and prevention interventions in the communities within the catchment area (typically a 5 km radius) of the CS (Ministère de la Santé Publique, 2013; Ministère de la Santé Publique et de la Lutte contre les Endémies, 2006). The MOPH in Niger plans to scale up RC—some targeted to communities beyond 5 km of CS or CSI to provide a standard package of preventive, promotive and curative services, including iCCM (Edir, 2019). At the time of the study, a midterm review of the National Community Health Strategy was being planned by the MOPH, a Global Financing Facility (GFF) investment case was also being developed and discussions on a new Health Sector Development Plan (2022–2026) were underway.

Study 2: Sierra Leone

Sierra Leone is a country covering 71,740 square kilometres on the coast of West Africa (Wikipedia contributors, 2022a). The estimated population was 7.1 million in 2015 (WorldPop and Statistics Sierra Leone, 2021) and the estimated under-five mortality rate was 126 deaths per 1 000 live births in 2014 (Institute for Health Metrics and Evaluation, 2019). In 2013, an estimated 76% of the population lived within a 60 minute-walk of a health facility (Oliphant *et al*., 2022a).

During the period of focus of Study 2 (2000-2016), Sierra Leone had four political administrative levels (chiefdoms, districts, provinces, and national) (Wikipedia contributors, 2021). The health system included a public and private sector organized in a decentralized, pyramidal structure with three administrative levels – tertiary, secondary, and primary – overseen by the MOHS (Ministry of Health and Sanitation, Government of Sierra Leone, 2012). Our analysis focuses on CHWs situated at the base of the primary level. The primary level was comprised of public health facilities, collectively known as peripheral health units (PHUs) providing PHC services and referral services to the secondary level (district hospitals). PHUs – in descending order according to size and availability of skilled health care workers – included community health centres (CHCs), community health posts (CHPs), and maternal and child health posts (MCHPs). The primary level also included private sector clinics focused on primary health care services. At the base of the primary level were CHWs.

CHWs are critical to the country's vision of a resilient national health system and prosperous socioeconomic development (Ministry of Health and Sanitation, 2017a; Ministry of Health and Sanitation, 2016; Ministry of Health and Sanitation, 2017b). Under the leadership of the Ministry of Health and Sanitation (MOHS) there was a large scale-up of CHWs employed by non-governmental organizations between 2000-2020, including during the Ebola crisis (JSI Research and Training Institute, Inc., 2020). As of 2020, there were more than 17 000 CHWs deployed in Sierra Leone (JSI Research and Training Institute, Inc., 2020). Prior to 2012, CHWs were considered "volunteers" and there was no national CHW policy. In 2012 the MOHS developed the first national CHW policy. CHWs were still considered "volunteers" but the policy recommended they be provided with a minimum motivation package of monetary and non-monetary incentives. However the monetary portion of the minimum package was not defined. In practice, CHWs were employed by non-governmental organizations (NGOs) but remuneration was not harmonized across NGOs. In 2016, the national CHW policy was revised, and the MOHS defined a minimum financial incentive of 100 000 Leones per month. In 2021, the financial incentives were increased to 200 000 Leones per month for CHWs in MOHS-defined "hard-to-reach" areas while the incentive for CHWs in MOHS-defined "easy-to-reach" areas remained at 100 000 Leones (for additional details, see the data supplement bmjgh-2021-008141supp001_data_supplement.pdf in Oliphant *et al*., 2022a). An assessment of the national CHW program incorporated findings from early outputs from this research and informed the new MOHS CHW policy for the period 2021-2025 (JSI Research and Training Institute, Inc., 2020). The new policy included three key policy shifts: harmonization and integration of all CHW cadres into the national CHW program, rightsizing the scale of the CHW network, and retargeting CHW deployment to areas of greatest need (Ministry of Health and Sanitation, 2020).

Study 3: Mali

Mali is a landlocked country covering 1.2 million square kilometres in the Sahel region of West Africa (Wikipedia contributors, 2022b). The estimated population was 20.5 million in 2020 (Bondarenko *et al*., 2020) and the estimated under-five mortality rate was 119 deaths per 1 000 live births in 2017 (Institute for Health Metrics and Evaluation, 2019). In 2020, an estimated 58% of the population lived within 5 kilometres of a health facility (Oliphant *et al*., 2022b).

At the time of focus of study 3 (2020), the health system included public, private, community, and confessional institutions organized in a decentralized, pyramidal structure

with four administrative levels – a tertiary referral level, a secondary referral level, a primary referral level and a primary level – overseen by the MSDS (Ministère de la Santé et du Développment Social et Ministère de la Promotion de la Femme, de l'Enfant et de la Famille, 2021). The primary level was composed of public sector community health centres (*Centres de santé communautaire*, CSCom) and private sector health facilities staffed by nurses and – in some cases – generalist doctors providing a minimum package of primary health care services and referral/counter-referral services to/from primary referral facilities (*Centres de santé de référence*, CSRef) staffed by nurses and doctors trained on referral services. CSCom were designed to serve the population within 5 km (Ministère de la Santé et de l'Hygiene Publique, 2015). At the base of the primary level were paid, full-time CHWs providing community-based primary health care services, including prevention, promotion, and curative services, conducting surveillance activities, and supervising part-time community health volunteers known as *relais* (Ministère de la Santé et de l'Hygiene Publique, 2015). The focus of our analysis was on the CHWs. The *relais* were beyond the scope of our analysis.

In Mali, CHWs have been a central part of the country's health and care workforce at the community level since 2008. At the time of writing, the country was updating the national community health strategy in the context of a new health sector development plan and ongoing health system reform aiming to achieve UHC through primary health care (Ministère de la Santé et du Développment Social et Ministère de la Promotion de la Femme, de l'Enfant et de la Famille, 2021; Ministère de la Santé et des Affaires Sociales, 2020).

Study design

This thesis used a combination of a quantitative approaches, including geospatial analysis (studies 1-3) and a systematic review (study 4). One paper was published for each study (at the time of submitting this thesis, the paper for study 3 had been submitted for publication but not yet published). Published peer review comments for each published paper are included in Appendix 2. For the systematic review, a protocol was published (Oliphant *et al*., 2017) and is included in Appendix 3, as well as a video summary (Cochrane EPOC, 2021) in Appendix 4, and a narrative summary (Glenton *et al*., 2021) in Appendix 5. Each paper includes a brief description of the study design and methods used within the main text (included in Chapter Three) and more detailed description within the online supplementary appendices of each paper. Table 1 summarizes the study design for each study.

Ethical considerations

The research was based on secondary analysis of existing datasets, all of which were free of personally identifiable information. The research received ethical clearance (registration number 15/7/271) from the University of the Western Cape's Senate Research Committee (Appendix 1).

Table 1. Study design

	Study 1	**Study 2**	**Study 3**	**Study 4**
Title	Optimising geographical accessibility to primary health care: a geospatial analysis of community health posts and community health workers in Niger	Optimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis	Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis	Integrated community case management of childhood illness in low- and middle-income countries
Objectives	To estimate the contribution of CHWs to geographical accessibility beyond the health facility network at national scale; to explore geospatial approaches for optimizing the scale-up and deployment of CHWs for maximizing their contribution geographical accessibility of integrated PHC services in Niger	To estimate the contribution of CHWs to geographical accessibility beyond the health facility network at national scale; to explore geospatial approaches for optimizing the scale-up and deployment of CHWs for maximizing their contribution geographical accessibility of integrated PHC services in Sierra Leone	To explore geospatial approaches for optimizing the scale-up and deployment of CHWs for maximizing their contribution geographical accessibility of integrated PHC services in Mali	To assess the effects of iCCM on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events, and coverage of careseeking for children younger than five years of age in LMICs.

Type of study	Quantitative	Quantitative	Quantitative	Quantitative
Study design	Descriptive	Descriptive	Descriptive	Cochrane systematic review
Population / sample	All CHWs and public sector health facilities; estimated population, U5 deaths, and *Pf* malaria cases beyond 60 minutes walking of primary health facilities	All CHWs and health facilities; estimated population, U5 deaths, and *Pf* malaria cases in MOHS-defined "hard-to-reach" and "easy-to-reach" areas	All CHWs and public sector health facilities; estimated population, U5 deaths, and *Pf* malaria cases beyond 5 kilometres walking of primary health facilities	Types of studies: randomized controlled trials, non-randomized trials, controlled before-after studies, interrupted time series, repeated measures studies following Cochrane Effective Practice and Organization of Care (EPOC) guidance. Types of participants: Children under-five and their caregivers in LMICs; any lay health workers (paid or voluntary) who: provide iCCM for two or more illnesses among children under-five; were trained on iCCM, but had received no formal professional or paraprofessional certificate or tertiary education degree Types of interventions: studies on the

				implementation of generic WHO/UNICEF iCCM (or local adaptation thereof) for at least two iCCM diseases; studies of unbranded iCCM. Comparison: iCCM with usual facility services; iCCM with usual facility services plus single-disease CCM for malaria Types of outcome measures including *Primary outcomes*: coverage of appropriate treatment from an appropriate provider of treatment services; coverage of appropriate treatment from an iCCM provider of treatment services; quality of care; case load or severity of illness at health facilities; measures of mortality (neonatal, infant, and under-five mortality); adverse events *Secondary outcomes:* coverage of careseeking to an appropriate

				provider of treatment services
Data collection	No data collection; secondary analysis of existing datasets	No data collection; secondary analysis of existing datasets	No data collection; secondary analysis of existing datasets	Conducted the review according to the published protocol (which followed Cochrane EPOC guidance) and reported any deviations from it; search methods, selection criteria, data collection, and analysis conducted per Cochrane EPOC guidance.
Analysis	Geospatial: geographical accessibility over time 2000-2012, geographic coverage, efficiency of CHW deployment	Geospatial: geographical accessibility over time 2000-2015, geographic coverage, efficiency of CHW deployment	Geospatial: geographic coverage, efficiency of CHW deployment	Conducted the review according to the published protocol (which followed Cochrane EPOC guidance) and reported any deviations from it; search methods, selection criteria, data collection, and analysis conducted per Cochrane EPOC guidance.
Data limitations	Lack of data on the uncertainty of the estimates of population counts; lack of settlement footprints for 2000-2012 (modelled population counts for 2000-2012 used a high resolution settlement	Lack of data on the uncertainty of the estimates of population counts; lack of settlement footprints for 2000-2014 (modelled population counts for 2000-2014 used a high resolution settlement	Lack of data on the uncertainty of the estimates of population counts; lack of data on national parks and other 'no-go' zones (e.g., military bases); travel speeds not empirically measured or estimated but	Given very low- to moderate-certainty evidence for all reported outcomes (GRADE) further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates.

	footprint for 2015); lack of data on national parks and other 'no-go' zones (e.g., military bases); travel speeds not empirically measured or estimated but based on estimated travel speeds used in similar analysis for Niger and in the region; analysis does not account for uncertainty of travel speed estimates, variation in walking speeds or common modes of transportation by different population groups, or subnational variation in travel speeds or common modes of transportation; analysis used self-reported data from CHWs on receipt of training and year of deployment, which may be subject to recall bias; does not account for accessing health services across national boundaries	footprint for 2015); lack of data on national parks and other 'no-go' zones (e.g., military bases); travel speeds not empirically measured or estimated but based on estimated travel speeds used in similar analysis for Sierra Leone and in the region; analysis does not account for uncertainty of travel speed estimates, variation in walking speeds or common modes of transportation by different population groups, or subnational variation in travel speeds or common modes of transportation; analysis used self-reported data from CHWs on receipt of training and year of deployment, which may be subject to recall bias; analysis does not account for	based on estimated travel speeds used in similar analysis in the region; analysis does not account for uncertainty of travel speed estimates, variation in walking speeds or common modes of transportation by different population groups, or subnational variation in travel speeds or common modes of transportation; analysis does not account for accessing health services across national boundaries	Moreover, evidence was not reported for three primary outcomes: quality of care, case load or severity of illness at health facilities, and adverse events – research is needed on these outcomes; three studies awaiting assessment and four ongoing studies will be considered for inclusion in the next review update and may change the estimates and/or our confidence in the estimates; variation in iCCM components and inputs across studies (particularly for payment of CHWs, supportive supervision); variation regarding inclusion of interventions for improving newborn health; variation in contextual settings (only one study outside Africa and this was in a mixed rural/urban area of northern India)

		accessing health services across national boundaries		

CHAPTER THREE: FINDINGS

This chapter is organized by study. The chapter begins with a summary of findings for study 1 followed by the full text of study 1. This is followed by a summary of findings and full text for studies 2-4.

Study 1: Oliphant NP, Ray N, Bensaid K, Ouedraogo, A., Gali, A. Y., Habi, O. et al. (2021). Optimising geographical accessibility to primary health care: a geospatial analysis of community health posts and community health workers in Niger. BMJ Global Health 6:e005238.doi:10.1136/bmjgh-2021-005238

What is already known?

• Previous studies have estimated geographical accessibility (as travel time) to health facilities, geographical accessibility to community health workers (CHWs) for subnational areas only and assessed efficiency of the distribution of hospitals in low/middle-income countries.

What are the new contributions from this study?

• Our analysis provides new insight on the contribution of CHWs to increasing geographical accessibility of integrated PHC services at community level in Niger between 2000-2013, as well as policy relevant variation across subnational areas, gender of the CHWs, training of the CHWs on specific interventions, and availability of essential commodities.

• Our analysis identifies important gaps in geographical accessibility and inefficiency in the distribution of community health posts and deployment of CHWs, pointing to opportunities for optimising scale and deployment of CHWs for maximizing geographical accessibility of integrated PHC services at community level, including iCCM, in Niger.

How this study might affect research, practice, or policy?

• Our analysis has inspired an updated analysis (currently being planned) aiming to inform national community health strategic planning and optimizing the scale-up of community health posts and CHWs. This will entail a medium-term capacity building component to enable the Ministry of Public Health (MOPH) and national/local research institutions to conduct this kind of analysis in the future without external technical assistance.

• The MOPH and partners could re-invest cost-savings stemming from future optimisation efforts to further strengthen the health policy and systems support needed for community

health posts and CHWs to deliver effective integrated PHC services such as iCCM (as described in study 4).

• The approaches to optimisation described in this study (and studies 2-3) could be adapted to similar contexts within sub-Saharan Africa to maximize the contribution of CHWs to geographical accessibility to integrated PHC services within the context of broader health sector planning.

Contribution of the candidate: The candidate (NPO) was responsible for the study conceptualisation, methodology, data curation and writing the draft manuscript. OH, IM, KB, AYG, NPO and NR collected data or provided feedback on data. NPO, NR and ZS conducted the geospatial analysis and were responsible for data visualisation. NPO, NR and TD verified the underlying data. TD, DJ, and NR provided supervision and overall guidance. All authors contributed to reviewing and editing the manuscript.

The comments from the peer review process are available in Appendix 2

BMJ Global Health

Optimising geographical accessibility to primary health care: a geospatial analysis of community health posts and community health workers in Niger

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ABSTRACT

Background Little is known about the contribution of community health posts and community health workers (CHWs) to geographical accessibility of primary healthcare (PHC) services at community level and strategies for optimising geographical accessibility to these services.

Methods Using a complete georeferenced census of community health posts and CHWs in Niger and other high-resolution spatial datasets, we modelled travel times to community health posts and CHWs between 2000 and 2013, accounting for training, commodities and maximum population capacity. We estimated additional CHWs needed to optimise geographical accessibility of the population beyond the reach of the existing community health post network. We assessed the efficiency of geographical targeting of the existing community health post network compared with networks designed to optimise geographical targeting of the estimated population, under-5 deaths and *Plasmodium falciparum* malaria cases.

Results The per cent of the population within 60-minute walking to the nearest community health post with a CHW increased from 0.0% to 17.5% between 2000 and 2013. An estimated 10.4 million people (58.5%) remained beyond a 60-minute catchment of community health posts. Optimal deployment of 7741 additional CHWs could increase geographical coverage from 41.5% to 82.9%. Geographical targeting of the existing community health post network was inefficient but optimised networks could improve efficiency by 32.3%–47.1%, depending on targeting metric.

Interpretations We provide the first estimates of geographical accessibility to community health posts and CHWs at national scale in Niger, highlighting improvements between 2000 and 2013, geographies where gaps remained and approaches for optimising geographical accessibility to PHC services at community level.

Key questions

What is already known?

- Previous studies have estimated geographical accessibility (as travel time) to health facilities, geographical accessibility to community health workers (CHWs) for subnational areas only, and assessed efficiency of the distribution of hospitals in low/middle-income countries.

What are the new findings?

- The per cent of the population within 60-minute walking to the nearest community health post with a paid, full-time CHW increased from 0.0% to 17.5% between 2000 and 2013, with 15.5% within 60-minute walking to the nearest health post with a CHW trained on integrated community case management (iCCM)—making primary healthcare (PHC) services at community level and iCCM, specifically, geographically accessible for an estimated 2.3 million and 2.0 million additional people, respectively.
- An estimated 10.4 million people (58.5%) remained beyond a 60-minute catchment of community health posts in 2013, with important variation across subnational geographies, training of CHWs and availability of essential commodities.
- Optimal deployment of 7741 additional CHWs could increase geographical coverage of the estimated total population from 41.5% to 82.9%, providing physical access to PHC services at community level for an additional 7.4 million people not covered.
- Optimised networks of community health posts increased efficiency of geographical targeting compared with the existing network by 32.3%–47.1%, depending on targeting metric.

BACKGROUND

Community health workers (CHWs) can play an important role in improving equitable access to quality primary healthcare (PHC) at community level in the context of Universal Health Coverage as front-line service providers and as a trusted bridge between health systems and communities.[1–3] CHWs typically focus on maternal, newborn and

Key questions

What do the new findings imply?

- The scale-up of community health posts staffed by paid, full-time CHWs improved geographical accessibility to PHC services at community level, including iCCM, between 2000 and 2013; however, efficiency of geographical targeting of community health posts was suboptimal, implying—that had scale-up been optimised—significant improvements in population coverage could have been realised, with cost-savings reinvested in further scale-up and health systems strengthening.
- The approaches described in this study could inform retargeting of the existing network of community health posts and future scale-up efforts to optimise geographical accessibility of PHC services at community level in Niger and could be adapted to similar contexts within sub-Saharan Africa.

child health and nutrition, providing a range of preventive, health promotion and curative services—including single disease or integrated community case management (iCCM).[4] iCCM is the provision of integrated case management services for two or more childhood illnesses among children less than 5 years of age by CHWs, where geographical accessibility (ie, physical access) to health facility-based case management services is limited.[5] In Niger, the Ministry of Public Health (MOPH) scaled up community health posts staffed by paid, full-time CHWs from the early 2000s. A midterm review of the National Community Health Strategy is planned for 2022, a Global Financing Facility (GFF) investment case is being developed and discussions on a new Health Sector Development Plan (2022–2026) are underway. Given this context, discussion on optimising geographical accessibility to PHC at community level is highly relevant. Previous studies in sub-Saharan Africa have estimated geographical accessibility (as travel time) to health facilities at national level[6 7] and CHWs for subnational areas only.[8–11] The efficiency of geographical targeting of health service locations has been assessed for hospitals in low-income and middle-income countries, but this did not include community health posts or CHWs.[12] In this article, we describe for the first time at national scale the number and geographical distribution of community health posts and CHWs in Niger. We estimate their contribution to geographical accessibility to PHC services at community level, efficiency of geographical targeting of the community health posts and needs for further scale-up of CHWs with the aim of optimising PHC at community level.

METHODS

In this section, we describe the study settings, data and methods used. Online supplemental appendix 1 provides a simplified analysis flow and additional details on the data and methods.

Study settings

During the period of focus of this study, 2000–2013, Niger was divided into four political administrative levels: communes, departments, regions and national.[13] The health system of Niger included a public and private sector organised in a decentralised, pyramidal structure with three administrative levels overseen by the MOPH. Details on the health system are provided in online supplemental appendix 1. Our analysis focuses on the first level (periphery) of the public sector, which is central to PHC at community level. The first level of the public sector is made up of referral facilities called *centre de santé intégré* (CSI) and community health posts called *case de santé* (CS). As of December 2012, there were 856 CSI offering a minimum package of services, focused on PHC, referral from and counter-referral to the CS, and supervision of the CS.[13] CSI were typically staffed by nurses—and in certain large communes by a generalist doctor and midwives[13]—and, according to national norms, were intended to serve a maximum population of 5000–15 000 inhabitants, depending on population density.[14] According to national norms, CS were intended to be situated 5 km beyond a supervising CSI and served a population of 2500–5000.[14] CS provided a minimum package of services, focused on PHC at community level, including prevention services, health promotion services, and services for reproductive, maternal, newborn and child health, including iCCM. CS were typically staffed by a cadre of paid, full-time CHWs called *agent de santé communautaire* (ASC) and/or, in some cases, a nurse.[14] CS and ASC were scaled up between 2000 and 2013—a period of considerable progress on under-5 mortality.[15 16] As of December 2012, there were 2451 CS.[13] Some CS were supported by one or more volunteer CHWs called *relais communautaire* (RC), providing health promotion and prevention interventions in the communities within the catchment area (typically a 5 km radius) of the CS.[13 14] The MOPH in Niger plans to scale up RC—some targeted to communities beyond 5 km of CS or CSI to provide a standard package of preventive, promotive and curative services, including iCCM.[17]

Data

To inform our models of travel time to service delivery locations, we obtained spatial datasets for the following inputs: administrative boundaries (levels 0–3),[18] a 2013 georeferenced census of health service delivery networks (CSI, CS and ASC),[19] digital elevation model,[20] land cover,[21] roads,[22] rivers and other water bodies (treated as barriers to movement where no road crossed),[23] and travel scenarios. To inform our analysis of accessibility coverage, geographical coverage, RC scale-up and efficiency of geographical targeting of the CS, we obtained modelled estimates for population counts for 2000–2013[24] and 2015.[25] Also to inform our analysis of the efficiency of geographical targeting of the CS, we obtained modelled estimates for the annual mean under-5 mortality rate in 2013[26] and modelled estimates for the

annual mean incidence of *Plasmodium falciparum* (*Pf*) malaria among all ages (0–99 years) in 2013,[27] as PHC services provided through the CS are intended to address under-5 mortality and malaria[14] —with the latter being a main cause for curative consultations among children under-5 in Niger.[13] We prepared the input datasets in the projected coordinate reference system WGS 84/UTM zone 32N (EPSG: 32632) for Niger at 100×100 m resolution for our analysis of accessibility coverage and 1×1 km for our analysis of geographical coverage, targeting and scale-up. Further details are in online supplemental appendix 1.

We prepared travel speed tables for two travel scenarios: (1) walking in dry conditions and (2) walking to the nearest road and then using motorised transportation (assumed to be immediately available) in dry conditions. We set travel speeds by travel scenario for each land cover class and road class. Travel speeds were adapted from previous studies and experience in Niger and broader sub-Saharan Africa.[7 28]

Assessing geographical accessibility

We assessed geographical accessibility through two measures: accessibility coverage and geographical coverage.

We defined accessibility coverage as the estimated percentage of people within a given travel time to the nearest health service delivery location of a given health service delivery network, accounting for travel speeds of different modes of transportation over different land cover classes and slope, with the direction of travel toward the health service delivery location.[28] We estimated accessibility coverage at 100×100 m resolution for the CSI and CS-ASC (includes CS with or without ASC and the small number of ASC sites not within a CS) networks in 2013—and for the ASC network by gender, year of deployment (2000–2013), training, and availability of essential commodities—using 30-minute and 60-minute cut-offs for administrative levels 0–3 and the two travel scenarios. We used 30-minute and 60-minute cut-offs as previous analyses have shown care-seeking delays as a function of travel time after these cut-offs[29] and they are clinically relevant (eg, for prompt treatment of severe illness).[30] The analysis was constrained to national borders but allowed for travel across subnational administrative boundaries. We used the 'geographic accessibility' module within AccessMod 5 (V.5.6.48)[28] to calculate travel time layers and the 'zonal statistics' module to calculate the zonal statistics for each travel time layer by administrative level.

We defined geographical coverage as the theoretical catchment area of a health service delivery location, within a maximum travel time, accounting for the mode of transportation and the maximum population coverage capacity of the type of health service delivery location.[28] We used the 'geographic coverage' module of AccessMod 5 (V.5.6.48)[28] to estimate geographical coverage for the CSI and CS-ASC networks in 2013 at 1×1 km resolution for the two travel scenarios. The maximum travel time was set at 60 min. The maximum population capacity was set at 10 000 for CSI and 2500 for CS-ASC based on norms of the MOPH of Niger.[14] The maximum extent of a catchment was therefore delimited by the maximum travel time of 60 min except in cases where the estimated population in the catchment exceeded the maximum population capacity of the health service delivery location—in which case the extent of the catchment was smaller than the maximum travel time and was defined by the area containing the estimated population, up to the maximum population capacity.

Assessing geographical coverage of a hypothetical scale-up network of RC

To estimate the number of RC needed to maximise geographical accessibility of the population beyond the geographical coverage of the existing CSI and CS-ASC networks, we simulated a hypothetical network of RC in grid cells with at least 250 people in 2013 located beyond the geographical coverage of the existing CSI and CS-ASC networks at 1×1 km resolution, using a ratio of 1 RC per 1000 population (with a minimum threshold of 250 people to allocate 1 RC). We conducted a geographical coverage analysis at 1×1 km resolution to estimate the per cent of the estimated residual population that could be covered by the hypothetical RC network, within a maximum travel time of 60-minute walking to the nearest RC and maximum population capacity of 1000 for each RC.

Assessing efficiency of geographical targeting

We assessed the efficiency of geographical targeting of the CS-ASC network, using the concept of technical efficiency. We defined technical efficiency as the maximisation of a health outcome (geographical coverage) for a given set of inputs (the number of CS-ASC).[31] We used the estimated population, under-5 deaths and *Pf* malaria cases (all ages) beyond the geographical coverage (60-minute walking) of the CSI network in 2013—hereafter called the estimated residual population, under-5 deaths and *Pf* malaria cases, respectively—as the 'populations' to target in our geographical targeting analysis. We assessed the efficiency of geographical targeting of the existing CS-ASC network with three metrics: (a) geographical coverage of the estimated residual population; (b) geographical coverage of the estimated residual under-5 deaths; and (c) geographical coverage of the estimated residual *Pf* malaria cases (all ages) beyond the catchment of the CSI network in 2013 at 1×1 km resolution compared with three hypothetical CS-ASC networks designed to optimise metrics a–c. For (a) we compared the existing CS-ASC network (n=2550) with the 2550 CS-ASC from the hypothetical network that maximised geographical coverage of the targeted population, using the MOPH norm of 1 CS-ASC per 2500 population as the maximum population capacity. There is no MOPH norm for the ratio of CS-ASC per under-5 deaths or *Pf* malaria cases. Assuming one CS-ASC could cover all estimated under-5 deaths or *Pf* malaria cases within their catchment

Table 1 Accessibility coverage of the front-line health facility and ASC networks

	Walking				Walking+motorised transportation			
	Covered 30 min (no)	Covered 60 min (no)	Covered 30 min (%)	Covered 60 min (%)	Covered 30 min (no)	Covered 60 min (no)	Covered 30 min (%)	Covered 60 min (%)
CSI+CS-ASC	7 555 209	9 702 395	41.8	53.7	10 049 232	11 847 974	55.6	65.5
CSI	4 454 595	5 617 195	24.6	31.1	7 499 712	9 375 295	41.5	51.9
CS-ASC	3 724 166	5 516 196	20.6	30.5	8 552 971	10 917 747	47.3	60.4
ASC	1 930 318	3 156 228	10.7	17.5	6 177 540	9 228 791	34.2	51.0
Female ASC	624 548	1 115 902	3.5	6.2	3 333 890	6 228 099	18.4	34.4
Male ASC	1 403 743	2 352 088	7.8	13.0	4 710 547	8 290 546	26.1	45.9
ASC trained on iCCM	1 681 118	2 807 629	9.3	15.5	5 789 678	8 866 791	32.0	49.0
Additional contribution ASC	1 598 393	2 312 056	8.8	12.8	3 333 890	6 228 099	18.4	34.4
Additional contribution ASC trained on iCCM	1 365 053	1 997 636	7.5	11.0	860 150	1 343 604	4.8	7.4

ASC, agent de santé communautaire; CS, case de santé; CSI, centre de santé intégré; iCCM, integrated community case management.

regardless of population size would be unrealistic. Instead of making this unrealistic assumption, for metrics (b) and (c) we based the number of CS-ASC required for the existing CS-ASC network and the hypothetical CS-ASC network on the estimated number of CS-ASC needed to cover the estimated residual population in each catchment, using the MOPH norm of 1 CS-ASC per 2500 population. We then compared the estimated geographical coverage attained through the first 2550 CS-ASC of the existing CS-ASC network to the first 2550 CS-ASC of the hypothetical CS-ASC network designed to optimise metrics b–c. We assessed the potential effect of uncertainty of the estimates for under-5 deaths and *Pf* malaria cases among all ages on interpretation of our targeting results (see online supplemental appendices 1 and 7).

Patient and public involvement

We did not involve patients or the public in this study.

RESULTS

Accessibility coverage

Accessibility coverage of the ASC network increased from 0.0% to 17.5% between 2000 and 2013, with large variation at subnational levels, given a 60-minute cut-off and walking scenario (table 1, figure 1, online supplemental

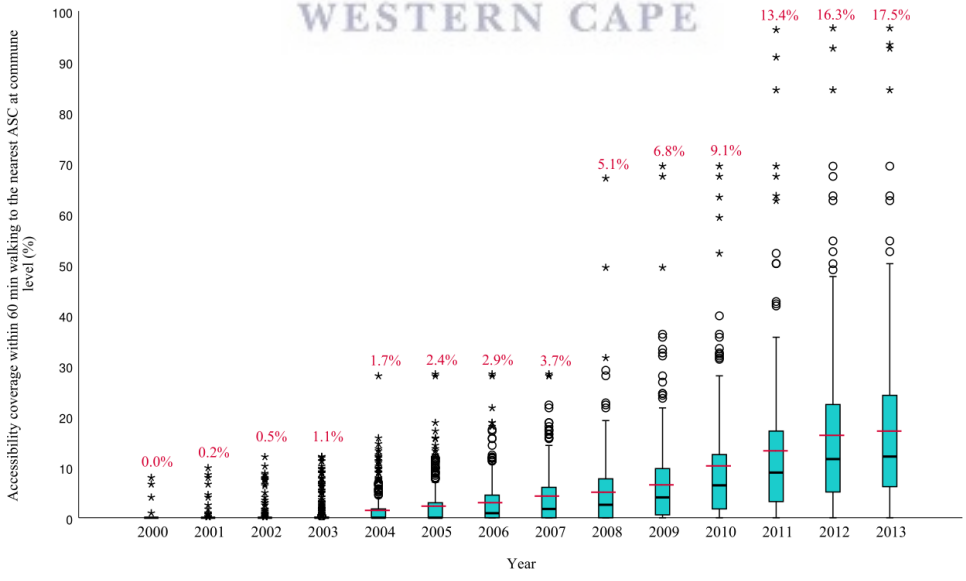

Figure 1 Median and interquartile range of the percent of the population within 60 minutes walking of an ASC at commune level (administrative level 3) between 2000-2013 at 100m x 100m resolution. Black lines indicate the median at commune level. Blue boxes represent the interquartile range at commune level. Circles and stars indicate communes outside of the interquartile range. Red lines and percentages indicate the national mean. ASC, Agent de santé communautaire.

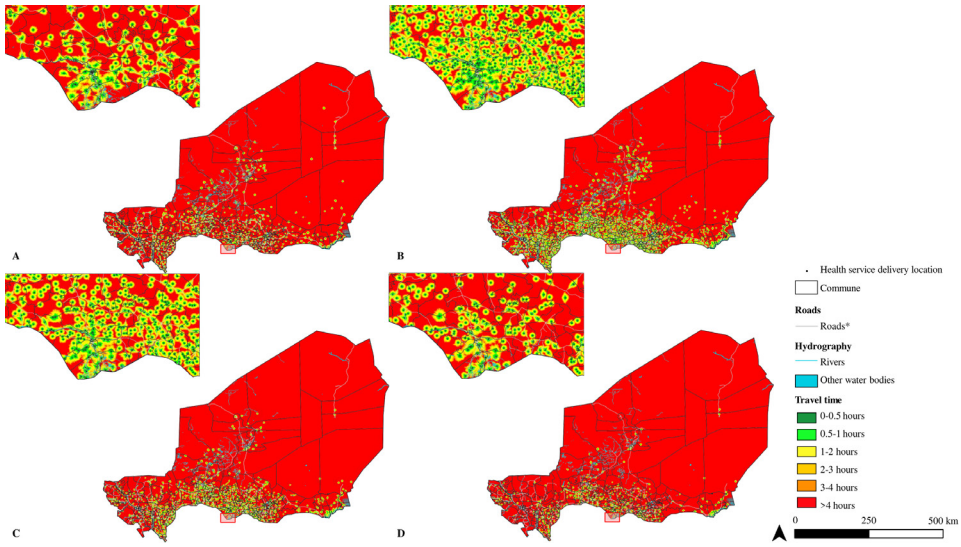

Figure 2 Geographic accessibility (travel time in minutes, walking in dry conditions) in 2013 at 100m x 100m resolution for A) *Centre de santé intégrée*, n=839; B) *Case de santé / Agent de santé communautaire*, n=2550; C) *Agent de santé communautaire*, n=1457; D) and D) *Agent de santé communautaire* trained on iCCM, n=1214. Inset near Madarounfa commune in Maradi region. *For visualization purposes road classes limited to motorway, trunk, primary, secondary and tertiary. **Other water bodies from landcover layer included permanent water bodies, temporary water bodies and herbaceous wetlands. iCCM, integrated community case managment.

appendix 2). Online supplemental videos 1 and 2 show the evolution of accessibility coverage of the ASC network between 2000 and 2013 by mode of transportation.

Accessibility coverage of the ASC network varied by gender of the ASC and training on specific interventions (table 1, online supplemental appendix 2 and figure 2A–L). Accessibility coverage of the ASC network trained on iCCM was 15.5% in 2013, given a 60-minute cut-off and walking scenario (table 1, figure 2D). The estimated additional contribution of the ASC network and ASC network trained on iCCM to accessibility coverage beyond the accessibility coverage of the existing CSI and CS (without ASC) networks combined, given a 60-minute cut-off and walking scenario, was 12.8% and 11.0%, covering an estimated 2.3 million and 2.0 million additional people, respectively (table 1).

Accessibility coverage in 2013, given a 60-minute cut-off and walking scenario, was 31.1% for the CSI network, 30.5% for the CS-ASC network and 53.7% for the combined CSI+CS-ASC network (table 1 and figure 2A–D). An estimated 8.3 million people (58.2%) remained beyond 60-minute walking to the nearest front-line health facility or ASC, without considering the maximum population capacity of these networks. Accessibility coverage of the CS network was lower when we considered availability of trained human resources (nurse or ASC) and essential commodities (online supplemental appendix 2 and figure 3A–G). Accessibility coverage of all health service delivery networks was higher when considering the walking plus motorised transportation travel scenario (online supplemental appendix 2 and figure 4A–F). We provide detailed results by administrative area in online supplemental appendix 2, tab 'Detailed_Results'.

Geographical coverage

Geographical coverage of the estimated total population in 2013 by the CSI network was 22.1%, assuming a walking scenario with a 60-minute catchment and maximum population capacity of 10 000 per CSI (figure 3 and online supplemental appendix 3, tab 'Summary'). Geographical coverage of the total estimated population in 2013 by the CS-ASC network was 19.4%, assuming a walking scenario with a 60-minute catchment and maximum population capacity of 2500 per CS-ASC (figure 3, online supplemental figure 3). Geographical coverage of the estimated residual population beyond the geographical coverage of the CSI network in 2013 by the CS-ASC network was 25.8%, providing an estimated 3·5 million additional people with physical access to PHC services, with important variation by region (online supplemental appendix 3, tab 'Summary' and online supplemental figure 6). An estimated 58.5% of the population in 2013—10.4 million people, predominantly rural—were beyond the geographical coverage of the combined CSI and CS-ASC networks, with 81.1% of the total uncovered population concentrated in the regions of Zinder, Maradi, Tillabéri and Tahoua (online supplemental figure 6B,C).

Geographical coverage of a hypothetical scale-up network of RC

A hypothetical network of 7741 RC in 6806 catchments with a maximum population capacity of 1000 people per RC, targeting 1×1 km cells with at least 250 people located beyond the geographical coverage of the existing CSI and CS-ASC networks, could cover 76.8% of this estimated residual population—providing physical access to PHC services for an estimated 7.4 million additional people

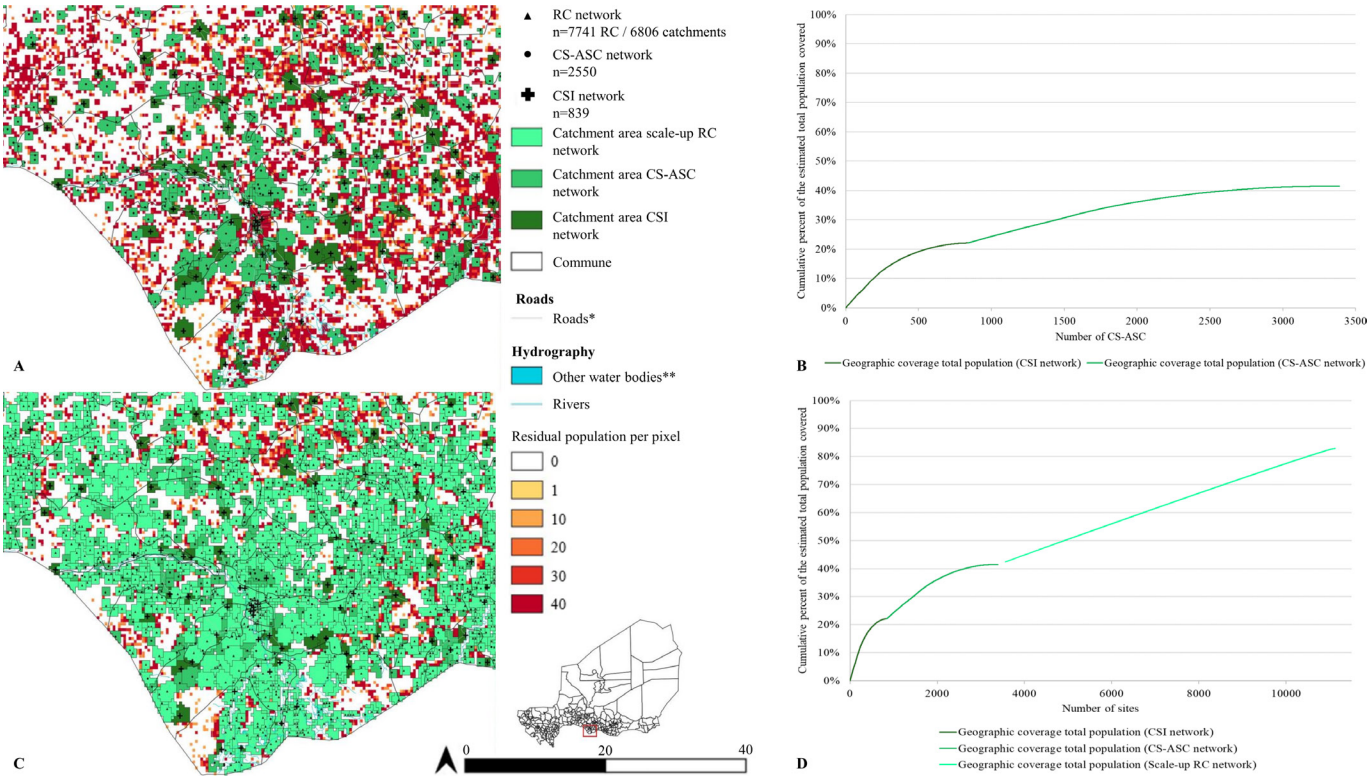

Figure 3 A) Geographic coverage at 1km x 1km resolution of the CSI (dark green) and CS-ASC networks (medium green) in 2013, 60-minute catchment (walking scenario), with inset near Madarounfa commune in Maradi region; B) Cumulative percent of the estimated total population covered within a 60-minute catchment, walking scenario (y-axis) by the number of CSI (x-axis, dark green line) and CS-ASC (x-axis, medium green line) at 1km x 1km resolution. C) Geographic coverage at 1km x 1km resolution of the CSI network (dark green), CS-ASC (medium green) and hypothetical scale-up RC network (light green) deployed to optimize geographic coverage of the residual population beyond the geographic coverage of the existing CSI and CS-ASC networks (60-minute catchment, walking scenario) in 2013, with maximum population capacity of 1000 people per RC, n=7741 RC in 6806 locations, and inset near Madarounfa commune in Maradi region; D) Cumulative percent of the estimated total population covered within a 60-minute catchment, walking scenario (y-axis) by the number of CSI (x-axis, dark green), CS-ASC (x-axis, medium green), and hypothetical scale-up RC network (x-axis, light green) at 1km x 1km resolution. The hypothetical scale-up RC network targeted 1km x 1km grid cells with at least 250 people situated beyond the geographic coverage of the existing CSI and CS-ASC networks (60-minute catchment, walking scenario) in 2013. Maximum population capacity was set to 1000 people per RC. CSI, Centre de santé intégrée; CS-ASC, Case de santé and Agent de santé communautaire; RC, Relais communautaire.

in 2013 (figure 3 and online supplemental appendix 6, tab 'Summary'). Geographical coverage of the estimated total population would increase from 41.5% covered by the existing CSI and CS-ASC networks to 82.9% by the combined CSI, CS-ASC and hypothetical RC networks in 2013 (online supplemental appendix 4, tab 'Summary').

Efficiency of geographical targeting

Geographical coverage of the estimated residual population beyond the geographical coverage of the existing CSI network was 37.0% by the hypothetical CS-ASC network compared with 25.8% by the existing CS-ASC network, covering an estimated 1.5 million additional people—a 43.6% gain in efficiency (figure 4 and online supplemental appendix 5, tab 'Comparison_Population'). Notably, over one-third (830) of the existing CS-ASC realised less than 30% of their maximum population capacity, indicating redundancy stemming from suboptimal geographical targeting (online supplemental appendix 5, tab 'rPop13_Existing'). Geographical coverage of the estimated residual under-5 deaths beyond the geographical coverage of the existing CSI network was 50.3% by the hypothetical CS-ASC network compared with 34.2% by the existing CS-ASC network, covering an estimated 11 900 under-5 deaths not otherwise covered—a 47.1% gain in efficiency (figure 4 and online supplemental appendix 5, tab 'Comparison_U5deaths'). Geographical coverage of the estimated residual *Pf* malaria cases (all ages) beyond the geographical coverage of the existing CSI network was 50.2% by the hypothetical CS-ASC network compared with 38.0% by the existing CS-ASC network, covering an estimated 737 000 *Pf* malaria cases not otherwise covered—a 32.3% gain in efficiency (figure 4 and online supplemental appendix 5, tab 'Comparison_Malaria'). Our uncertainty analysis for the efficiency of geographical targeting indicates bins/groups of CS-ASC catchments with relatively higher efficiency of geographical targeting could be distinguished from bins/groups of CS-ASC catchments with relatively lower efficiency of

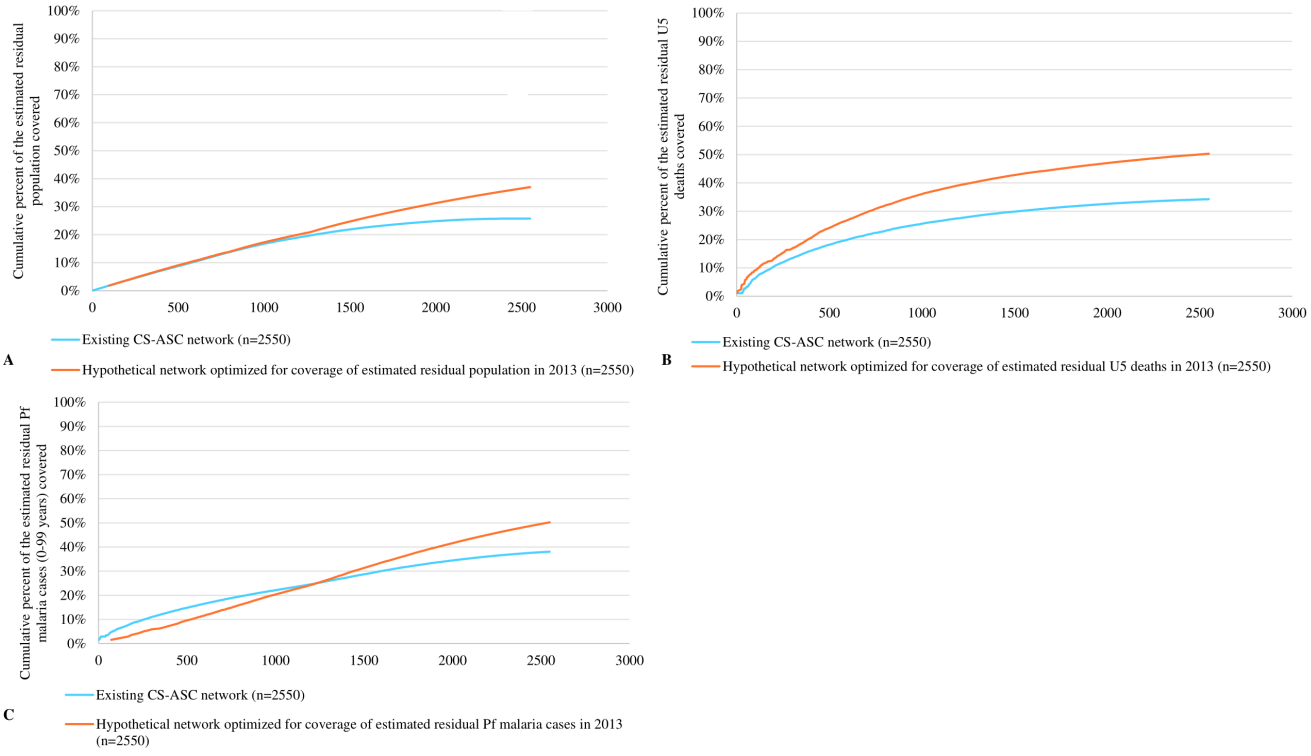

Figure 4 Targeting of the existing CS-ASC network compared to hypothetical optimized networks at 1km x 1km resolution. A) Comparison of the percent of the estimated residual population beyond the geographic coverage of the existing CSI network (60-minute catchment, walking scenario) that was covered by the existing CS-ASC network compared to a hypothetical CS-ASC network deployed to optimize geographic coverage of the estimated residual population; B) Comparison of the percent of the estimated residual under-five deaths beyond the geographic coverage of the existing CSI network (60-minute catchment, walking scenario) that was covered by the existing CS-ASC network compared to a hypothetical CS-ASC network deployed to optimize geographic coverage of the estimated residual under-five deaths; C) Comparison of the percent of the estimated residual *Pf* malaria cases among all ages (0-99 years) beyond the geographic coverage of the existing CSI network (60-minute catchment, walking scenario) that was covered by the existing CS-ASC network compared to a hypothetical CS-ASC network deployed to optimize geographic coverage of the estimated residual *Pf* malaria cases among all ages (0-99 years). All analyses at 1km x 1km resolution. CS-ASC, Case de santé and Agent de santé communautaire; U5, children under five years of age; Pf, Plasmodium falciparum.

geographical targeting (online supplemental appendix 6).

DISCUSSION

Implications for policy

We understand that rational decisions on targeting and scale-up of community health posts and CHWs, like with health facilities, cannot be addressed purely through modelling, as there are many factors involved in the political economy of health system planning and decision-making that are difficult (or impossible) to capture in models.[32 33] Nonetheless, in our view modelling can provide useful insight for planning and policy decisions. Below we outline key implications of our analysis for policymakers in Niger, as well as other countries of sub-Saharan Africa, with similar contexts and interest in optimising PHC at community level.

First, scale-up of the community health posts (CS) staffed by paid, full-time CHWs (ASC) greatly improved geographical accessibility of PHC services at community level between 2000 and 2013. Other research has indicated that the expansion of PHC at community level may have contributed to improvements in under-5 mortality and other health outcomes[15 16] and still other research has documented the factors that led to the expansion and support for its implementation, including the use of heavily indebted poor countries' funds to finance the construction of the community health posts under the 'special programme' of President Mamadou Tandja, multilateral and bilateral funding to support the monthly payment of CHWs, training and commodities, as well as loans from the World Bank conditional on removal of user fees for children under-5.[32] The experience in Niger with the expansion of the community health posts staffed by paid, full-time CHWs may provide an exemplar model from West Africa from which to learn about scaling up PHC at community level.

Second, our results on the efficiency of geographical targeting of the community health post network imply retargeting of community health posts could result in significant improvements in population coverage and cost-savings that could be reinvested in further scale-up

and strengthening of the health system, particularly in the regions of Zinder, Maradi, Tillabéri and Tahoua where over 80% of the uncovered population live. That said, we recognise retargeting community health posts (and thereby resources for CHW) may be disruptive and politically contentious. A less disruptive and perhaps more politically feasible option would be to apply the geographical targeting and scale-up approaches we have described here to optimise further scale-up of the community health post network staffed by paid, full-time CHWs and/or scale the volunteer CHW (RC) network. Compared with the status quo planning process, as evidenced by the inefficiency of the existing community health post network, we would anticipate this optimisation of PHC at community level would result in significant improvements in population coverage and cost-savings that could be reinvested in further scale-up and strengthening of the health system.

Regarding further scale-up of PHC services at community level, there are two additional considerations: first, if choosing between scaling the community health post network of paid, full-time CHWs (ASC) and scaling the volunteer CHW (RC) network, a key consideration is that the scope of work of the RC is more restricted than that of the ASC and the populations covered by the RC would still require geographical accessibility to PHC services that are beyond the remit of the RC but within the scope of the ASC. Depending on the package of PHC services at community level being considered, it may be more efficient and prudent from an equity perspective to optimise the scale-up of the network of community health posts with the paid, full-time CHW and progressively upgrade community health posts to referral facilities (CSI), where needed, to enable broadening of the package of services that are geographically accessible to the population rather than scale up the RC network. Second, in our analysis the scaled up RC network targeted grid cells (100×100 m) with at least 250 population beyond the catchment of the existing referral facility (CSI) and community health post (CS) networks and increased geographical coverage of the population from 41.5% to 82.9%. Covering the remaining 15%–20% of the population would require extending geographical accessibility of PHC services at community level to increasingly small, dispersed communities and will be increasingly less efficient and more logistically challenging than covering the first 80% of the population. Other countries with similar contexts in sub-Saharan Africa are likely to face this challenge. Future analysis and research through collaborative, country-led processes should aim to find optimised, context-specific solutions for covering populations at risk of being left behind.

At the time of writing this manuscript, coauthors were working with the MOPH to update this analysis using datasets from 2020 to 2021. However, we anticipate the insights above will remain valid and useful to planners and policymakers in Niger as they prepare a midterm review of the National Community Health Strategy in 2022, develop an investment case for the GFF and develop a new Health Sector Development Plan for 2024–2028. Planners and policymakers in other countries of sub-Saharan Africa with similar contexts, who are interested in optimising PHC at community level, might also benefit from these insights.

Limitations

There are important limitations to this study. First, we did not include secondary or tertiary facilities or outreach/mobile sites. We focused on the question of physical access to PHC at community level through community health posts with CHWs and the first level referral health facilities (to which the former refer), rather than secondary or tertiary health facilities and permanent, fixed service locations rather than periodic, mobile services. Several coauthors are currently working with the MOPH on an update to this analysis that will be inclusive of all facility types and CHWs based on data from 2020 to 2021. Second, our analysis is limited by the completeness and quality of the publicly available data on road and river networks. We acknowledge that more complete and/or accurate government or proprietary road and river network data may be available. For the river network, we acknowledge that some rivers, streams and other waterways may not be perennial barriers to movement. We attempted to mitigate this limitation by allowing major road classes (motorway, trunk, primary, secondary and tertiary) to cross rivers/streams and by incorporating data on the hydrographic network from the high-resolution Copernicus land cover layer[21] in our merged land cover layer. We also conducted a sensitivity analysis using only waterways classified as 'rivers' in the rivers input layer as barriers to movement and found this made no important difference to the results (online supplemental appendix 2, tab 'Sensitivity_analysis'). Third, our accessibility coverage, geographical coverage and targeting analyses do not account for uncertainty of the estimates of population. Previous analyses of accessibility coverage and geographical coverage have not uncounted for uncertainty of this kind, but we acknowledge this is an important limitation and area for improving future modelling. Fourth, our analysis does not account for national parks or other 'no–go' zones (eg, military bases) due to lack of access to the geography of these objects for 2013. Fifth, our travel speeds were based on estimated travel speeds used in similar analyses for Niger and other countries in sub-Saharan Africa in the dry season.[7 28] The travel speeds used in our analysis do not account for travel speeds in the rainy season. This choice was justified given that the rainy season spans only 3–4 months of the year and the effects of the rainy season on geographical accessibility are anticipated to be limited in duration (total seasonal rainfall is estimated to result from only 40–50 rain events of which only 2.4%–4.5% are estimated to be extreme rain events) and geographically localised.[34] For these reasons, adjusting the travel speeds to account for the rainy season using a generalised correction factor would be inappropriate.

Adequately adjusting the travel speeds would entail use of empirical data and/or expert knowledge at the local level about the effects of rain events on travel speeds (eg, frequency, duration and location of washed-out bridges, flooding, reductions in travel speeds) which was beyond the scope of the current exercise. Our analysis also does not account for differences in travel speeds by population groups (eg, pregnant women, people with illness and caregivers carrying sick children may walk slower than the general population), river transportation, and our walking plus motorised transportation scenario assumes immediate access to a vehicle once a road is reached and does not account for road traffic or factors impacting road traffic (eg, traffic lights). In addition, we did not attempt to account for uncertainty of the travel speed estimates as some analyses have done using an arbitrary, generalised correction factor of ±20%,[35 36] because in our view it would be better to use empirical data and/or local expert knowledge on this uncertainty and ascertaining such information was beyond the means of the current analysis. Sixth, our analysis does not account for the possibility of accessing health service delivery locations across national boundaries, an important consideration for cross-border and migrant populations. Seventh, the modelled population counts for 2000–2012 use the High Resolution Settlement Layer population settlement footprint from 2015,[25] which may not accurately reflect the population settlement footprint for the early 2000s. Eighth, for our targeting analysis, we resampled the modelled estimates of under-5 mortality rates and *Pf* incidence from 5 km resolution to 1 km resolution due to lack of estimates at 1 km resolution, effectively assuming the values for these parameters at the finer 1 km resolution. However, this limitation is moot given that the aim of the targeting analysis is to optimise the order of cell prioritisation (which potential location for a community health post should be prioritised over another), cell prioritisation is concerned with the relationship between cells (not the absolute value of cells) and the relationship between cells at 5 km resolution was maintained at 1 km resolution. Lastly, the accuracy of the modelled estimates of under-5 mortality rates[26] and *Pf* malaria incidence[27] used in our targeting analysis is unknown. Despite this limitation, results from our uncertainty analysis indicated that our targeting approach could be used to confidently identify bins/groups of health service delivery catchment areas that are relatively more efficient at geographical targeting than other bins/groups—and that this information could be used to optimise geographical targeting of community health posts staffed by CHWs (ASC). An update to this analysis is planned with the MOPH for 2021 and will seek to address the above limitations.

We acknowledge that, in addition to physical accessibility, it is important to consider social and economic barriers to care-seeking (eg, social norms, intrahousehold power dynamics, costs of transportation, opportunity costs of travel time, costs of services and commodities) which may influence access to and use of health services.[37] It is also important to consider the quality of health services and the potential for bypassing.[38 39] Lastly, predominate modes of transportation may vary by socioeconomic status and geography[40] and they may change in response to contextual factors (eg, the lockdowns due to COVID-19 in 2020).

CONCLUSION

Geographical accessibility of PHC services at community level improved in Niger between 2000 and 2013 through the scale-up of community health posts staffed by paid, full-time CHWs, providing an estimated 2.3 million additional people with physical access to PHC services at community level—including 2.0 million additional people with physical access to iCCM. However, as of 2013, gaps in geographical accessibility remained and efficiency of geographical targeting of community health posts was suboptimal. The approaches to geographical targeting and scale-up described here could be useful for optimising geographical accessibility to PHC services at community level in Niger and similar contexts of sub-Saharan Africa.

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Contributors NPO was responsible for the study conceptualisation, methodology, data curation and writing the draft manuscript. OH, IM, KB, AYG, NPO and NR collected data or provided feedback on data. NPO, NR and ZS conducted the formal analysis and were responsible for data visualisation. NPO, NR and TD verified the underlying data. TD, DJ and NR provided supervision and overall guidance. All authors contributed to reviewing and editing the manuscript.

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Ethics approval The 2013 georeferenced census of health service delivery networks (CSI, CS and ASC)[19] was conducted by the National Statistics Institute of Niger and the MOPH in the context of management of the public health sector and did not require ethical approval. The protocol for secondary analysis of the 2013 census of CSI, CS and ASC was approved by the Ethics Committee of the University of Western Cape (Registration no: 15/7/271).

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Data availability statement Data are available in a public, open access repository under the Creative Commons Attribution 4.0 Unported (CC BY 4.0) licence, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: https://creativecommons.org/licenses/by/4.0/. Supplemental appendices 2–6, videos 1–2, and all model outputs are available in supplemental appendix 1b at https://doi.org/10.5281/zenodo.4428176. All model inputs (except existing service delivery locations) are available in supplemental appendix 1c at https://doi.org/10.6084/m9.figshare.13536779.v6. Health service delivery location data are only available through data sharing agreements with UNICEF and the Ministry of Public Health of Niger.

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What is already known on this topic?

• Previous studies in Sierra Leone have explored geographical accessibility to antenatal care and childbirth services at health facilities but not community-based PHC services provided by CHWs.

What are the new contributions from this study?

• Our analysis provides new insight on the contribution of CHWs to increasing geographical accessibility of integrated PHC services at community level in Sierra Leone between 2000-2015, as well as policy relevant variation across subnational areas, gender of the CHW, and training of the CHW on specific interventions.

• Our analysis identifies important misalignment between the scale and deployment of the existing CHW workforce and current national policy, and points to opportunities for optimising the scale and deployment of CHWs to maximize geographical accessibility to integrated PHC services at community level, including iCCM, in Sierra Leone.

How this study might affect research, practice, or policy?

• Earlier outputs of our analysis (same study) informed the national community health strategy 2022-2025, including the Ministry of Health and Sanitation (MOHS) plan to rightsize and retarget the CHW workforce to where it is needed most.

• Our current analysis supports the MOHS decision to rightsize and retarget the CHW workforce to where it is needed most to maximize geographical accessibility to integrated PHC services and the efficiency of CHW deployment. The MOHS could use our analysis to fine-tune operational planning and implementation of CHW policy in the context of broader planning of the health and care workforce and health sector.

• MOHS and partners could consider re-investing cost-savings from rightsizing and retargeting toward the professionalization of CHWs and strengthening the health policy and systems components needed for CHWs to effectively deliver integrated PHC services, including iCCM (as described in study 4).

• The approaches to optimisation described in this study (and studies 1 and 3) could be adapted to similar contexts within sub-Saharan Africa to maximize the contribution of

CHWs to geographical accessibility to integrated PHC services within the context of broader health sector planning.

Contribution of the candidate: The candidate (NPO) was responsible for the study conceptualisation, methodology, data curation and writing the draft manuscript. EM, MS, JK, AK, KH, SO, and NPO led or provided technical assistance to and oversight of data collection for the main datasets used. NPO, AC, and NR conducted the geospatial analysis. EM, MS, JK, AK, KH, SO, NPO, AC, and NR provided feedback on data and data visualisation. NPO, AC, NR, and TD verified the underlying data. TD, DJ, and NR provided supervision and overall guidance. All authors reviewed and interpreted the results of the analysis presented in the manuscript and contributed to editing the manuscript

Review comments from the peer review process are available in Appendix 2

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Optimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis

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ABSTRACT

Background Little is known about strategies for optimising the scale and deployment of community health workers (CHWs) to maximise geographic accessibility of primary healthcare services.

Methods We used data from a national georeferenced census of CHWs and other spatial datasets in Sierra Leone to undertake a geospatial analysis exploring optimisation of the scale and deployment of CHWs, with the aim of informing implementation of current CHW policy and future plans of the Ministry of Health and Sanitation.

Results The per cent of the population within 30 min walking to the nearest CHW with preservice training increased from 16.1% to 80.4% between 2000 and 2015. Contrary to current national policy, most of this increase occurred in areas within 3 km of a health facility where nearly two-thirds (64.5%) of CHWs were deployed. Ministry of Health and Sanitation-defined 'easy-to-reach' and 'hard-to-reach' areas, geographic areas that should be targeted for CHW deployment, were less well covered, with 19.2% and 34.6% of the population in 2015 beyond a 30 min walk to a CHW, respectively. Optimised CHW networks in these areas were more efficiently deployed than existing networks by 22.4%–71.9%, depending on targeting metric.

Interpretations Our analysis supports the Ministry of Health and Sanitation plan to rightsize and retarget the CHW workforce. Other countries in sub-Saharan Africa interested in optimising the scale and deployment of their CHW workforce in the context of broader human resources for health and health sector planning may look to Sierra Leone as an exemplar model from which to learn.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies in Sierra Leone have explored geographical accessibility to antenatal care and childbirth services at health facilities but not community-based primary healthcare (PHC) services provided by community health workers (CHWs).

WHAT THIS STUDY ADDS

⇒ Our analysis provides new insight on the contribution of CHWs to increasing geographical accessibility of community-based PHC services in Sierra Leone between 2000 and 2015, as well as policy relevant variation across subnational areas, gender of the CHW and training of the CHW on specific interventions.

⇒ Our analysis identifies important misalignment between the scale and geographic distribution of the existing CHW workforce and current national policy, and points to opportunities for optimising scale and efficiency of CHW deployment.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ Our analysis supports Ministry of Health and Sanitation (MOHS) plans to rightsize and retarget the CHW workforce.

⇒ The MOHS could use our analysis and future iterations to fine-tune planning and implementation of CHW policy in the context of broader HRH and health sector planning.

⇒ MOHS and partners could consider re-investing cost-savings from rightsizing and retargeting towards the professionalisation of CHWs and strengthening the systems components needed to optimise CHW performance.

BACKGROUND

Countries committed to achieving Universal Health Coverage (UHC) as part of the Sustainable Development Goals set in 2015 and reaffirmed that commitment at the United Nations General Assembly High Level Meeting on UHC in 2019.[1] Achieving UHC and ensuring effective pandemic preparedness and response will require strengthening health systems by investing in primary healthcare (PHC), particularly frontline health workers at the primary healthcare level and in communities.[2–5] CHWs are foundational to the PHC approach as frontline human resources for health (HRH), essential members of PHC teams providing community-based PHC services and a trusted

bridge between the health system and communities.[6–9] Research has shown CHWs can be a cost-effective and equity-promoting investment, particularly when they are well-supported by the health system and communities they serve.[10–15] Investment in CHWs can also promote the economic development and the empowerment of women through paid work.[10 16] Globally, there is a severe HRH shortage, including for CHWs, compounded by a maldistribution of HRH, with the most severe affects in Africa, particularly in rural, remote and underserved geographic areas.[17 18] Globally, financing of HRH is inadequate, including for CHWs with an estimated funding gap of US$5.4 billion annually.[19]

In Sierra Leone, CHWs are essential frontline HRH critical to the country's vision of a resilient national health system and prosperous socioeconomic development.[20–22] Under the leadership of the Ministry of Health and Sanitation (MOHS), there was a large scale-up of CHWs employed by non-governmental organisations between 2000 and 2020, including during the Ebola crisis.[23] As of 2020, there were >17 000 CHWs deployed in Sierra Leone.[23] An assessment of the national CHW programme incorporated findings from earlier iterations of our analysis, and informed the new MOHS CHW policy for the period 2021–2025.[23] The new policy included three key policy shifts: harmonisation and integration of all CHW cadres into the national CHW programme, rightsizing the scale of the CHW network and retargeting CHW deployment to areas of greatest need.[24]

ries strive to increase financing for HRH, including for CHWs, concurrent efforts are needed to optimise impact and efficiency of available funding through rightsizing scale and improving the equitable distribution of HRH, including CHWs. Geospatial analysis using geographic information systems can be a powerful tool in the HRH toolkit for optimising scale and deployment of HRH. However, few countries leverage the potential of geospatial analysis, contributing to inefficiencies and inequities in the distribution of HRH and geographical accessibility of health services.[17 18]

We used data from a national georeferenced census of CHWs and other spatial datasets in Sierra Leone to undertake a geospatial analysis exploring optimisation of the scale and deployment of CHWs with the aim of informing implementation of the new CHW policy and future MOHS planning.

DATA AND METHODS

We provide a detailed description of the data and methods in online supplemental appendix 1, including a simplified analysis flow (online supplemental appendix 1 figure 1). Methods were adapted from previous work in the region by Oliphant *et al*.[25]

Study setting

During our period of focus, 2000–2016, Sierra Leone had four political administrative levels (chiefdoms, districts, provinces and national).[26] The health system included a public and private sector organised in a decentralised, pyramidal structure with three administrative levels—tertiary, secondary and primary—overseen by the MOHS.[27] Our analysis focuses on CHWs situated at the base of the primary level. The primary level comprised public health facilities, collectively known as peripheral health units (PHUs) providing PHC services and referral services to the secondary level (district hospitals). PHUs—in descending order according to size and availability of skilled healthcare workers—included community health centres, community health posts and maternal and child health posts. The primary level also included private sector clinics focused on primary healthcare services.

At the base of the primary level were CHWs. National CHW policy evolved over time, including the development of the first national CHW policy in 2012 (covering 2012–2015)[28] and subsequent updates in 2016 (covering 2016–2020)[21] and 2021 (covering 2021–2025).[24] According to the national CHW policy of 2012–2015, a CHW was defined as a community member selected by the community and trained to provide basic essential health services and information at community level.[28] Following a standardised 10-day preservice training designed by the MOHS, CHWs were allowed to provide a standard package of community-based PHC services, including prevention, promotion and curative services, as well as surveillance activities, through household visits. The national CHW policy of 2012–2015 did not include geographic criteria for guiding the deployment of CHWs (ie, the CHW could be selected from and work in communities regardless of proximity to health facilities). The national CHW policy of 2021–2025 sought to rightsize and retarget the CHW network and was informed, in part, by early iterations of our analysis.[23 24] Additional details on the evolution of CHW policy, including the definition of CHWs, package of services, selection, training, certification, deployment, CHW per population ratios and supervision are provided in online supplemental appendix 1.

Data

We obtained the following spatial datasets to inform our models of travel time to CHWs and health facilities: administrative boundaries (levels 0–3),[29] a 2016 national georeferenced master facility list (Ministry of Health and Sanitation, the Republic of Sierra Leone, UNICEF, 2016), a 2016 national georeferenced CHW master list (CHWML) (Ministry of Health and Sanitation, the Republic of Sierra Leone, UNICEF, 2016), digital elevation model,[30] land cover,[31] roads,[32] waterbodies[33] (treated as barriers to movement where roads did not cross) and travel scenarios (online supplemental appendix 1 figures 27-37). As of 2016, there were 14 632 working CHWs of which 14 579 CHWs (99.6%) had geographic coordinates for the main settlement in which they worked and 14 494 CHWs (99.1%) reported they received the standard 10-day preservice training of the MOHS (online supplemental appendix 1 figure 38). Data on training

and year of deployment were self-reported by CHWs in the CHWML. For our analysis of accessibility coverage, geographic coverage and efficiency of deployment, we obtained modelled estimates for population counts for 2000–2015.[34 35] Community-based PHC services provided by CHWs are intended to address under-five (U5) mortality and malaria was a main cause for curative consultations among children U5 in Sierra Leone.[27] For this reason, we obtained modelled estimates of the annual mean U5 mortality rate in 2015[36] and modelled estimates of the annual mean incidence of *Plasmodium falciparum* (*Pf*) malaria among all ages (0–99 years) in 2015[37] to inform our efficiency analysis. We prepared the input datasets in the projected coordinate reference system EPSG:2161—Sierra Leone 1968/UTM zone 28N for Sierra Leone at 100 m×100 m resolution for our analysis of accessibility coverage and 1 km×1 km for our analysis of geographic coverage and efficiency of deployment.

We prepared a travel speed table for the travel scenario walking in dry conditions (online supplemental appendix 1). We adapted travel speeds for each land cover class and road class from previous studies.[25 38 39] Travel speeds refer to the population walking in dry conditions in the direction of the CHW. Travel speeds and analysis for other travel scenarios (eg, travel in wet conditions, motorised travel) that were not our main focus are provided in online supplemental appendix 1.

Geographic areas relevant to CHW policy

The current CHW policy for 2021–2025 included two policy-relevant geographic areas: easy-to-reach (ETR) and hard-to-reach (HTR) areas.[24] The MOHS defined ETR areas as areas 3–5 km from a health facility and not in difficult terrain. The MOHS did not define 'not in difficult terrain'. Hills, mountains and water bodies can increase the travel time needed to traverse an area or impede travel altogether, depending on the mode of transport. We accounted for the effect of such geographic features on travel time in our analysis and defined 'not in difficult terrain' as areas within 60 min walking of a health facility. The MOHS-defined HTR areas as areas beyond 5 km from a health facility or between 3 and 5 km of a health facility and in an area with difficult terrain. The MOHS did not define 'difficult terrain'. We defined 'difficult terrain' as beyond 60 min walking of a health facility. This is a change from previous definitions of ETR and HTR areas in Sierra Leone. In the CHW policy for 2016–2020, the MOHS defined ETR areas as areas within 3 km of a health facility and HTR areas as areas beyond 3 km from a health facility.[21] The MOHS definitions of ETR and HTR areas in the 2016–2020 policy did not mention 'difficult terrain'. The CHW policy of 2012, covering the period 2012–2015, did not provide definitions for HTR and did not mention ETR.[28]

We conducted our analysis for three geographic areas relevant to the current CHW policy for 2021–2025: areas within 3 km of a health facility, which are not prioritised for CHW deployment in the 2021–2025 CHW policy, ETR areas and HTR areas. Populated areas within 3 km of a health facility covered a total of 12 990 km^2 with an estimated population of 5.5 million in 2015 (77.2% of the total population). Populated ETR areas covered a total of 3 345 km^2 with an estimated population of 167 000 in 2015 (2.4% of the total population). Populated HTR areas covered a total of 14 878 km^2 with an estimated population of 1.4 million in 2015 (20.2% of the total population). Further details on the data and methods used to derive these geographic areas are in online supplemental appendix 1 1.

Assessing accessibility coverage

We defined accessibility coverage as the estimated percentage of people within a given travel time to the nearest health service delivery location, accounting for travel speeds of different modes of transportation over different land cover classes.[39] The slope of the terrain is accounted for by correcting for walking speeds,[40] and by considering a direction of travel towards the health service delivery location.[39]

We estimated accessibility coverage at 100 m×100 m resolution for the health facility and CHW networks in 2015. We also did this for the CHW networks in ETR and HTR areas, gender of the CHW, year of deployment (2000–2015), preservice training and training on specific interventions. We used 10 min, 30 min and 60 min cutoffs as previous analyses have shown care seeking decays as a function of travel time after these cutoffs[41] and they are clinically relevant (eg, for prompt treatment of severe illness).[42] The analysis was constrained to national borders but allowed for travel across subnational administrative boundaries. We used the 'accessibility' module within AccessMod 5 (V.5.6.56)[41] to calculate travel time layers and the 'zonal statistics' module to calculate zonal statistics for each travel time layer by administrative level.

Assessing efficiency of deployment in ETR and HTR areas

We assessed the efficiency of deployment of the existing CHW networks and compared them with hypothetical networks designed to optimise efficiency of CHW deployment. We defined efficiency of deployment as the geographic coverage of the estimated population achieved by a given number of CHWs, based on an adaptation of the definition of technical efficiency by Palmer and Torgerson.[43] A CHW network designed to optimise efficiency of CHW deployment is one that maximises geographic coverage of the population with the fewest number of CHWs. This requires deploying CHWs such that each CHW maximises the gain in geographic coverage of the population. We assessed efficiency of deployment by comparing the gain/loss in geographic coverage achieved by optimised CHW networks compared with the existing CHW networks, given the same number of CHWs. We defined geographic coverage as the estimated population within a theoretical catchment area of the CHW networks, given a 30 min maximum travel time (walking scenario) and the maximum population capacity of the

CHWs.[39] We assessed geographic coverage of (a) the estimated population in 2015, (b) the estimated U5 deaths in 2015 and (c) the estimated *Pf* malaria cases in 2015 by the existing CHW networks in 2016 at 1 km×1 km resolution using the 'geographic coverage' module of AccessMod 5 (V.5.6.56).[39] We then assessed geographic coverage of a–c using the hypothetical CHW networks in 2016 designed to optimise metrics a–c, and compared these results with the results from the existing networks. The maximum population capacity for CHWs was based on the MOHS norms for the ratio of CHWs per population from the 2021 CHW policy.[24] We used the lower bound of the MOHS range for the ratio of CHW per population to be conservative in our estimates: 500 for CHWs in ETR areas and 300 for CHWs in HTR areas. The maximum extent of a catchment was therefore delimited by the maximum travel time of 30 min except in cases where the estimated population in the catchment exceeded the maximum population capacity. In this case, the extent of the catchment was defined by the area containing the estimated population, up to the maximum population capacity.

For (a) we compared the efficiency of deployment of the existing CHW networks with hypothetical networks of the same number of CHWs (n=1521 in ETR areas and n=3650 in HTR areas). We used the MOHS norms for CHWs to population stated above. There is no MOHS norm for the ratio of CHW per U5 deaths or *Pf* malaria cases. Assuming one CHW could cover all estimated U5 deaths or *Pf* malaria cases within their catchment regardless of population size would be unrealistic. For metrics (b) and (c), we based the number of CHW required for the existing CHW networks and the hypothetical CHW networks on the estimated number of CHW needed to cover the estimated population in each catchment using the MOHS norms above. We then compared the estimated geographic coverage attained in ETR areas by the first 1521 CHW of the existing CHW network with the first 1521 CHW of the hypothetical CHW network designed to optimise metrics b–c. We did the same comparison for HTR areas, using the first 3650 CHW of the existing CHW network and first 3650 CHW of the hypothetical CHW network designed to optimise metrics b–c. We assessed the potential effect of uncertainty of the estimates for U5 deaths and *Pf* malaria cases among all ages on interpretation of our efficiency results (see online supplemental appendix 1 and 4).

Patient and public involvement statement

We did not involve patients or the public in this study.

RESULTS

Accessibility coverage

Three-quarters (76.1%) of the estimated population in 2015 had walking access to a health facility within 60 min (table 1). Accessibility coverage within a 30 min walk to a CHW increased from 16.0% to 80.4% between 2000 and 2015 (table 1). Contrary to current national policy, most of the increase in accessibility coverage of CHWs occurred within 3 km of a health facility where nearly two-thirds (64.5%) of CHWs were deployed. Increases in accessibility coverage were least pronounced in ETR and HTR areas, where only 10.4% and 25.0% of CHWs were deployed, respectively (table 1, online supplemental appendix 1 figure 35). Accessibility coverage of the estimated population in ETR and HTR areas within a 30 min walk to a CHW was 80.9% and 65.4%, respectively, covering an estimated 135 000 and 801 000 people (table 1). Online supplemental video shows the evolution of travel time (walking) to a CHW between 2000 and 2015, indicating a relatively slower scale-up between 2000 and 2010 and a rapid scale-up thereafter—continuing during the Ebola outbreak of 2015–2016. Accessibility coverage within a 30 min walk to a CHW was higher for male CHWs compared with female CHWs, with the disparity most pronounced in ETR and HTR areas (table 1). Accessibility coverage within a 30 min walk varied by training on specific interventions, with the highest accessibility coverage (near 74%) for community case management (CCM) for malaria, prevention and promotion interventions, and CCM index (CCM for malaria plus identification and referral for severe malnutrition) and lower accessibility coverage for reproductive, maternal and newborn health (RMNH) interventions (65.5%) Ebola virus disease signal functions (60.2%) and all packages (48.3%) (table 1). Accessibility coverage also varied by travel scenario, with higher accessibility coverage for dry scenarios versus wet scenarios and walking plus motorised transportation scenarios versus walking scenarios. We provide additional maps in online supplemental appendix 1 figures 2–19 and detailed results at national and subnational levels (chiefdoms) by travel scenario in online supplemental appendix 2, tab 'Detailed_Results'.

Efficiency of deployment

ETR areas

The hypothetical CHW network in ETR areas was 43.2% more efficient than the existing network in terms of geographic coverage of the estimated population within a 30 min catchment (97.0% vs 67.7%) (figures 1 and 2A and online supplemental appendix 3, tab 'Comparison_Pop_ETR'). A majority (53%) of the existing CHW network realised <30% of their maximum population capacity (500), indicating redundancy from inefficient deployment. Additionally, 80% of the estimated population not covered by the existing CHW network in 2015 was concentrated in just 36.6% (56/153) of communes (online supplemental appendix 1 figures 20–22 and 26). The hypothetical CHW network in ETR areas was 27.2% more efficient than the existing network in terms of geographic coverage of the estimated U5 deaths within a 30 min catchment (95.1% vs 74.8%) (figure 2B, online supplemental appendix 3, tab 'Comparison_U5d_ETR'). The hypothetical CHW network in ETR areas was 26.1% more efficient than the existing network in terms of geographic coverage of the estimated *Pf* malaria

Table 1 Accessibility coverage of the estimated population in 2015 by the health facility and CHW networks, walking scenario

	Among population within 3 km of a health facility, % within travel time			Among estimated population in ETR areas, % within travel time			Among estimated population in HTR areas, % within travel time			Among total estimated population in 2015, % within travel time		
Network*	10 min	30 min	60 min	10 min	30 min	60 min	10 min	30 min	60 min	10 min	30 min	60 min
Health facility	54.8	84.5	95.8	0.0	0.0	92.2	0.0	0.0	0.0	42.3	65.2	76.1
CHW	68.0	84.4	96.3	69.5	80.9	97.0	56.1	65.4	75.3	65.6	80.4	92.0
CHW in 2000 with preservice training	5.3	20.6	31.0	0.9	2.1	3.8	0.4	0.5	0.9	4.2	16.1	24.2
CHW with preservice training	67.9	84.4	96.3	69.5	80.8	97.0	56.1	65.4	75.3	65.5	80.4	92.0
Female CHW with preservice training	47.9	63.0	79.8	27.3	39.5	63.4	20.1	26.8	41.0	41.7	55.0	71.4
Male CHW with preservice training	60.7	80.6	95.6	62.0	77.4	94.7	49.1	59.3	71.8	58.4	76.1	90.6
CHW with preservice training and training on prevention and promotion interventions	60.6	79.3	92.7	61.3	72.6	91.2	47.7	56.5	67.3	57.9	74.4	87.4
CHW with preservice training and training on RMNH interventions	53.5	71.5	87.0	41.7	52.3	76.1	36.2	44.5	57.0	49.7	65.5	80.5
CHW with preservice training and training on CCM for malaria	61.9	79.5	91.5	63.7	71.7	86.6	48.9	56.9	66.9	59.2	74.7	86.3
CHW with preservice training and training on CCM index	60.9	78.7	90.8	62.6	70.4	84.8	48.3	56.3	66.4	58.4	73.9	85.6
CHW with preservice training and training on EVD signal functions	48.9	67.7	84.0	33.3	44.0	70.4	26.9	34.0	47.6	44.0	60.2	76.2
CHW with preservice training and training on all packages	38.3	56.3	71.5	20.9	25.6	50.0	16.4	20.7	31.2	33.4	48.3	62.8

*Results for the health facility network are as of May 2016. Results for the CHW networks are as of February 2016, except where noted (row three is for CHWs in the year 2000 that had preservice training).
CCM, community case management; CHW, community health worker; ETR, easy-to-reach area; EVD, Ebola virus disease; RMNH, reproductive, maternal, newborn health.

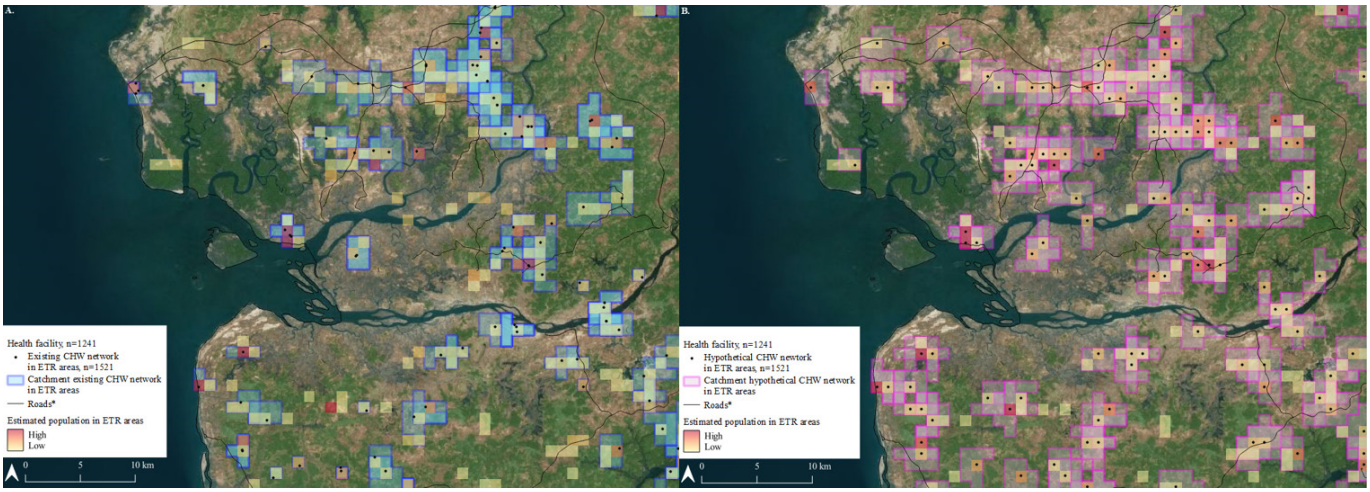

Figure 1 Modelled catchment areas of the existing CHW network in ETR areas, and hypothetical optimised CHW network in ETR areas in 2016 at 1 km×1 km resolution. (A) Modelled 30 min catchment areas of the existing CHW network (blue) in ETR areas in 2016; (B) modelled 30 min catchment areas of the hypothetical optimised CHW network (pink) in ETR areas in 2016. All analyses at 1 km×1 km resolution based on a walking scenario and maximum population capacity of the given network. Images depict chiefdoms within Kambia and Port Loko districts in Northern province. *For visualisation purposes, road classes limited to motorway, trunk, primary, secondary and tertiary. CHW, community health worker; ETR, easy-to-reach area.

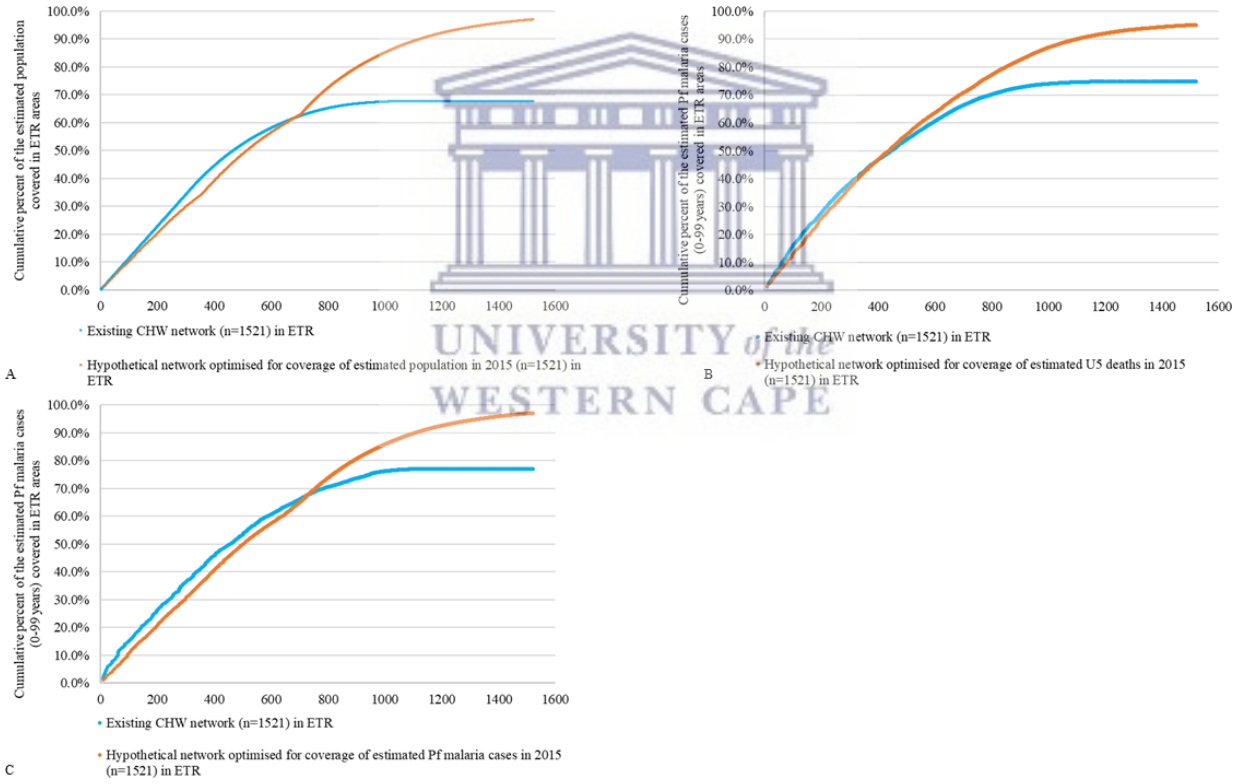

Figure 2 Efficiency of deployment of the existing CHW network compared with hypothetical optimised CHW networks in ETR areas at 1 km×1 km resolution. (A) Comparison of the per cent of the estimated population in ETR areas covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated population in ETR areas; (B) comparison of the per cent of the estimated U5 deaths in ETR areas covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated U5 deaths in ETR areas; (C) comparison of the per cent of the estimated Pf malaria cases among all ages (0–99 years) in ETR areas that was covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated Pf malaria cases among all ages (0–99 years) in ETR areas. All analyses at 1 km×1 km resolution. CHW, community health worker; ETR, easy-to-reach area; Pf, *Plasmodium falciparum*; U5, under-five.

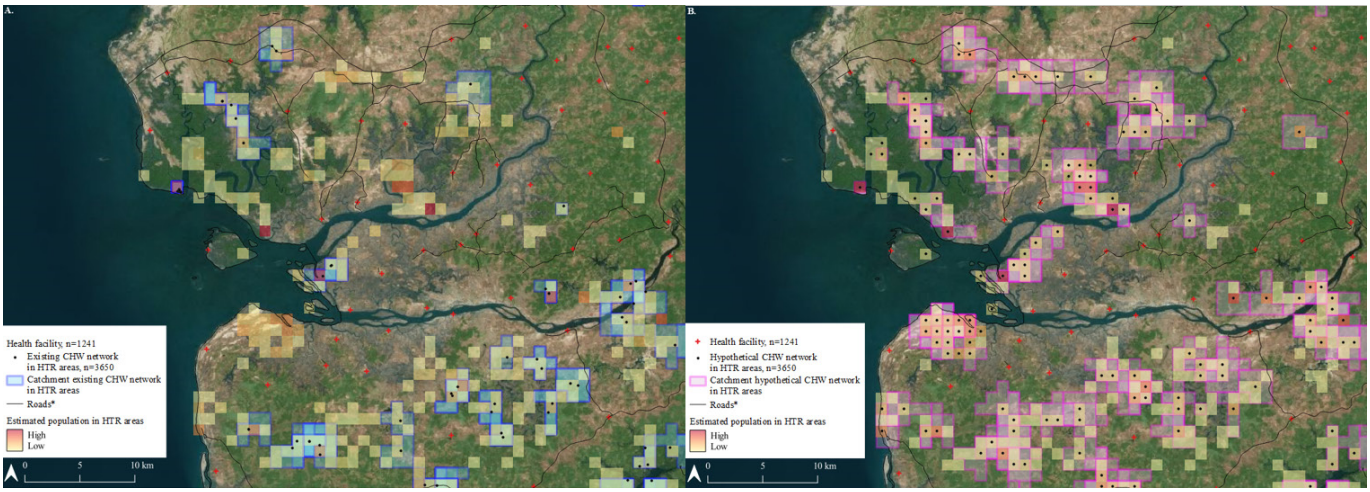

Figure 3 Modelled catchment areas of the existing CHW network in HTR areas, and hypothetical optimised CHW network in HTR areas in 2016 at 1 km×1 km resolution. (A) Modelled 30 min catchment areas of the existing CHW network (blue) in HTR areas in 2016; (B) modelled 30 min catchment areas of the hypothetical optimised CHW network (pink) in HTR areas in 2016. All analyses at 1 km×1 km resolution based on a walking scenario and maximum population capacity of the given network. Images depict chiefdoms within Kambia and Port Loko districts in Northern province. *For visualisation purposes, road classes limited to motorway, trunk, primary, secondary and tertiary. CHW, community health worker; HTR, hard-to-reach area.

cases (all ages) within a 30 min catchment (97.1% vs 77.0%) (figure 2C, online supplemental appendix 3, tab 'Comparison_Cases_ETR').

HTR areas

The hypothetical CHW network in HTR areas was 71.9% more efficient than the existing network in terms of geographic coverage of the estimated population within a 30 min catchment (78.3% vs 45.5%) (figures 3 and 4A and online supplemental appendix 3, tab 'Comparison_Pop_HTR'). Nearly half (47%) of the existing CHW network in HTR realised <30% of their maximum population capacity (300), indicating redundancy from inefficient deployment. Additionally, 80% of the estimated population not covered by the existing CHW network in 2015 was concentrated in just 37.2% (57/153) of communes (online supplemental appendix 1 figures 23–25). The hypothetical CHW network in HTR areas was 38.9% more efficient than the existing network in terms of geographic coverage of the estimated U5 deaths within a 30 min catchment (90.1% vs 64.9%) (figure 4B, online supplemental appendix 3, tab 'Comparison_U5d_HTR'). The hypothetical CHW network in HTR areas was 22.4% more efficient than the existing network in terms of geographic coverage of the estimated *Pf* malaria cases (all ages) within a 30 min catchment (79.7% vs 65.1%) (figure 4C, online supplemental appendix 3, tab 'Comparison_Cases_HTR').

DISCUSSION

This was the first study to assess geographical accessibility and efficiency of deployment of CHWs at national scale in Sierra Leone. Accessibility coverage of CHWs increased between 2000 and 2015 but most of the increase occurred within 3 km of a health facility, contrary to current national policy. ETR and HTR areas were less well covered by CHWs. There was substantial variation in access to a CHW across subnational geographies. Access to female CHWs was lower than male CHWs. Access to CHWs trained on RMNH interventions was lower than access to CHWs trained on prevention and promotion interventions or community case management for malaria. Optimised CHW networks in ETR and HTR areas were more efficiently deployed than existing networks by 26.1%–43.2% and 22.4%–71.9%, respectively, depending on targeting metric.

Implications for policy

Planning for the scale-up and efficient deployment of the CHW workforce, like with broader HRH and health sector planning, cannot be addressed purely through modelling. The political economy of such planning is complex, involving multiple factors that are difficult to capture in models.[44 45] That said, modelling can be a useful tool among others, for policy makers and planners. Below we outline the implications of our analysis for policy makers and planners in Sierra Leone, as well as other countries in sub-Saharan Africa with similar contexts and interest in optimising PHC at community level.

First, scale-up of CHWs improved geographical accessibility of PHC at community level between 2000 and 2015 but most of the increase occurred within 3 km of a health facility, where a majority of CHWs were deployed. This pattern broadly reflects the population distribution—77.2% of the population in 2015 were within 3 km of a health facility—this is similar to the urban skew of the broader HRH workforce[20] and reflects early CHW policy (prior to 2016, CHW could be selected from and work in communities regardless of proximity to health facilities). But it does not align with current national policy and

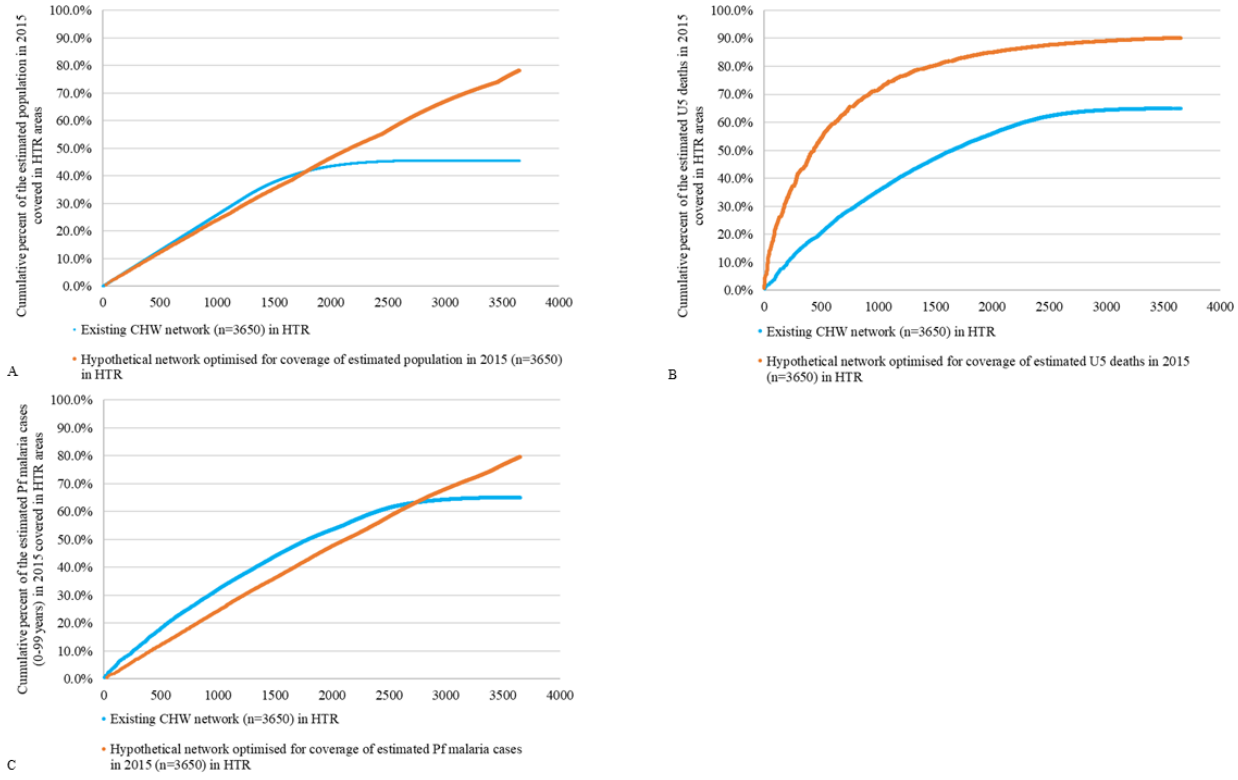

Figure 4 Efficiency of deployment of the existing CHW network compared with hypothetical optimised CHW networks in HTR areas at 1 km×1 km resolution. (A) Comparison of the per cent of the estimated population in HTR areas covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated population in HTR areas; (B) comparison of the per cent of the estimated U5 deaths in HTR areas covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated U5 deaths in HTR areas; (C) comparison of the per cent of the estimated Pf malaria cases among all ages (0–99 years) in HTR areas that was covered within a 30 min catchment area (walking) by the existing CHW network compared with a hypothetical CHW network deployed to optimise geographic coverage of the estimated Pf malaria cases among all ages (0–99 years) in HTR areas. All analyses at 1 km×1 km resolution. CHW, community health worker; HTR, hard-to-reach area; Pf, *Plasmodium falciparum*; U5, under-five.

therefore warrants rethinking. With the 2021–2025 CHW policy, the MOHS plans to rightsize and retarget the CHW workforce (including CHW peer supervisors) by reducing it by 40% and retargeting CHW recruitment and deployment towards ETR and HTR areas. This is a bold move to optimise scale and deployment of CHWs in the context of broader efforts to optimise HRH deployment.[22] This key shift was informed by an earlier iteration of our current analysis, which was included in an assessment of the National CHW Programme by JSI[23] and broader CHW policy discussions. Our current analysis supports this important policy decision by the MOHS. However, optimising scale and deployment of CHWs comes with operational challenges. For example, employers will need to end the employment of CHWs and CHW peer supervisors located within 3 km of a health facility. Affected workers should be compensated fairly for early termination of their employment. Planners should anticipate the need to engage affected communities to regain their trust. Similarly, new CHWs and CHW peer supervisors will need to be recruited from communities in ETR and HTR areas not already adequately covered. They will need to be trained, paid, supervised and supported. This will require effective planning, coordination, logistics and resources. But on balance, the positives outweigh the negatives. We estimate the cost-savings from the planned rightsizing and retargeting of the CHW workforce to be approximately US$3.8 million annually (40% of the current annual cost of US$9.5 million).[23] Cost-savings could be re-directed towards professionalising the CHW workforce and strengthening the health system and community enablers needed to optimise CHW performance,[1 2 9] which have been well described to have major shortfalls in Sierra Leone[46–48] and most national CHW programmes.[14 49–52]

Second, our analysis highlighted an important gender disparity in CHW deployment (35% of CHWs were female and 65% were male). This gender disparity may negatively impact the use of specific services (eg, interventions for sexual health, RMNH).[15] The MOHS intends to address this gender disparity in implementation of the 2021–2025 CHW policy, shifting the gender distribution to 60% female and 40% male. This would be an important shift from an HRH gender equity lens. It could improve the use of interventions such as those noted above. Lastly, it would contribute to greater gender

equity in socioeconomic development by employing and empowering more women.[10 15] However, addressing the gender disparity in ETR and HTR areas may prove to be challenging, given gender disparities in education levels in rural communities. The MOHS may need to consider a range of gender responsive actions along the HRH cycle (eg, planning, recruitment, performance management and retention) to adequately and sustainably address the gender disparities identified.

Third, our analysis highlighted important variation in CHW training. Nearly all CHWs self-reported that they received preservice training but there was large variation in terms of training on specific services, indicating that the standard MOHS preservice training may not have been systematically implemented. The MOHS may need to strengthen coordination and oversight of the implementation of the standard MOHS preservice training as well as in-service training. This could be aided by updating and maintaining the national georeferenced CHWML hosted within or linked to the national human resources for health information system—iHRIS—and using the CHWML as the basis for tracking, planning and coordinating training.[53]

Fourth, the current focus of the MOHS on rightsizing and retargeting the CHW workforce could enable future discussions on a sustainable financing pathway for CHWs,[10 19 54 55] inclusive of increasing government financing for CHWs and a pathway for integration of CHWs within the civil service.[16]

Limitations

There are several important limitations of our study. First, our analysis is limited by the completeness and quality of the publicly available road and river network data. We acknowledge that more complete and/or higher quality data on roads and rivers may be available outside the public domain. We acknowledge that not all rivers may be perennial barriers to movement, particularly where bridges exist. We attempted to mitigate this limitation by allowing major road classes to cross rivers. Second, our analysis does not account for uncertainty of the estimates of population counts, limiting our ability to account for this source of uncertainty in measures of physical accessibility to services. Estimates of the uncertainty of the estimated population counts in Sierra Leone for the years 2000–2015 were not available, but we acknowledge that availability of this kind of data will be important for improving future modelling efforts. Third, the estimated population counts for 2000–2014 use the 2015 population settlement footprint from 2015,[34] which may not accurately reflect the population settlement footprint for the period 2000–2014. Fourth, our analysis is based on estimated travel speeds from other studies in sub-Saharan Africa, not empirical data from Sierra Leone or local expert knowledge, although research indicates these speeds may be appropriate in the Sierra Leone context.[56] Our analysis does not account for uncertainty of travel speed estimates. Additionally, our analysis does not account for variation in walking speeds or common modes of transportation used across population groups. For example, pregnant women, people with illness, caregivers of ill children, the elderly population, people with disabilities may walk slower than the general population, modes of transport may differ by socioeconomic status and boat travel may be important in certain geographic areas. A planned update to this analysis in 2021–2022 will attempt to address the limitations above regarding travel speeds and modes of transportation by incorporating information derived from subnational level workshops with local experts. Fifth, our analysis used CHW self-reported data on receipt of training and year of deployment, which may be subject to recall bias. Sixth, our analysis did not account for the possibility of accessing health services across national boundaries, an important consideration for border communities and migrant populations.

We acknowledge that there are many factors beyond physical accessibility that affect access to and use of health services, such as social and economic barriers to care seeking.[57] Such factors may impact access to and use of health services independently of physical accessibility or through interactions with physical accessibility.[58] It is also important to consider quality of services, including population perceptions of the quality of services, and the potential for bypassing.[59 60]

We also acknowledge that this kind of modelling can be challenging. Integration into national processes and policy takes time and requires strengthening national institutional capacity. Additionally, operationalising the optimised deployment poses many challenges as noted above. But despite these challenges, this kind of modelling can be very useful as we have demonstrated in the case of Sierra Leone. At the time of writing, coauthors—including those from the MOHS—were updating this analysis with datasets from 2021, with a view of fine-tuning implementation of the 2021–2025 CHW policy and informing updates to broader HRH and health sector development plans and strategies.

CONCLUSION

Geographical accessibility of PHC services at community level improved in Sierra Leone between 2000 and 2015 through the scale-up of CHWs. However, the scale and deployment of the CHW network no longer aligns with current national policy. The new CHW policy for 2021–2025 calls for a rightsizing and retargeting of the CHW network and our analysis supports this policy decision by identifying important inefficiencies of scale and deployment. Countries in sub-Saharan Africa with similar interest in optimising scale and deployment of their CHW workforce in the context of broader HRH and health sector planning may look to Sierra Leone as an exemplar model from which to learn.

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Contributors NPO was responsible for the overall study conceptualisation, methodology, data curation, geospatial analysis, data visualisation and writing the draft manuscript with substantial contributions from all authors. NPO, AC and NR conducted the geospatial analysis. EM, MS, JK, AK, KH, SO'C, NPO, AC and NR collected data or provided feedback on data or data visualisation. NPO, AC, NR and TD verified the underlying data. TD, DJ and NR provided supervision and overall guidance. All authors reviewed, interpreted and provided feedback on the results. All authors reviewed and edited the manuscript. NPO was responsible for the overall content as the guarantor.

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Data availability statement Data are available in a public, open access repository. Data are available in a public, open access repository under the Creative Commons Attribution 4.0 Unported (CC BY 4.0) licence, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made. See: https://creativecommons.org/licenses/by/4.0/. Supplemental appendices 2-4, video 1, all model inputs (except existing service delivery locations) and all model outputs are available in supplemental appendix 1b at https://doi.org/10.5281/zenodo.5712134. Health service delivery location data are only available through data sharing agreements with the MOHS and UNICEF.

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Study 3: Oliphant NP, Sy Z, Koné B, Berthé M, Beebe M, et al. (2022) Improving the efficiency of scale-up and deployment of community health workers in Mali: A geospatial analysis. PLOS Global Public Health 2(10): e0000626. https://doi.org/10.1371/journal.pgph.0000626

What is already known on this topic?

• A previous study in Mali explored costing of the CHW services using a geospatial approach but not geographical accessibility to integrated PHC services provided by CHWs.

What are the new contributions from this study?

• Our analysis provides new insight on the optimal scale and deployment of CHWs in Mali for maximizing geographical accessibility of integrated PHC services, including iCCM, at community level.

• Our analysis identifies fine-scale geographic areas with estimated deficits/surpluses of CHWs, comparing an optimized CHW network with the existing CHW network.

• Our analysis found no important differences in geographic coverage of the estimated population, U5 deaths, and Pf malaria cases when prioritizing/targeting CHW deployment based on the estimated population, U5 deaths, or Pf malaria cases, indicating equivalence of approaches for optimizing the scale and deployment of CHWs; which may be particularly relevant where policy makers and planners would like to consider multiple criteria.

How this study might affect research, practice, or policy?

• At the time of writing, the Ministry of Health and Social Development (MSDS in French) was using our analysis to inform decisions on the scale-up and deployment of CHWs in the context of updating the national strategic plan for community health (2021-2025) as well as the planning for the health and care workforce and health sector as part of the country's current health sector reform.

• MOHS and partners could consider re-investing cost-savings from rightsizing and retargeting toward the professionalization of CHWs and strengthening the health policy and systems components needed to for CHWs to effectively delivery integrated PHC services, including iCCM (as described in study 4).

• The equivalence of geographic coverage across outcomes of interest and approaches for optimizing the scale and deployment of CHWs may provide policy makers and planners

with confidence that trade-offs between the approaches are negligible and that any of the approaches will perform equally well across outcome.

• The approaches to optimisation described in this study (and studies 1-2) could be adapted to similar contexts within sub-Saharan Africa to maximize the contribution of CHWs to geographical accessibility to integrated PHC services within the context of broader health sector planning.

Contribution of the candidate: The candidate (NPO) was jointly responsible with ZS for the study conceptualisation, methodology, data curation and writing the draft manuscript. BK, MB, MB, MS, MD, ST, BD, ABD, CHD, TY, SF, DJ, NR, and TD provided inputs to the conceptualisation and methodology. BK, MB, MB, MS, MD, ST, BD, ABD, CHD, ZS, and NPO led or provided technical assistance to and oversight of data collection for the main datasets used. NPO, ZS, and NR conducted the geospatial analysis. BK, MB, MB, MS, MD, ST, BD, ABD, CHD, ZS, NPO, and NR All provided feedback on data and data visualisation. BK, MB, MB, MS, MD, ST, BD, ABD, CHD, ZS, and NPO verified the underlying data. TD, DJ, and NR provided supervision and overall guidance. All authors reviewed and interpreted the results of the analysis presented in the manuscript and contributed to editing the manuscript. NPO, ZS, BK, MB, MB, MS, and MD contributed equally to the work.

Review comments from the peer review process are available in Appendix

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May 16, 2022

Dear Editorial staff of *PLOS Global Public Health*,

For your consideration, please accept herewith a research article entitled "Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis". It has been widely recognized that achieving universal health coverage (UHC) and ensuring effective pandemic preparedness and response will require strengthening health systems by investing in primary health care (PHC), particularly frontline human resources for health (HRH), including community health workers (CHWs). CHWs are foundational to the PHC approach as frontline HRH, essential members of multidisciplinary PHC teams providing community-based PHC services and serving as a trusted bridge between the health system and communities. However, globally there is a severe shortage of CHWs, compounded by maldistribution, and an estimated annual funding gap for CHWs of US$5.4 billion.

While countries strive to increase financing for HRH, including for CHWs, concurrent efforts are needed to optimise impact and efficiency of available funding through optimising scale and deployment of HRH. Geospatial analysis using geographic information systems (GIS) can be a powerful tool in the HRH toolkit in this regard. However few countries leverage the potential of geospatial analysis, contributing to inefficiencies and inequities in the distribution of HRH and geographical accessibility of health services.

In this article, we provide high quality, original research exploring optimisation of the scale and deployment of CHWs in Mali with the aim of informing implementation of current CHW policy and future planning of the Ministry of Health and Social Development. Few studies of this kind have been published. Our study is the first of its kind in Mali and the first to compare the efficiency of different hypothetical scale-up scenarios using spatial data on the distribution of the estimated population, under-five deaths, and *Plasmodium falciparum* malaria.

We believe our study would greatly appeal to the audience of *PLOS Global Public Health*, given its policy relevance for optimising CHW scale and deployment in Mali and countries with similar contexts and interest in optimising their CHW workforce in the context of broader health workforce and health sector planning efforts. Our study presents the experience of Mali as an exemplar model from which to learn in this regard. Importantly, our group of authors reflects the gender equity and diversity expected of *PLOS Global Health*, including authors from the Ministry of Health and Social Development and others with extensive experience in the country, which informed our bespoke modelling approach, and reflects our collaborative effort. Thank you for your consideration.

Sincerely,

Nicholas P. Oliphant (on behalf of all co-authors)

PLOS GLOBAL PUBLIC HEALTH

RESEARCH ARTICLE

Improving the efficiency of scale-up and deployment of community health workers in Mali: A geospatial analysis

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Abstract

Optimising the scale and deployment of community health workers (CHWs) is important for maximizing geographical accessibility of integrated primary health care (PHC) services. Yet little is known about approaches for doing so. We used geospatial analysis to model optimised scale-up and deployment of CHWs in Mali, to inform strategic and operational planning by the Ministry of Health and Social Development. Accessibility catchments were modelled based on travel time, accounting for barriers to movement. We compared geographic coverage of the estimated population, under-five deaths, and plasmodium falciparum (*Pf*) malaria cases across different hypothetical optimised CHW networks and identified surpluses and deficits of CHWs compared to the existing CHW network. A network of 15 843 CHW, if optimally deployed, would ensure that 77.3% of the population beyond 5 km of the CSCom (community health centre) and CSRef (referral health facility) network would be within a 30-minute walk of a CHW. The same network would cover an estimated 59.5% of U5 deaths and 58.5% of *Pf* malaria cases. As an intermediary step, an optimised network of 4 500 CHW, primarily filling deficits of CHW in the regions of Kayes, Koulikoro, Sikasso, and Ségou would ensure geographic coverage for 31.3% of the estimated population. There were no important differences in geographic coverage percentage when prioritizing CHW scale-up and deployment based on the estimated population, U5 deaths, or *Pf* malaria cases. Our geospatial analysis provides useful information to policymakers and planners in Mali for optimising the scale-up and deployment of CHW and, in turn, for maximizing the

Supplemental appendices 1-3, all model inputs (except existing service delivery locations) and all model outputs are available from the Public Data Repository: https://doi.org/10.5281/zenodo.6551988. Health service delivery location data are only available through data-sharing agreements with the MSDS.

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value-for-money of resources of investment in CHWs in the context of the country's health sector reform. Countries with similar interests in optimising the scale and deployment of their CHW workforce may look to Mali as an exemplar model from which to learn.

Introduction

Achieving universal health coverage (UHC) and ensuring effective pandemic preparedness and response will require increased investment in primary health care (PHC). It will also require strengthening health systems, particularly at the primary health care level and in communities [1–4]. Community health workers (CHWs) are essential to the PHC approach as members of multidisciplinary PHC teams providing community-based PHC services tailored to population needs and preferences and serving as a trusted bridge between the health system and communities [5–8]. Investments in CHWs can be cost-effective and equity-promoting, particularly when CHWs are fairly remunerated and well-supported by the health system and communities they serve [9–14]. Investment in CHWs can also promote economic development and gender equality through fair pay in formal sector jobs, decent working conditions, opportunities for women in leadership roles, as well as social dialogue and collective bargaining [9,15–17]. However, globally there is a human resources for health (HRH) shortage, including for CHWs. The WHO estimates a deficit of 18 (range 16–19) million health workers by 2030 [18]. This deficit is exacerbated by a maldistribution of HRH, including CHWs, with the most severe effects in Africa, particularly in rural, remote, and under-served geographic areas [18–21].

As countries strive to increase sustainable financing for HRH, including for CHWs, concurrent efforts are needed to maximize the impact and efficiency of available funding through optimising the scale and deployment of HRH. Global strategies and frameworks from the WHO call for optimising the distribution of HRH and geographical accessibility to integrated PHC services [18,22,23]. Geospatial analysis using geographic information systems (GIS) can be a powerful tool in the HRH toolkit in this regard. However few countries have used geospatial analysis to optimise the scale and deployment of HRH. Previous research has focused on the use of geospatial analysis to assess the geographical accessibility of health facilities [24–26], the distribution of health facility-based HRH [27,28], and the efficiency of deployment of existing CHW networks and/or optimising the scale-up and efficiency of deployment of CHWs for subnational geographic areas [29–32] or using a Euclidean distance-based approach [33,34]. To our knowledge, only three countries have used geospatial analysis with a modelling approach based on travel-time to explore the optimization of the scale and deployment of CHWs at national scale [20–22].

In Mali, CHWs–known as *Agents de santé communautaire* or *CHWs*–have been a central part of the country's HRH at the community level since 2008. At the time of writing, the Ministry of Health and Social Development (MSDS is the French acronym) country was updating the national community health strategy in the context of a new health sector development plan and ongoing health system reform aiming to achieve UHC through primary health care [35,36]. CHWs are intended to extend equitable access to community-based primary health care services with the objective of reducing morbidity and mortality among mothers and children under-five in communities beyond 5 km of a health facility [37]. *Plasmodium falciparum* (*Pf*) malaria is a main cause of morbidity and mortality and among children under-five [37].

Policy questions

In the context of updating the national community health strategy, the MSDS was interested in two policy questions:

1. How can we optimise scale-up and deployment of the CHWs? Given the objective to reduce morbidity and mortality among mothers and children under-five years of age, is it more efficient to deploy CHWs based on the estimated population, under-five deaths, or *Pf* (*plasmodium falciparum*) malaria cases beyond 5 km of the CSCom and CSRef network? Does one of these approaches perform best overall in terms of efficiency of deployment?
2. What percent of the population beyond 5 km of the CSCom and CSRef network can be covered by an optimised CHW network and how many CHWs are needed to do so? Comparing the existing CHW network and an optimised and scaled-up CHW network, are there deficits/surpluses of CHWs and where are the deficits/surpluses of CHWs located?

We used data from a national CHW master list and other spatial datasets in a geospatial analysis to model optimised scale-up and deployment of CHWs in Mali and inform strategic and operational planning by the MSDS. We modelled accessibility catchments based on travel time, accounting for barriers to movement, and compared geographic coverage of the estimated population, under-five deaths, and *Pf* malaria cases across hypothetical optimised networks when CHW deployment prioritised the estimated population, under-five deaths, or *Pf* malaria cases. Lastly, we compared a hypothetical optimised CHW network with the existing CHW network to identify surpluses and deficits of CHWs.

Data and methods

Study setting

In 2020 the health system included public, private, community, and confessional institutions organized in a decentralized, pyramidal structure with four administrative levels–a tertiary referral level, a secondary referral level, a primary referral level and a primary level–overseen by the MSDS [35]. The primary level was composed of public sector community health centres (*Centres de santé communautaire*, CSCom) and private sector health facilities staffed by nurses and–in some cases–generalist doctors providing a minimum package of primary health care services and referral/counter-referral services to/from primary referral facilities (*Centres de santé de référence*, CSRef) staffed by nurses and doctors trained on referral services (S1 Appendix 1 available via https://doi.org/10.5281/zenodo.6551988). CSCom were designed to serve the population within 5 km [37]. At the base of the primary level were paid, full-time CHWs providing community-based primary health care services, including prevention, promotion, and curative services, conducting surveillance activities, and supervising part-time community health volunteers known as *relais* [37]. The focus of our analysis was on the CHWs. The *relais* were beyond the scope of the current analysis.

According to the national community health strategy of 2016–2020, CHWs were defined as a paid, full-time CHW, recruited from, and living in the community they serve and recognized by the MSDS as meeting the minimum criteria for CHWs [37]. CHWs were allowed to provide a standard minimum package of services defined by the MSDS and implemented in the context of the national community health strategy [37]. This minimum primary health care package included prevention, promotion, and curative services [28]. This included household visits to promote reproductive, maternal, newborn, and child health and nutrition, and water and sanitation interventions; provision of family planning, integrated community case management (iCCM) of diarrhoea, pneumonia, malaria, and acute malnutrition among children

under-five, monitoring of vital events such as births and deaths, disease surveillance; participation in mass campaigns (e.g. for childhood vaccinations, distribution of seasonal malaria chemoprevention, and long-lasting insecticide-treated bednets) and supervision of the *relais* [37]. CHWs were deployed to CHW sites, i.e., villages selected by the community health association where the CHWs lived and worked and, in principle, located in rural areas beyond 5 km from a CSCom [37]. CHWs were attached to the nearest CSCom for supervision and resupply [37]. The catchment of a CHW was defined as the area within 3–4 km of the CHW site [37]. CHW sites were, in principle, the largest village within the catchment area of the CHW which also included satellite villages (i.e., villages apart from the CHW site but within the CHW catchment area and meant to be served by the CHW through outreach) [37]. The national community health strategy 2016–2020 indicated a norm of 1 CHW per 700 population in the regions of the Center and South (Kayes, Koulikoro, Mopti, Segou, Sikasso) and 1 CHW per 300–500 population in the regions of the North (Gao, Tombouctou) [37]. For our analysis, and in agreement with the MSDS, we used the ratio of 1 CHW per 700 population for the regions of the Center and South and 1 CHW per 500 for the regions of the North.

Data

We obtained the following spatial datasets to inform our models of geographic coverage and efficiency of deployment of the CHWs: administrative boundaries (national, regional, commune) [38–40], a 2020 national georeferenced master facility list [41], a 2020 national CHW master list (CHWML) [42], digital elevation model [43], land cover [44], roads [45], official population estimates at commune level for 2020 [46], estimated population count at 100 m x 100 m resolution for 2020 [47] and travel scenarios. As of 2020, there were 3 104 working CHWs. Integrated PHC services provided by CHWs were intended to address under-five mortality, with *Pf* malaria as a major driver of curative consultations among children under-five in Mali [48]. Because the MSDS was interested to explore the efficiency of deployment of CHWs vis a vis the spatial distribution of estimated under-five deaths, in addition to the efficiency of their deployment vis a vis the estimated population, we obtained modelled estimates of the annual mean under-five mortality rate in 2017 [49] and estimated live births [50] at 5 kmx 5 km resolution to develop a raster layer for the estimated under-five deaths in 2020 at 1 kmx 1km. Similarly, because the MSDS was interested to explore the efficiency of deployment of CHWs vis a vis the spatial distribution of estimated *Pf* malaria cases, we obtained modelled estimates of the annual mean incidence of *Pf* malaria among all ages (0–99 years) in 2019 at 5 kmx 5 km resolution [51] to develop a raster layer for the estimated *Pf* malaria cases (all ages) in 2020 at 1 kmx 1km. We prepared the input datasets in the projected coordinate reference system EPSG:32629—WGS 84 / UTM zone 29N for Mali at 1 kmx 1 km resolution. We used one travel scenario, walking in dry conditions, reflecting the most relevant travel scenario for the population served by the CHWs. We prepared a travel speed table reflecting walking in dry conditions (S1 Appendix available via https://doi.org/10.5281/zenodo.6551988). We adapted travel speeds for each land cover class and road class from previous studies [20,52,53]. Travel speeds refer to the population walking in dry conditions in the direction of the CHW.

Populations of interest

We considered three populations of interest for the first policy question:

a. the estimated population in areas beyond 5 km of a CSRef or CSCom in 2020;

b. the estimated under-five deaths in areas beyond 5 km of a CSRef or CSCom in 2020; and

c. the estimated *Pf* malaria cases in areas beyond 5 km of a CSRef or CSCom in 2020.

Hypothetical CHW networks

We considered three hypothetical CHW networks for the first policy question (see Table 1 for definitions).

In preparation for our hypothetical scale-up CHW networks, we analysed the spatial distribution of the estimated population beyond 5 km from a CSCom or CSRef. We found that this population was predominantly located in 1 kmx 1 km grid cells with an estimated population of at least 150 people. A 1 kmx 1 km grid cell with an estimated 150 people is equivalent to roughly 20% of the 1 CHW to 700 population ratio for regions of the South and roughly 30% of the 1 CHW to 500 population ratio for regions of the North. We restricted potential CHW sites for our hypothetical scale-up CHW networks to 1 kmx 1 km grid cells beyond 5 km of a CSCom with an estimated population of at least 150 people. This helped avoid deploying CHWs to areas with less than 20–30% of the expected CHW to population ratio, which would be an inefficient use of CHWs.

Further details on the data and methods used to derive these geographic areas are in S1 Appendix available via https://doi.org/10.5281/zenodo.6551988.

Geographic coverage

The national community health strategy defined the catchment area of a CHW as the area within 3–4 km of the CHW site [37]. This definition ignores barriers to movement and the maximum population capacity of the CHW. To model more realistic catchment areas, we defined the catchment area of the CHWs using the concept of geographic coverage. Geographic coverage is defined as the theoretical catchment area of a health service delivery location, within a maximum travel time, accounting for the mode of transportation and the maximum population capacity of the type of health service delivery location [53]. In our

Table 1. Definitions for the hypothetical CHW networks.

Hypothetical CHW network	Definition
Prioritizing population	A hypothetical CHW network deployed to prioritize geographic coverage of the estimated population in areas beyond 5 km from a CSRef or CSCom in 2020 by ordering the processing order (deployment) based on the estimated population in areas beyond 5 km from a CSRef or CSCom in 2020 within a 30-minute catchment area of a given CHW, prioritizing catchments with a higher estimated population over those with a lower estimated population.
Prioritizing U5 deaths	A hypothetical CHW network deployed to prioritize geographic coverage of the estimated under-five deaths in areas beyond 5 km from a CSRef or CSCom in 2020 by ordering the processing order (deployment) based on the estimated under-five deaths in areas beyond 5 km from a CSRef or CSCom in 2020 within a 30-minute catchment area of a given CHW, prioritizing catchments with a higher estimated number of under-five deaths over those with a lower estimated number of under-five deaths.
Prioritizing *Pf* malaria cases	A hypothetical CHW network deployed to prioritize geographic coverage of the estimated Pf malaria cases among all ages (0–99 years) in areas beyond 5 km from a CSRef or CSCom in 2020 by ordering the processing order (deployment) based on the estimated number of Pf malaria cases in areas beyond 5 km from a CSRef or CSCom in 2020 within a 30-minute catchment area of a given CHW, prioritizing catchments with a higher estimated number of Pf malaria cases over those with a lower estimated number of Pf malaria cases.

See pages 18, 22–23 of S1 Appendix available via https://doi.org/10.5281/zenodo.6551988 for additional details on the hypothetical CHW networks.

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analysis we defined geographic coverage as the estimated population (of interest) within a theoretical catchment area of the CHW network, given a 30-minute maximum travel time (walking scenario) and the maximum population capacity of the CHWs. The maximum population capacity for CHWs was based on the MSDS norms for the ratio of CHWs per population noted above. The maximum extent of an CHW catchment was therefore delimited by the maximum travel time of 30 minutes except in cases where the estimated population in the catchment exceeded the maximum population capacity. In this case, the extent of the catchment was defined by the area containing the estimated population, up to the maximum population capacity. There was no MSDS norm for the ratio of CHW per U5 deaths or *Pf* malaria cases. Assuming one CHW could cover all estimated U5 deaths or *Pf* malaria cases within their catchment regardless of population size would be unrealistic. For metrics (b) and (c) we based the number of CHWs required for the hypothetical CHW networks on the estimated number of CHW needed to cover the estimated population in each catchment using the MSDS norms above. We used the "geographic coverage" module of AccessMod 5.6.56 for all analyses [53].

Assessing the efficiency of scale-up and deployment

We defined efficiency of deployment as the geographic coverage of the estimated population of interest achieved by a given number of CHWs, based on an adaptation of Palmer and Torgerson's definition of technical efficiency [54]. A CHW network designed to optimise the efficiency of CHW deployment maximizes geographic coverage of the population of interest with the fewest number of CHWs. This requires deploying CHWs such that each CHW maximizes the gain in geographic coverage of the population. We assessed the efficiency of deployment by comparing the gain/loss of geographic coverage for each hypothetical CHW network compared to each of the other hypothetical CHW networks, given the same number of CHWs, for each of the populations of interest.

The above analysis resulted in nine results, three results per population of interest (a-c above), and three results per hypothetical network (defined in Table 1). For each population of interest (a-c,) we compared the efficiency of deployment of CHWs across the hypothetical networks using a visual inspection of the slope of geographic coverage.

Comparison with the existing network of CHW

For the second policy question, we used the hypothetical CHW network prioritizing the population at full scale to determine the geographic coverage of the estimated population beyond 5 km of the CSCom and CSRef networks that could be achieved, and the estimated number of CHWs needed to do so. We also estimated what could be achieved in terms of geographic coverage with the first 4 500 CHWs of the hypothetical CHW network (ranked in order of greatest contribution to geographic coverage to least contribution). We compared the hypothetical CHW network at full scale and the first 4 500 hypothetical CHWs with the existing network of CHWs to estimate deficits/surpluses of CHWs at national, regional, district, and CSCom catchment area levels. The first 4 500 CHWs of the hypothetical CHW network was used as a comparison as it presented a practical and feasible next target, given the existing network of 3 104 CHWs and anticipated levels of funding for CHWs in the near-term.

Ethics statements

Our analysis did not include data from or about individual human participants. We did not involve patients or the public in this study.

Ethics approval

The 2016 national georeferenced master lists of health facilities [31] and CHWs [32] were developed by the Ministry of Health and Sanitation, with support from technical and financial partners, in the context of management of the public health sector and did not require ethical approval. The protocol for secondary analysis used in this study was approved by the Ethics Committee of the University of Western Cape (Registration no: 15/7/271).

Results

Efficiency of deployment

A hypothetical network of 15 843 CHWs would ensure 77.4% of the estimated 2020 population beyond 5 km of a CSRef or CSCom were within a 30-minute walk of an CHW. Across the three hypothetical CHW networks, there was less than 0.6 percentage points difference in geographic coverage when prioritizing the estimated population, estimated U5 deaths, or estimated *Pf* malaria cases among all ages (0–99 years) in 2020 within a 30-minute catchment of an CHW (Table 2 and Fig 1; also see tabs "Comparison_Pop", "Comparison_U5d", and "Comparison_Cases" in S2 Appendix available via https://doi.org/10.5281/zenodo.6551988).

Comparison with the existing network of CHW

Table 3 compares the number of CHWs needed by region and district according to a) the full hypothetical scaled-up network of CHWs prioritizing the estimated population (n = 15 843) b) the first 4 500 CHWs within the hypothetical scaled-up network of CHW (a subset of (a)) and c) the existing CHW network (n = 3 401). Column (d) provides the difference in the number of CHW between the full hypothetical network of CHW prioritizing the estimated population and the existing CHW network. Column (e) provides the difference in the number of CHWs between the first 4 500 CHW within the hypothetical network of CHW and the existing CHW network. Deficits in terms of CHWs are shown in red and surpluses are shown in blue.

Overall, there was a deficit of 12 739 CHWs between the existing CHW network (n = 3 401) and the full hypothetical CHW network (n = 15 843). The largest deficits were in the regions of Kayes, Koulikoro, Sikasso, and Ségou. Compared to the first 4 500 CHWs of the hypothetical CHW network, there was a deficit of 1 397 CHWs. For the latter comparison, the deficit was again concentrated in the regions of Kayes, Koulikoro, Sikasso, and Ségou but there were surpluses in certain districts, most notably in Commune VI of Bamako, Ansongo (region of Gao), and Bankass (region of Mopti). We provide results for the estimated deficits and surpluses of CHWs at the subdistrict level for each CSCom in Mali in S3 Appendix (available via https://doi.org/10.5281/zenodo.6551988), tab "CSCom_Comparison", located in the Public Data Repository. Fig 2 shows the 30-minute catchment area (blue) of the hypothetical CHW network prioritising geographic coverage of the estimated population in 2020. Text boxes for example CSCom indicate existing CHWs, estimated need based on the full model, estimated need based on the first 4 500 model, and deficits/surpluses comparing the existing CHW network with the models.

Table 2. Geographic coverage of the estimated population, estimated U5 deaths, and estimated Pf malaria cases within a 30-minute catchment (walking in dry conditions) of an CHW, by three hypothetical CHW networks.

Hypothetical CHW network (n = 15 843)	Estimated population	Estimated U5 deaths	Estimated *Pf* malaria cases
Prioritizing population	77.4%	59.5%	58.5%
Prioritizing U5 deaths	77.4%	59.8%	58.8%
Prioritizing *Pf* malaria cases	76.8%	59.8%	58.8%

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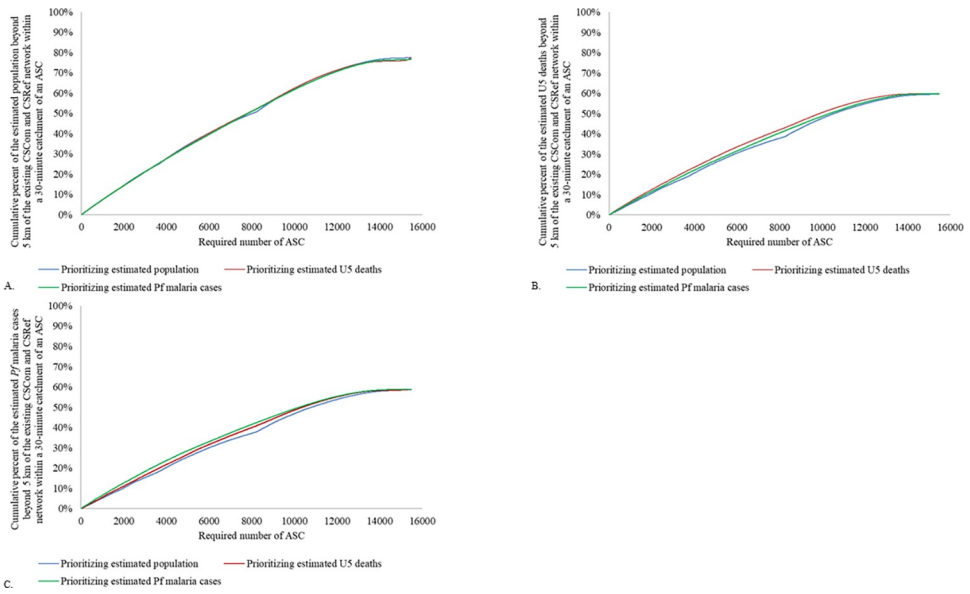

Fig 1. Comparison of geographic coverage beyond 5 km of the existing CSCom and CSRef network according to CHW scale-up and deployment approach at 1 kmx 1 km resolution. A) Geographic coverage of the estimated population in 2020 beyond 5 km of the existing CSCom and CSRef network covered within a 30-minute catchment area (walking) by the CHW network, according to CHW scale-up scenario; B) Geographic coverage of the estimated under-five deaths in 2020 beyond 5 km of the existing CSCom and CSRef network covered within a 30-minute catchment area (walking) by the CHW network, according to CHW scale-up scenario; C) Geographic coverage of the estimated *Pf* malaria cases in 2020 beyond 5 km of the existing CSCom and CSRef network covered within a 30-minute catchment area (walking) by the CHW network, according to CHW scale-up and deployment approach. All analyses at 1kmx 1km resolution.

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Discussion

WHO's global strategy on human resources for health, normative guidance on optimising health policy and system support for CHWs, the WHO and UNICEF operational framework for PHC, and the Working for Health Action Plan 2022–2030 call for optimising the distribution of the health and care workforce, including CHWs [5,18,23,24]. However only three previous studies have used geospatial analysis to assess the efficiency of CHW deployment at national scale using robust modelling approaches [20–22]. Champagne *et al.* compared the efficiency of various CHW deployment scenarios in terms of optimising geographic coverage of the estimated population in Haiti [22]. Oliphant *et al.* (2021) and Oliphant *et al.* (2022) compared the efficiency of CHW deployment of the existing CHW network compared to three hypothetical optimised CHW networks designed to optimise geographic coverage of the estimated population, under-five deaths, and *Pf* malaria cases, respectively, and found that the existing CHW networks were inefficiently deployed across all three targeting metrics [20,21]. However, unlike our study, these previous studies did not compare the efficiency of approaches for optimising the scale and deployment of CHWs nationally across each of these outcomes of interest [20,21]. Our study is the first to do so, providing new insight on the trade-offs (or lack thereof) between approaches and a roadmap for optimising the scale and deployment of CHWs in Mali. At the time of writing, policymakers, and planners in Mali (including authors of this study) were using our results to inform decisions on future scale-up and deployment of CHWs. As an intermediary milestone, the MSDS aims to progressively fill the gap between the existing CHW network and the first 4 500 CHWs of the optimised scale-up network that prioritized geographic coverage of the estimated population (given the

Table 3. Estimated number of CHW needed by region and district.

Region	District	a) Accessmod full CHW network (n = 15 843)	b) Accessmod first 4 500 CHW	c) Existing CHWs	d) Difference c-a	e) Difference c-b
Kayes	Bafoulabe	213	37	29	-184	-8
	Diema	318	98	24	-294	-74
	Kayes	417	167	45	-372	-122
	Kenieba	320	85	22	-298	-63
	Kita	453	62	73	-380	11
	Nioro	254	85	9	-245	-76
	Oussoubidiagnan	180	40	20	-160	-20
	Sagabari	47	5	8	-39	3
	Sefeto	75	43	3	-72	-40
	Yelimane	103	41	14	-89	-27
	Kayes Total	**2 380**	**663**	**247**	**-2 133**	**-416**
Koulikoro	Banamba	289	48	75	-214	27
	Dioila	423	117	114	-309	-3
	Fana	339	110	106	-233	-4
	Kalabancoro	157	43	25	-132	-18
	Kangaba	169	66	53	-116	-13
	Kati	387	75	41	-346	-34
	Kolokani	538	68	66	-472	-2
	Koulikoro	281	50	67	-214	17
	Nara	405	72	61	-344	-11
	Ouelessebougou	245	44	27	-218	-17
	Koulikoro Total	3 233	**693**	**635**	**-2 598**	**-58**
Sikasso	Bougouni	770	160	139	-631	-21
	Kadiolo	245	96	70	-175	-26
	Kignan	145	59	52	-93	-7
	Kolondieba	326	115	86	-240	-29
	Koutiala	589	156	95	-494	-61
	Niena	237	105	50	-187	-55
	Selingue	28	3	18	-10	15
	Sikasso	445	117	87	-358	-30
	Yanfolila	153	34	35	-118	1
	Yorosso	249	68	38	-211	-30
	Sikasso Total	**3 187**	**913**	**670**	**-2 517**	**-243**
Ségou	Baraoueli	285	89	37	-248	-52
	Bla	362	120	53	-309	-67
	Macina	409	139	81	-328	-58
	Markala	248	115	150	-98	35
	Niono	411	198	93	-318	-105
	San	466	161	65	-401	-96
	Ségou	651	181	76	-575	-105
	Tominian	468	81	69	-399	-12
	Ségou Total	**3 300**	**1 084**	**624**	**-2 676**	**-460**

(*Continued*)

Table 3. (Continued)

Region	District	a) Accessmod full CHW network (n = 15 843)	b) Accessmod first 4 500 CHW	c) Existing CHWs	d) Difference c-a	e) Difference c-b
Mopti	Bandiagara	459	139	44	-415	-95
	Bankass	453	145	247	-206	102
	Djenne	230	142	35	-195	-107
	Douentza	358	79	52	-306	-27
	Koro	642	288	45	-597	-243
	Mopti	308	114	31	-277	-83
	Tenenkou	253	52	33	-220	-19
	Youwarou	211	47	40	-171	-7
	Mopti Total	**2 914**	**1 006**	**527**	**-2 387**	**-479**
Gao	Almoustrat	9	4	0	-9	-4
	Ansongo	85	14	126	41	112
	Bourem	93	3	0	-93	-3
	Gao	72	10	20	-52	10
	Gao Total	**259**	**31**	**146**	**-113**	**115**
Tombouctou	Dire	63	15	0	-63	-15
	Goundam	69	7	0	-69	-7
	Gourma-rharous	33	4	0	-33	-4
	Niafunke	270	47	20	-250	-27
	Tombouctou	59	38	0	-59	-38
	Tombouctou Total	**494**	**111**	**20**	**-474**	**-91**
Kidal	Abeibara	8	0	0	-8	0
	Kidal	0	0	0	0	0
	Tessalit	7	0	0	-7	0
	Tin-essako	0	0	0	0	0
	Kidal Total	**15**	**0**	**0**	**-15**	**0**
Menaka	Anderamboukane	11	0	0	-11	0
	Menaka	7	0	10	3	10
	Tidermene	3	0	0	-3	0
	Menaka Total	**21**	**0**	**10**	**-11**	**10**
Taoudenit	Al-ourche	0	0	0	0	0
	Boujbeha	0	0	0	0	0
	Taoudenit	40	0	0	-40	0
	Taoudenit Total	**40**	**0**	**0**	**-40**	**0**
Bamako	Commune I	0	0	0	0	0
	Commune II	0	0	0	0	0
	Commune III	0	0	0	0	0
	Commune IV	0	0	0	0	0
	Commune V	0	0	0	0	0
	Commune VI	0	0	225	225	225
	Bamako Total	**0**	**0**	**225**	**225**	**225**
Grand Total		**15 843**	**4 501**	**3 104**	**-12 739**	**-1 397**

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negligible differences in efficiency between the hypothetical optimised networks). We support this approach as it is a practical and feasible near-term target given anticipated funding and it will maximize the value for money of available resources for integrated primary health care at

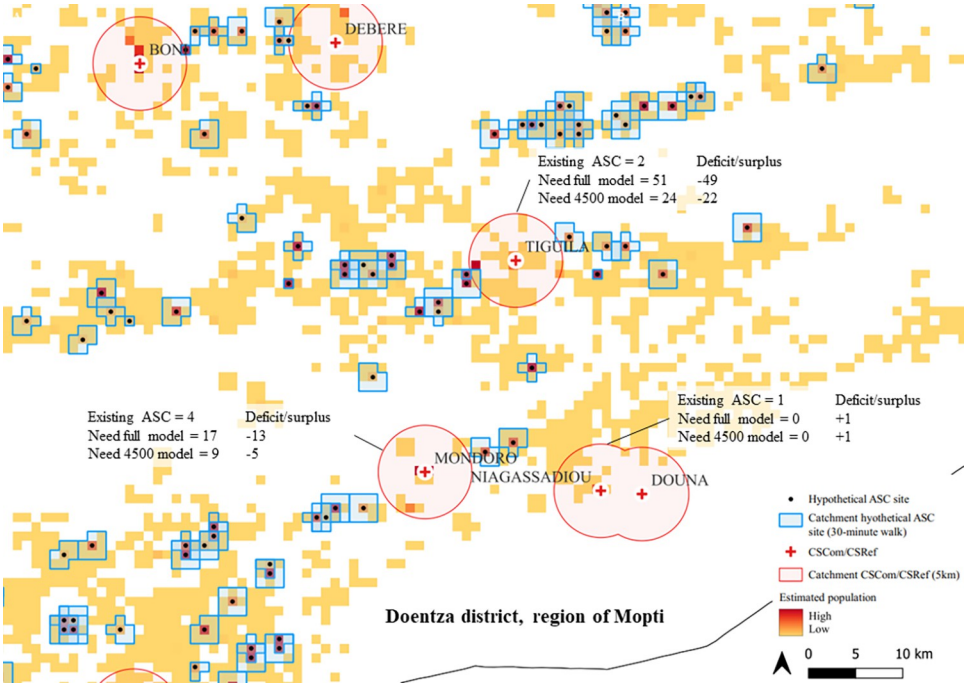

Fig 2. Modelled 30-minute catchment areas of the hypothetical CHW network prioritizing geographic coverage of the estimated population in 2020 at 1 kmx 1 km resolution. The 30-minute catchment area (blue) of the hypothetical CHW network prioritising geographic coverage of the estimated population in 2020 based on a walking scenario and the maximum population capacity of the CHW site. Text boxes for example CSCom indicate existing CHWs, estimated need based on the full model, estimated need based on the first 4 500 model, and deficits/surpluses comparing the existing CHW network with the models. The image depicts the area around the Tiguila CSCom in the Douentza district, region of Mopti, Mali.

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community level within the context of the current health system reform led by the MSDS. Recently, the Council of Ministers in Mali signed a decree officially recognizing CHWs as part of the health system. This is a remarkable milestone as it effectively lays the foundation for the possibility of domestic financing–and thereby sustainable financing–of CHWs in the future. Also of note, the WHO, at the time of writing, was planning a health labour market assessment in Mali and our results will be useful for informing that assessment as part of broader national HRH planning.

The fact that we found no important differences in geographic coverage between the approaches for scaling up and deploying CHWs has important implications for decisions on CHW deployment, as well as service integration. For example, policymakers and planners in Mali can be confident that their decision to scale up and deploy CHWs based on geographic coverage of the population adequately addresses other important concerns such as targeting the estimated burden of under-five deaths and *Pf* malaria cases. This type of analysis could be conducted in other contexts and may be particularly relevant where policymakers and planners would like to consider multiple criteria for scale-up and deployment.

While our analysis does not directly address gender equity–plans for the scale-up of CHWs and the dedicated supervisors [55] needed to effectively support the CHWs should aim to maximize gender equity of these two workforces [5]. This could be done through, for example, secondary analysis of the CHWML for the existing CHW network using a gender lens and considering affirmative action to preferentially select women during recruitment of new CHWs, following WHO guidance [5,6]. Our study also does not address CHW performance

or the optimization of the health policy and systems supports needed to maximize CHW performance [5]. These issues have been addressed previously through situational analyses and robust implementation research leading to the health sector reform and update to the national community health strategy–and will continue to be addressed in future research [36,55–58]. Planning for the scale-up of the CHW network should consider the comprehensive needs of CHWs (and their dedicated supervisors) so that they can be most effective [5,6,55,56]. For example, the participation of communities in the selection of candidates, competency-based pre-service training and accreditation, fair remuneration, dedicated supervision, equipment, job-aids and digital tools, commodities, means of transportation/funding for transportation costs for the CHWs and the dedicated supervisors for facilitated referral of patients, as well as quality improvement at CSCom and CHW levels [5,6,55–59]. Cost savings realized through the optimal deployment of additional CHWs in the future can be invested in ensuring the system components above are well-supported.

While our results point to certain CSCom and districts with an estimated surplus of CHWs according to current MSDS policy on CHW deployment, we do not recommend changing the deployment of the existing CHW network. The number of CSCom with a surplus of CHWs is small (102 CSCom) and the surplus is also small (553 CHWs). Changing the deployment of the existing CHW networks would be disruptive to the communities served, could negatively impact the trust of the affected communities in the health system, would have important negative socioeconomic impacts on the affected CHWs and their families, and would ignore the documented positive impact of CHWs in certain peri-urban areas (e.g., Yirimadio in Bamako) [58]. Instead, we support the MSDS' focus on using the results to inform future scale-up and deployment of new, additional CHWs as noted above.

As noted above 22.7% of the population remained uncovered by the hypothetical scaled-up network of CHWs. This population was in small, dispersed settlements of less than 150 people per 1 km2. To cover this population, the MSDS will need to consider the cost-benefits of different approaches e.g., 1) further expansion of the number of CHWs to such communities 2) targeting certain CHWs with motorbikes to facilitate mobile outreach by the CHWs to such communities, and 3) a combination of and 1 & 2, depending on local context.

Lastly and perhaps most importantly, to maximize the value of this kind of analysis it needs to be integrated into and updated as part of national health sector reviews and planning processes. Ideally, this kind of modelling approach would inform not only decisions on the scale-up and deployment of CHWs but also health facilities, such as the CSCom, and be considered in broader HRH and health sector strategy development and planning. As the health system expands through scaling-up CHWs and CSCom, informed by this kind of modelling, policymakers and planners in Mali will need to periodically update the modelling as part of national reviews to account for actual health system expansion and updates to other key datasets (e.g., population). Integration of this kind of modelling into national processes as described above will be challenging. The modelling approach is data-intensive, takes time, requires a country-led approach with leadership from the MSDS, strengthening national institutional capacity, flexibility to adapt to national processes and subnational contexts, and a clear understanding of its limitations and how it can complement/be complemented by other sources of information and considerations that may be important in the decision-making process (e.g., values, political priorities). Mali has embarked on this process with this first analysis and the use of the outputs to inform national planning for the scale-up and deployment of CHWs. At the time of writing, the MSDS and development partners–including co-authors–were discussing a plan for institutional capacity building and planning the first institutional capacity building workshop to be conducted in 2022.

Limitations

There are several important limitations of our study. First, our analysis is limited by the completeness and quality of the publicly available road and river network data. More complete and/or higher quality data on roads and rivers may be available outside the public domain. Second, estimates of the uncertainty of the estimated population counts for Mali were not available, limiting our ability to account for this source of uncertainty in measures of physical accessibility to services. Availability of this kind of data will be important for improving future modelling efforts. Third, for our targeting analysis, we resampled the modelled estimates of U5 mortality rates and *Pf* malaria incidence from 5 kmx 5km resolution to 1 kmx 1 km resolution due to lack of estimates at 1 km resolution, assuming the values for these parameters at the finer 1 kmx 1 km resolution. However, this limitation is moot given that the aim is to optimise the order of cell prioritisation (which location for a CHW should be prioritised over another), cell prioritisation is concerned with the relationship between cells (not the absolute value of cells) and the relationship between cells at 5 kmx 5 km resolution was maintained at 1 kmx 1 km resolution [20]. Third, our analysis is based on estimated travel speeds from other studies in the region [20,52,53], not empirical data from Mali or local expert knowledge, and does not account for uncertainty. Similarly, our analysis does not account for variation in walking speeds or common modes of transportation used across population groups or subnational areas. For example, pregnant women, people with illness, caregivers of ill children, the elderly population, and people with disabilities may walk slower than the general population, and predominant modes of transport may differ by geographic area or socioeconomic status. Future iterations of this analysis should attempt to address the limitations above regarding travel speeds and modes of transportation by incorporating information derived from sub-national level workshops with local experts. Fourth, our analysis did not account for the possibility of accessing health services across national boundaries, an important consideration for border communities and migrant populations. Fifth, our analysis did not account for social and economic barriers to care-seeking which may impact access to and use of health services independently of physical accessibility or through interactions with physical accessibility [60–62]. Lastly, our analysis did not consider the stockouts of equipment, supplies or commodities, quality of services and the potential for bypassing [63,64].

Conclusion

A network of 15 843 CHWs in Mali, if optimally deployed, would ensure 77.3% of the population beyond 5 km of a CSCom or CSRef were within a 30-minute walk of a CHW. There were no important differences in geographic coverage across a range of outcomes when prioritizing scale-up based on the estimated population, estimated U5 deaths, or estimated *Pf* malaria cases. Our geospatial analysis provides useful information to policymakers and planners in Mali for optimising the scale-up and deployment of CHWs and, in turn, for maximizing the value-for-money of resources for community-based primary health care in the context of the country's health sector reform. Countries with similar interests in optimising the scale and deployment of their CHW workforce may look to Mali as an exemplar model from which to learn.

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development of the first national master list of CHWs in Mali in 2021. #CHWsCount #PayCHWs #CountCHWs.

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Study 4: Oliphant, N. P., Daniels, K., Odendaal, W. A., Besada, D., Manda, S., Kinney, M., et al. (2017). Integrated community case management of childhood illness in low- and middle-income countries. Cochrane Database of Systematic Reviews 11(CD012882).doi:10.1002/14651858.CD012882

What is already known on this topic?

• Previous systematic reviews have assessed the effects of single-disease community case management (CCM) among children under-five in LMICs using the GRADE approach for assessing the certainty of evidence. One systematic review assessed the effects of iCCM for malaria and pneumonia (i.e., iCCM for two diseases) on malaria outcomes among children under-five in LMICs but did not use the GRADE approach for assessing the certainty of evidence and did not assess the effects of iCCM as an integrated approach on outcomes across diseases.

What are the new contributions from this study?

• Provides the most robust assessment to-date of the effects of iCCM as an integrated approach on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events, and coverage of careseeking for children younger than five years of age in low- and middle-income countries.

• When compared to usual facility services, iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness. However, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness. iCCM may have little or no effect on neonatal mortality and we are uncertain of the effect on infant mortality or under-five mortality.

• Given the very low- to moderate-certainty evidence for all reported outcomes in the systematic review, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, evidence was not reported for three primary outcomes: quality of care, case load or severity of illness at health facilities, and adverse events – research is needed on these outcomes.

• The study concludes that iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness. However, the evidence presented here

underscores the importance of moving beyond training and deployment to valuing iCCM providers, strengthening health systems and engaging community systems.

How this study might affect research, practice, or policy?

• As low- and middle-income countries strive to achieve universal health coverage, many will consider the role of iCCM as part of PHC. Our review identifies weaknesses across health policy and systems needed for CHWs to effectively deliver integrated PHC services such as iCCM and underscores the importance of moving beyond piecemeal approaches to investment in PHC, focused mostly on training health and care workers, toward more comprehensive health policy and systems strengthening efforts in alignment with WHO and UNICEF normative guidance.

• As countries optimize the deployment of CHWs (as described in studies 1-3) they should consider re-investing cost-savings from optimization toward the professionalization of CHWs and strengthening health policy and systems needed for CHWs to work effectively and to enjoy the conditions of decent work in alignment with WHO and UNICEF normative guidance.

Contribution of the candidate: NPO and TD coordinated the review. NPO, KD, DB, EWJ, SM, TD, WAO, MK, and KL. WAO conducted the search strategy. NPO, KD, DB, EWJ, TD, WAO, MK screened abstracts and full texts. NPO, KD, DB, EWJ, TD, WAO, MK extracted data. NPO, SM entered data into Review Manager. SM, NPO, TD conducted the data analysis. NPO and TD drafted the review. NPO, KD, DB, EWJ, SM, TD, WAO, MK reviewed the draft review and provided feedback for the final review. All review authors agreed to the final version of the review. TD and DJ provided supervision and overall guidance.

Review comments from the peer review process are available in Appendix 2. The published protocol for the review is provided in Appendix 3. A published video summary of the review is provided in Appendix 4. A published narrative summary of the review is provided in Appendix 5.

Cochrane Library

Cochrane Database of Systematic Reviews

Integrated community case management of childhood illness in low- and middle-income countries (Review)

Oliphant NP, Manda S, Daniels K, Odendaal WA, Besada D, Kinney M, White Johansson E, Doherty T

Oliphant NP, Manda S, Daniels K, Odendaal WA, Besada D, Kinney M, White Johansson E, Doherty T. Integrated community case management of childhood illness in low- and middle-income countries. *Cochrane Database of Systematic Reviews* 2021, Issue 2. Art. No.: CD012882.
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[Intervention Review]

Integrated community case management of childhood illness in low- and middle-income countries

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ABSTRACT

Background

The leading causes of mortality globally in children younger than five years of age (under-fives), and particularly in the regions of sub-Saharan Africa (SSA) and Southern Asia, in 2018 were infectious diseases, including pneumonia (15%), diarrhoea (8%), malaria (5%) and newborn sepsis (7%) (UNICEF 2019). Nutrition-related factors contributed to 45% of under-five deaths (UNICEF 2019).

World Health Organization (WHO) and United Nations Children's Fund (UNICEF), in collaboration with other development partners, have developed an approach – now known as integrated community case management (iCCM) – to bring treatment services for children 'closer to home'. The iCCM approach provides integrated case management services for two or more illnesses – including diarrhoea, pneumonia, malaria, severe acute malnutrition or neonatal sepsis – among under-fives at community level (i.e. outside of healthcare facilities) by lay health workers where there is limited access to health facility-based case management services (WHO/UNICEF 2012).

Objectives

To assess the effects of the integrated community case management (iCCM) strategy on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events and coverage of careseeking for children younger than five years of age in low- and middle-income countries.

Search methods

We searched CENTRAL, MEDLINE, Embase and CINAHL on 7 November 2019, Virtual Health Library on 8 November 2019, and Popline on 5 December 2018, three other databases on 22 March 2019 and two trial registers on 8 November 2019. We performed reference checking, and citation searching, and contacted study authors to identify additional studies.

Selection criteria

Randomized controlled trials (RCTs), cluster-RCTs, controlled before-after studies (CBAs), interrupted time series (ITS) studies and repeated measures studies comparing generic WHO/UNICEF iCCM (or local adaptation thereof) for at least two iCCM diseases with usual facility services (facility treatment services) with or without single disease community case management (CCM). We included studies reporting on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events and coverage of careseeking for under-fives in low- and middle-income countries.

Data collection and analysis

At least two review authors independently screened abstracts, screened full texts and extracted data using a standardised data collection form adapted from the EPOC Good Practice Data Collection Form. We resolved any disagreements through discussion or, if required, we consulted a third review author not involved in the original screening. We contacted study authors for clarification or additional details when necessary. We reported risk ratios (RR) for dichotomous outcomes and hazard ratios (HR) for time to event outcomes, with 95% confidence intervals (CI), adjusted for clustering, where possible. We used estimates of effect from the primary analysis reported by the investigators, where possible. We analysed the effects of randomized trials and other study types separately. We used the GRADE approach to assess the certainty of evidence.

Main results

We included seven studies, of which three were cluster RCTs and four were CBAs. Six of the seven studies were in SSA and one study was in Southern Asia.

The iCCM components and inputs were fairly consistent across the seven studies with notable variation for the training and deployment component (e.g. on payment of iCCM providers) and the system component (e.g. on improving information systems).

When compared to usual facility services, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness (RR 0.96, 95% CI 0.77 to 1.19; 2 CBA studies, 5898 children; very low-certainty evidence). iCCM may have little to no effect on neonatal mortality (HR 1.01, 95% 0.73 to 1.28; 2 trials, 65,209 children; low-certainty evidence). We are uncertain of the effect of iCCM on infant mortality (HR 1.02, 95% CI 0.83 to 1.26; 2 trials, 60,480 children; very low-certainty evidence) and under-five mortality (HR 1.18, 95% CI 1.01 to 1.37; 1 trial, 4729 children; very low-certainty evidence). iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness by 68% (RR 1.68, 95% CI 1.24 to 2.27; 2 trials, 9853 children; moderate-certainty evidence). None of the studies reported quality of care, severity of illness or adverse events for this comparison.

When compared to usual facility services plus CCM for malaria, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness (very low-certainty evidence) and iCCM may have little or no effect on careseeking to an appropriate provider for any iCCM illness (RR 1.06, 95% CI 0.97 to 1.17; 1 trial, 811 children; low-certainty evidence). None of the studies reported quality of care, case load or severity of illness at health facilities, mortality or adverse events for this comparison.

Authors' conclusions

iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness. However, the evidence presented here underscores the importance of moving beyond training and deployment to valuing iCCM providers, strengthening health systems and engaging community systems.

PLAIN LANGUAGE SUMMARY

Integrated community case management of childhood illness in low- and middle-income countries

What was the aim of this review?

This Cochrane Review aimed to assess the effects of integrated community case management (iCCM) for children under-five in low- and middle-income countries. The review authors collected and analysed all relevant studies to answer this question and found seven studies.

Key messages

When iCCM is compared to usual facility services, it probably increases the number of parents who seek care from a healthcare worker. But we do not know if more children get the correct treatment, and it may have no effect on the number of children who die.

What was studied in the review?

Each year, more than five million children die before the age of five. Most of these children live in sub-Saharan Africa or Central and Southern Asia. Many of these children suffer from infectious diseases including pneumonia and diarrhoea; and from malaria and malnutrition. And many children have more than one of these illnesses at the same time. These children do not always have easy access to healthcare services.

To address these problems, the World Health Organization, United Nations Children's Fund (UNICEF) and others have developed an approach known as iCCM. iCCM focuses on children under five years of age living in rural and hard-to-reach areas. They receive services from lay health workers who are based in the community, outside of healthcare facilities.

There are three main components of iCCM:

– Lay health workers are trained to assess children's health, provide services for common childhood illnesses and refer children to healthcare facilities where necessary. (A lay health worker is a lay person who has received some training to deliver healthcare services but is not a health professional.)

– Systems are put in place to make sure that the lay health workers have good access to supplies, get regular supervision and can easily refer children on to healthcare facilities.

– Families and communities receive communication and information about good practices for health and nutrition.

What were the main results of the review?

The review authors found seven relevant studies. Six were from sub-Saharan Africa and one was from Southern Asia. Some of the studies compared settings that had iCCM with settings that only had usual healthcare facilities. Some of the other studies compared settings that had iCCM with settings that had usual healthcare facilities as well as community-based management of malaria.

When iCCM is compared to usual facility services:

– It probably increases the number of parents who seek care from a healthcare worker when their children have common childhood illnesses.

– We do not know if more children get the correct treatment for childhood illnesses because the certainty of the evidence was very low.

– There may be no effect on the number of newborn children who die.

– We do not know what the effect is on the number of infants and children under-five years who die.

– We do not know what the effect is on quality of care, side effects or the number of children who attend healthcare facilities because the studies did not measure this.

When iCCM is compared to usual facility services plus community-based management of malaria:

– It may have no effect on the number of parents who seek care from a healthcare worker when their children have common childhood illnesses.

– We do not know if more children get the correct treatment for childhood illnesses because the certainty of the evidence was very low.

– We do not know what the effect is on the number of children who die.

– We do not know what the effect is on quality of care, side effects or the number of children who attend healthcare facilities because the studies did not measure this.

How up-to-date is this review?

The review authors searched for studies that had been published up to 7 November 2019.

SUMMARY OF FINDINGS

Summary of findings 1. Summary of findings: integrated community case management versus usual facility services

iCCM compared to usual facility services

Patient or population: children U5

Settings: middle- and low-income countries

Intervention: iCCM

Comparison: usual facility services

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Certainty of the evidence (GRADE)	Narrative results
	Assumed risk	Corresponding risk				
	Control (baseline risk in comparison)	iCCM (endline in intervention)				
1. Coverage of appropriate treatment						
From an appropriate provider						
Any iCCM illness	**44 children U5 with any iCCM illness who received appropriate treatment from an appropriate provider, per 100 children U5 with any iCCM illness**	**39 children U5 with any iCCM illness who received appropriate treatment from an appropriate provider, per 100 children U5 with any iCCM illness** (37 to 41 children)	**RR 0.96** (0.77 to 1.19)	5898 children (2 CBAs)[a,b]	⊕⊖⊖⊖ **Very low** [c]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness.
2. Quality of care						
No studies reported this outcome.						We do not know the effect of iCCM on quality of care.
3. Case load or severity of illness at health facilities						
No studies reported this outcome.						We do not know the effect of iCCM on case load or severity of illness at health facilities.

4. Mortality						
Neonatal mortality rate	**43 neonatal deaths per 1000 live births**	**43 neonatal deaths per 1000 live births** (40 to 45)	**HR 1.01** (0.77 to 1.33)	65,209 children (2 cRCTs)[d,e]	⊕⊕⊖⊖ **Low** [f]	iCCM may have little or no effect on neonatal mortality.
Infant mortality rate	**66 infant deaths per 1000 live births**	**66 infant deaths per 1000 live births** (64 to 69)	**HR 0.98** (0.72 to 1.34)	65,209 children (2 cRCTs)[d,e]	⊕⊖⊖⊖ **Very low** [g]	We are uncertain of the effect of iCCM on infant mortality.
U5 mortality rate	**113 U5 deaths per 1000 live births**	**134 U5 deaths per 1000 live births** (120 to 148)	**HR 1.16** (0.99 to 1.36)	4729 children (1 cRCT)[e]	⊕⊖⊖⊖ **Very low** [h]	We are uncertain of the effect of iCCM on U5 mortality.
5. Adverse events						
No studies reported this outcome.						We do not know the effect of iCCM on adverse events.
6. Coverage of careseeking						
To an appropriate provider of treatment services						
Any iCCM illness	**27 children U5 with any iCCM illness for whom care was sought from an appropriate provider, per 100 children U5 with any iCCM illness**	**47 children U5 with any iCCM illness for whom care was sought from an appropriate provider, per 100 children U5 with any iCCM illness** (45 to 48 children)	**RR 1.68** (1.24 to 2.27)	9853 children (2 cRCTs)[e,i]	⊕⊕⊕⊖ **Moderate** [j]	iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness.

*The basis for the **assumed risk** is the control group risk across studies (number of events in control group across studies / total in control group across studies). The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CBA: controlled before-after study; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **HR:** hazard ratio; **iCCM:** integrated community case management; **RR:** risk ratio; **U5:** aged < 5 years.

GRADE Working Group grades of evidence
High certainty: This research provides a very good indication of the likely effect. The likelihood that the effect will be substantially different** is low.
Moderate certainty: This research provides a good indication of the likely effect. The likelihood that the effect will be substantially different** is moderate.
Low certainty: This research provides some indication of the likely effect. However, the likelihood that it will be substantially different** is high.
Very low certainty: This research does not provide a reliable indication of the likely effect. The likelihood that the effect will be substantially different** is very high.

** Substantially different = a large enough difference that it might affect a decision

[a] Yansaneh 2014.
[b] Mubiru 2015.

[c]Downgraded three levels. We downgraded by two for serious risk of bias due to the studies being CBAs. We downgraded by one for serious inconsistency and serious imprecision. Heterogeneity was high (I^2 = 90%, P < 0.00001), with large effects in one CBA study (Mubiru 2015), and modest/no effects in the other CBA study (Yansaneh 2014). Confidence intervals included important effects to no effect.

[d] Bhandari 2012a.

[e] Boone 2016.

[f]Downgraded two levels. Heterogeneity was moderate (I^2 = 55%) but not statistically significant (P = 0.14). The effects were inconsistent across the two studies but confidence intervals overlapped and included no effect, therefore, we did not downgrade for serious inconsistency. Both trials included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India, which may be contextually different than the typical rural environment where iCCM is implemented, so we downgraded one level for indirectness. We downgraded one level for serious imprecision due to large confidence intervals that included an important effect to no important effect.

[g]Downgraded three levels. Heterogeneity was high (I^2 = 77%, P = 0.04) with inconsistent effects (Bhandari 2012a had a benefit of 15% and Boone 2016 had no effect), so we downgraded one level for serious inconsistency. Both trials included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India which may be contextually different than the typical rural environment where iCCM is implemented, so we downgraded one level for indirectness. We downgraded two levels for serious imprecision due to large confidence intervals that included an important effect to no important effect.

[h]Downgraded three levels. We downgraded two levels for indirectness. Prior to January 2009, chloroquine was the treatment for malaria according to the national protocol and resistance to chloroquine may have reduced effectiveness of the intervention. Artemisinin-based combination therapy (ACTs) were introduced in January 2009, first in health facilities and later among community health workers. The authors indicated that, due to this sequencing, people may have accessed ACTs sooner in control clusters than in intervention clusters – and this may have impacted the effect of the intervention, so we downgraded one level for indirectness. We also downgraded one level for indirectness due to the effect being based on a single cluster-randomized controlled trial. We downgraded one level for serious imprecision due to large confidence intervals that included an important effect to no important effect.

[i] Bhandari 2012a/Mazumder 2014.

[j]Downgraded one level overall. Heterogeneity was high (I^2 = 96%, P < 0.00001), but the effect was consistent (moderate-to-large effects in favour of the intervention) across studies and confidence intervals overlapped, therefore, we did not downgrade for serious inconsistency. Both trials included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India which may contextually different than the typical rural environment where iCCM is implemented, so we downgraded one level for indirectness.

Summary of findings 2. Summary of findings: integrated community case management versus usual facility services plus CCM for malaria

iCCM compared to usual facility services + CCM for malaria						
Patient or population: children U5 **Settings:** middle- and low-income countries **Intervention:** iCCM **Comparison:** usual facility services + CCM for malaria						
Outcomes	**Illustrative comparative risks* (95% CI)**		**Relative effect (95% CI)**	**No of participants (studies)**	**Certainty of the evidence (GRADE)**	**Narrative results**
	Assumed risk	**Corresponding risk**				

	Control (baseline risk in comparison)	iCCM (endline in intervention)				
1. Coverage of appropriate treatment						
From an appropriate provider						
Any iCCM illness	**18 children U5 with any iCCM illness who received appropriate treatment from an appropriate provider, per 100 children U5 with any iCCM illness**	**24 children U5 with any iCCM illness who received appropriate treatment from an appropriate provider, per 100 children U5 with any iCCM illness** (22 to 25 children)	**RR 1.59** (0.66 to 3.87)	7876 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness.
2. Quality of care						
No studies reported this outcome.						We do not know the effect of iCCM on quality of care.
3. Case load or severity of illness at health facilities						
No studies reported this outcome.						We do not know the effect of iCCM on case load or severity of illness at health facilities.
4. Mortality						
No studies reported this outcome.						We do not know the effect of iCCM on mortality.
5. Adverse events						
No studies reported this outcome.						We do not know the effect of iCCM on adverse events.
6. Coverage of careseeking						
To an appropriate provider of treatment services						
Any iCCM illness	**66 children U5 with any iCCM illness for whom care was sought from an appropriate provider,**	**70 children U5 with any iCCM illness for whom care was sought from an appropriate provider, per 100**	**RR 1.21** (0.90 to 1.62)	811 children (1 cRCT)[c]	⊕⊕⊖⊖ **Low** [d]	iCCM may have little or no effect on careseeking to an appropriate provider of treatment services for any iCCM illness.

	per 100 children U5 with any iCCM illness	**children U5 with any iCCM illness** (65 to 74 children)

*The basis for the **assumed risk** is the control group risk across studies (number of events in control group across studies / total in control group across studies). The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CBA: controlled before-after study; **CCM:** community case management; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management; **RR:** risk ratio; **U5:** aged under-five years.

GRADE Working Group grades of evidence

High certainty: This research provides a very good indication of the likely effect. The likelihood that the effect will be substantially different** is low.
Moderate certainty: This research provides a good indication of the likely effect. The likelihood that the effect will be substantially different** is moderate.
Low certainty: This research provides some indication of the likely effect. However, the likelihood that it will be substantially different** is high.
Very low certainty: This research does not provide a reliable indication of the likely effect. The likelihood that the effect will be substantially different** is very high.

** Substantially different = a large enough difference that it might affect a decision

[a] Munos 2016.
[b]Downgraded three levels (two levels for serious risk of bias due to the study being a CBA, one level for serious imprecision).
[c] Kalyango 2012a.
[d]Downgraded two levels. We downgraded one level for risk of bias because the primary outcome measure for Kalyango 2012a, U5 mortality, has never been published – indicating risk of reporting bias for this study. We downgraded one level for indirectness due to the effect being based on a single cluster-randomized controlled trial.

BACKGROUND

Description of the condition

The mortality rate in children younger than five years of age (under-fives) declined by 59% (55% to 60%) between 1990 and 2018 and most regions had reduced under-five mortality by at least 50% over the same period (UNICEF 2019). By 2018, 121/195 countries had achieved an under-five mortality rate below the Sustainable Development Goal target of 25 or fewer deaths per 1000 live births (UNICEF 2019). However in 2018, there were still an estimated 5.3 (5.1 to 5.7) million deaths among children under-five, with an estimated 2.5 million deaths in the first month of life, 1.5 million deaths between one and 11 months of age, and 1.3 million deaths between one and four years of age (UNICEF 2019). In 2018, 52% of all under-five deaths – 2.8 (2.6 to 3.1) million deaths – occurred in the region of sub-Saharan Africa (SSA) and 29% of all under-five deaths – 1.5 (1.4 to 1.7) million deaths – occurred in the region of Central and Southern Asia (UNICEF 2019). High mortality rates persist in many low- and middle-income countries (LMICs), particularly in these regions, with large disparities within countries (Golding 2017; UNICEF 2019). In 2018, the leading causes of under-five mortality globally, and particularly in the regions of SSA and Southern Asia, were infectious diseases, including pneumonia (15%), diarrhoea (8%), malaria (5%) and newborn sepsis (7%) (UNICEF 2019). Nutrition-related factors contributed to 45% of under-five deaths (UNICEF 2019).

Efficacious interventions for addressing the major causes of preventable under-five mortality exist (Darmstadt 2005; Jones 2003). In the mid-1990s the World Health Organization (WHO), the United Nations Children's Fund (UNICEF) and technical partners developed a strategy called the Integrated Management of Childhood Illness (IMCI) to reduce child mortality, illness and disability, and to promote improved growth and development among children under-five (Tulloch 1999; WHO 1997). IMCI includes three main components (Gera 2016; Tulloch 1999):

- improvements in case-management skills of health staff through the provision of locally adapted guidelines on IMCI and activities to promote their use;
- improvements in the health system required for effective management of childhood illnesses; and
- improvements in family and community practices.

IMCI was designed to deliver treatment interventions of known efficacy for the main causes of under-five mortality through an integrated case management approach, recognising that children presenting at health facilities often have multiple, overlapping signs and symptoms of these conditions (Fenn 2005; O'Dempsey 1993; Tulloch 1999; WHO 1997). One Cochrane Review of IMCI concluded with low certainty that IMCI may reduce under-five mortality, may reduce infant mortality (where interventions for the neonatal period are included) and may have mixed effects on careseeking behaviour, morbidity and quality of care (Gera 2016).

In an earlier multicountry evaluation of IMCI, Bryce and colleagues found that "improving the quality of care in first-line government health facilities was not sufficient" to improve low utilization and population coverage; the components on health systems and family and community practices were slow to be implemented (if at all); and they concluded that "Delivery systems that rely solely on government health facilities must be expanded to include the full range of potential channels in a setting and strong community-based approaches … we must move beyond health facilities, and develop new and more effective ways of reaching children with proven interventions to prevent mortality. In most high-mortality settings, this means providing case management at community level, as well as focusing on prevention and reducing rates of undernutrition" (Bryce 2005).

Other researchers have also found accessibility of treatment services at government health facilities to be inadequate, particularly in SSA (Blanford 2012; Huerta Munoz 2012; Noor 2003; Noor 2006; Tsoka 2004).

Description of the intervention

In the 2000s, the WHO and UNICEF, in collaboration with other development partners, developed an approach – now known as integrated community case management (iCCM) – to bring treatment services for children 'closer to home' and advocated for LMICs to adopt it (Bennett 2015; Diaz 2014; WHO/UNICEF 2012). The transfer of iCCM policy from the global level to national levels has been complex, characterised by "early" and "later" adopters and variation in the role of international organisations and policy transfer strategies used (Bennett 2015). Overall, the adoption of iCCM and its adaptation to national contexts by ministries of health has been rapid, particularly in SSA where most countries have some form of written policy to enable implementation of iCCM (Rasanathan 2014).

Definition

iCCM is an extension of IMCI – providing treatment services outside the healthcare facility at community level (Bennett 2015; Gera 2016); and c-IMCI – the original community-based component of IMCI which focused on promoting key family and community practices for improving child health (WHO 1997). iCCM is an approach to providing integrated case management services for two or more illnesses – including diarrhoea, pneumonia and malaria (the latter in malaria-affected countries) – among children under-five at community level (i.e. outside of healthcare facilities) by lay health workers (also called community health workers (CHW)) where there is limited access to health facility-based case management services (WHO/UNICEF 2012). Case management services as defined here include assessment, treatment and referral services (WHO/UNICEF 2012), following locally adapted WHO/UNICEF guidelines (WHO 2011). In some contexts, iCCM may also include case management services for acute malnutrition and newborn illness (Rasanathan 2014; WHO 2007). iCCM is considered an equity-focused approach in that it is primarily implemented in rural and hard-to-reach areas with limited access to facility-based case management services (WHO/UNICEF 2012).

Components of the intervention

There are three main components of iCCM (Diaz 2014; McGorman 2012; WHO/UNICEF 2012; Young 2012). Table 1 classifies the three main components of iCCM according to the Effective Practice and Organization of Care (EPOC) taxonomy of health systems interventions (EPOC 2015), providing a framework and common language for understanding and describing iCCM, its components and inputs. The three main components of iCCM are summarised below.

- Training and deployment component: interventions with the main purpose of increasing access to integrated case management services for children under-five by increasing the number of lay health workers trained on the generic or adapted WHO/UNICEF guidelines for integrated case management services and deployed where facility-based case management services are limited.
- Systems component: interventions with the main purpose of improving implementation of iCCM by strengthening health systems' organisation and management, including supplies, specifically related to iCCM.
- Communication and community mobilisation component: interventions with the main purpose of promoting good practices for health and nutrition and generating demand for case management services for ill children through communication and mobilisation of communities and caregivers.

iCCM providers

iCCM providers may include any lay health workers (paid or voluntary) who:

- provide iCCM (integrated case management services for two or more illnesses among children under-five);
- are trained on iCCM, but have received no formal professional or paraprofessional certificate or tertiary education degree (adapted from Lewin 2010).

This definition includes iCCM providers who receive a certificate on completion of their iCCM training but excludes healthcare providers who receive prelicensure or postlicensure training certified by a professional body, such as a nursing or midwifery council.

Package of services

iCCM providers deliver integrated case management services for two or more illnesses among children under-five (WHO/UNICEF 2012; Young 2012), including:

- assessment and classification of the child's condition(s) using a simplified IMCI-adapted algorithm;
- referral of cases with general danger signs and other complicated cases;
- provision of treatment for the following conditions:
  - non-severe pneumonia with oral antibiotics;
  - non-severe diarrhoea with oral rehydration salts (ORS) and zinc;
  - non-severe malaria with artemisinin-based combination therapy (ACT) (in malaria-affected countries).

iCCM may also include assessment, classification and treatment of neonatal sepsis with oral antibiotics and referral as necessary; and assessment, classification and treatment of uncomplicated severe acute malnutrition (SAM) with ready-to-use therapeutic food (RUTF) and oral antibiotics, with referral as necessary (Rasanathan 2014; WHO 2007).

How the intervention might work

Interventions in the training and deployment component target lay health workers to improve access to integrated case management services for children under-five at community level where facility-based case management services are limited. The logic of these interventions assumes that increasing the number of lay health workers trained to deliver integrated case management services based on locally adapted WHO/UNICEF guidelines (WHO 2011) for children under-five (who may present with multiple, overlapping symptoms), and deploying them to areas where facility-based case management services are limited, will improve the availability and geographic accessibility of integrated case management services by bringing these services closer to caregivers (Diaz 2014; WHO/UNICEF 2012; Young 2012).

Interventions in the systems component aim to strengthen health systems components such as supply chain management, supervision, referral pathways and health management information systems. The logic of these interventions assumes that effective iCCM implementation is dependent on a continuous supply of drugs and diagnostic tools, regular supervision, effective referral mechanisms and a strong health management information system.

Interventions in the communication and community mobilisation component target communities and caregivers with the main purpose of promoting good practices for health and nutrition and generating demand for case management services for ill children through communication and mobilisation of communities and caregivers**.** The logic of these interventions assumes that effective iCCM implementation is dependent on effective communication and mobilisation strategies, plans, materials, and messages around good health and nutrition practices, as well as for increasing demand for case management services.

Why it is important to do this review

WHO and UNICEF have endorsed iCCM (WHO/UNICEF 2012), and the uptake of iCCM by national governments has been rapid (Rasanathan 2014; UNICEF 2005). Evidence-based policy making is critical to improving health outcomes (Bosch-Capblanch 2012; Langlois 2015; Lavis 2009; Oliver 2014). To date, no systematic review of iCCM – that is, as an integrated approach for the management of diarrhoea, pneumonia, malaria (in malaria-affected areas), acute malnutrition or newborn sepsis (or combinations of these conditions) at the community level by lay health workers – has been undertaken. This presents an important information gap relevant to evidence-based decision-making by the general public, healthcare workers, policy makers and researchers in LMICs.

Systematic reviews have been undertaken and published on single-disease community case management (CCM) – that is CCM for diarrhoea (Das 2013), malaria (Okwundu 2013; Ruizendaal 2014; Sazawal 2003), and pneumonia (Das 2013; Druetz 2013; Ruizendaal 2014; Sazawal 2003) – among children under-five in LMICs. The reviews that used the GRADE approach reported moderate-certainty evidence for the effectiveness of CCM on careseeking behaviour (Das 2013), mostly moderate-certainty evidence for the effectiveness of CCM on appropriate treatment (Das 2013; Okwundu 2013), and timeliness of treatment (Okwundu 2013), and mostly moderate-certainty evidence for effectiveness of CCM on mortality among children under-five (Das 2013; Okwundu 2013). Two reviews included studies on iCCM (Das 2013; Druetz 2013); however, only Das 2013 used GRADE and both were primarily

focused on the effects of CCM – not iCCM – and, therefore, did not address the objectives of this review.

A systematic review of community-based management of pneumonia by Theodoratou 2010 included studies on CCM by lay health workers but did not report these results separately from the results of studies that included other types of healthcare workers such as nurses.

One systematic review assessed the effect of integrating CCM for malaria with other interventions, including CCM for pneumonia, on outcomes for CCM for malaria – in particular quality of care and facilitators and barriers to high-quality CCM for malaria (Smith Paintain 2014). They found that integrating additional interventions with case management services at community level for malaria did not reduce the quality of the malaria services in contexts where training and supervision were maintained but quality of pneumonia case management was lower and variable (Smith Paintain 2014). This review did not use GRADE and was focused on the effects of iCCM on malaria outcomes, not outcomes across diseases as in our review.

A scoping review of programmatic evidence that did not assess study quality examined iCCM training, supervision and quality of care, and reported positive effects on quality of care in large iCCM programmes where multifaceted interventions including training, supervision and supply chain management were implemented (Bosch-Capblanch 2014).

Amouzou and colleagues undertook a non-systematic review of the impact of iCCM on under-five mortality in SSA and reported that large heterogeneity of programme implementation and evaluation design precluded meta-analysis, but revealed in six of eight studies a greater decline in mortality among children aged two to 59 months in intervention areas compared to comparison areas (Amouzou 2014).

Other systematic and non-systematic reviews have covered the effectiveness of lay health workers in terms of providing a range of maternal, newborn and child health interventions (Christopher 2011; Hopkins 2007; Lewin 2010; Sanders 2007; Zaidi 2009).

The current review will build on previous reviews – which primarily focused on CCM or effects of iCCM on outcomes for a single disease – by focusing on the effects of iCCM as an integrated approach on outcomes across diseases, including the GRADE approach for assessing the certainty of the evidence.

OBJECTIVES

To assess the effects of the integrated community case management (iCCM) strategy on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events and coverage of careseeking for children under-five in low- and middle-income countries.

METHODS

Criteria for considering studies for this review

Types of studies

We considered types of studies for inclusion based on EPOC guidance (EPOC 2017a).

- Randomized controlled trials (RCTs), including cluster-RCTs (cRCTs), with at least two intervention (iCCM) sites and at least two control sites (no iCCM).
- Non-randomized trials with at least two intervention (iCCM) sites and at least two control (no iCCM) sites and adjustment for baseline characteristics and confounders.
- Controlled before-after studies (CBAs) with at least two intervention (iCCM) sites and at least two control (no iCCM) sites in which allocation to different comparison groups was not made by study investigators, and outcomes were measured in both intervention and control groups at baseline and after the iCCM programme had been introduced.
- Interrupted time series (ITS) studies with a clearly defined point in time when the intervention (iCCM) occurred, at least three data points before and three after the introduction of iCCM, and met EPOC standard criteria for methodological quality of ITS designs.
- Repeated measures studies, specifically ITS studies where measurements were made in the same individuals at each time point.

As a strategy, iCCM was intended to target areas within LMICs with poor geographic accessibility to facility-based case management services, and this review provides evidence relevant to this approach in these settings. For this reason, included studies were restricted to LMICs as categorised by the World Bank using gross national income per capita in US dollars and the Atlas conversion factor (World Bank 2012). We did not restrict the inclusion of studies by language, publication status or date of publication. We considered for inclusion full-text published studies, conference abstracts, unpublished full-text studies and unpublished data.

Types of participants

Types of recipients

Children under-five and their caregivers in LMICs.

Types of healthcare providers

Any lay health workers (paid or voluntary) who:

- provide iCCM for two or more illnesses among children under-five;
- were trained on iCCM, but had received no formal professional or paraprofessional certificate or tertiary education degree (adapted from Lewin 2010).

Types of interventions

We considered for inclusion studies on the implementation of generic WHO/UNICEF iCCM (or local adaptation thereof) for at least two of the following iCCM diseases: diarrhoea, malaria (in endemic areas), pneumonia, SAM and newborn sepsis. We also considered for inclusion studies with implementation of unbranded iCCM (i.e. where the intervention was not called by the name 'iCCM' but

where generic WHO/UNICEF iCCM for at least two iCCM diseases had been implemented). We recognised that iCCM in some contexts may include other childhood illnesses. Therefore, we considered studies of iCCM that included other childhood illnesses (e.g. antiretroviral therapy adherence for HIV, paediatric tuberculosis services) as long as they included at least two iCCM diseases.

To be considered for inclusion, a study must have had at minimum included training and deployment of lay health workers for iCCM as one component plus system interventions to supply the necessary commodities and equipment with or without other system interventions or interventions for community mobilisation and engagement.

Comparison

We compared iCCM with usual facility services (facility treatment services without single-disease CCM). We also compared iCCM with usual facility services plus single-disease CCM for malaria. We also suspected that effects would vary depending on a number of programme and contextual factors. For instance, iCCM may have involved multiple components (Table 1), including health systems interventions and interventions for communication and community mobilisation not all of which may have been implemented in all contexts, in the same way or with the same strength. These are summarised below in Subgroup analysis and investigation of heterogeneity.

Types of outcome measures

Primary outcomes

- Coverage of appropriate treatment by an appropriate provider: the proportion of children under-five with one or more childhood illnesses (diarrhoea, malaria, pneumonia, SAM, newborn sepsis or newborn local infection) who received appropriate treatment from an 'appropriate provider' of treatment services (trained, certified or otherwise qualified public or private provider, including iCCM providers). This could have included oral rehydration therapy and zinc for diarrhoea; antimalarial drug prescription for fever (where the treatment protocol was presumptive treatment without confirmation by rapid diagnostic test (RDT) or microscopy) and RDT- or microscopy-confirmed malaria (for the latter, see Differences between protocol and review); RUTF for SAM; and antibiotics for newborn sepsis as well as antibiotics for newborn local infection, which was not prespecified (see Differences between protocol and review). Coverage of appropriate treatment for pneumonia was not included due to the lack of a valid way to measure this outcome (Bryce 2013).
- Quality of care assessed by adherence to standard/adapted WHO/UNICEF iCCM practice guidelines. This could have included correct assessment (iCCM provider's assessment matched a gold standard assessment); correct classification (iCCM provider's classification matched a gold standard classification); and correct treatment (iCCM provider's treatment matched a gold standard treatment). We did not exclude studies using other standards or indicators.
- Case load or severity of illness at health facilities. This could have included the proportion of facility case load made up by severe diarrhoea, severe malaria (in endemic settings), severe pneumonia and cases with general danger signs or other complications.
- Measures of mortality (neonatal, infant and under-five mortality).
- Adverse events.

Secondary outcomes

- Coverage of careseeking to an 'appropriate provider' of treatment services. This could have included careseeking to a trained, certified or otherwise qualified public or private provider (including iCCM providers) of treatment services for diarrhoea, fever, suspected pneumonia, malnutrition, newborn sepsis and newborn local infection or newborn danger signs (the latter two illnesses were not prespecified, see Differences between protocol and review).

Search methods for identification of studies

Electronic searches

We searched the following electronic databases for primary studies:

- Cochrane Central Register of Controlled Trials (CENTRAL) 2019, Issue 10, part of the Cochrane Library. (www.cochranelibrary.com) (searched 7 November 2019);
- MEDLINE and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily 1946 to 5 November 2019 (searched 7 November 2019);
- Embase 1974 to 6 November 2019, Ovid (searched 7 November 2019);
- CINAHL 1981 to present, EBSCOhost (searched 7 November 2019);
- Virtual Health Library (VHL Regional Portal: bvsalud.org/en/) (searched 8 November 2019);
- POPLINE, K4Health (searched 5 December 2018).

The EPOC Information Specialist in consultation with the review authors developed the search strategies. Search strategies comprised keywords and controlled vocabulary terms. We applied no language or time limits. We searched all databases from database start date to date of search. All strategies used are reported in Appendix 1.

Searching other resources

We conducted a grey literature search to identify studies not indexed in the databases listed in Electronic searches.

Grey literature

- Grey Literature Report (www.greylit.org) (searched 22 March 2019).
- OpenGrey (www.opengrey.eu) (searched 22 March 2019).
- Eldis (www.eldis.org/) (searched 22 March 2019).

Trial registries

- ClinicalTrials.gov, U.S. National Institutes of Health (NIH) (www.clinicaltrials.gov) (searched 8 November 2019).
- International Clinical Trials Registry Platform (ICTRP), WHO (www.who.int/ictrp/en) (searched 8 November 2019).

We also:

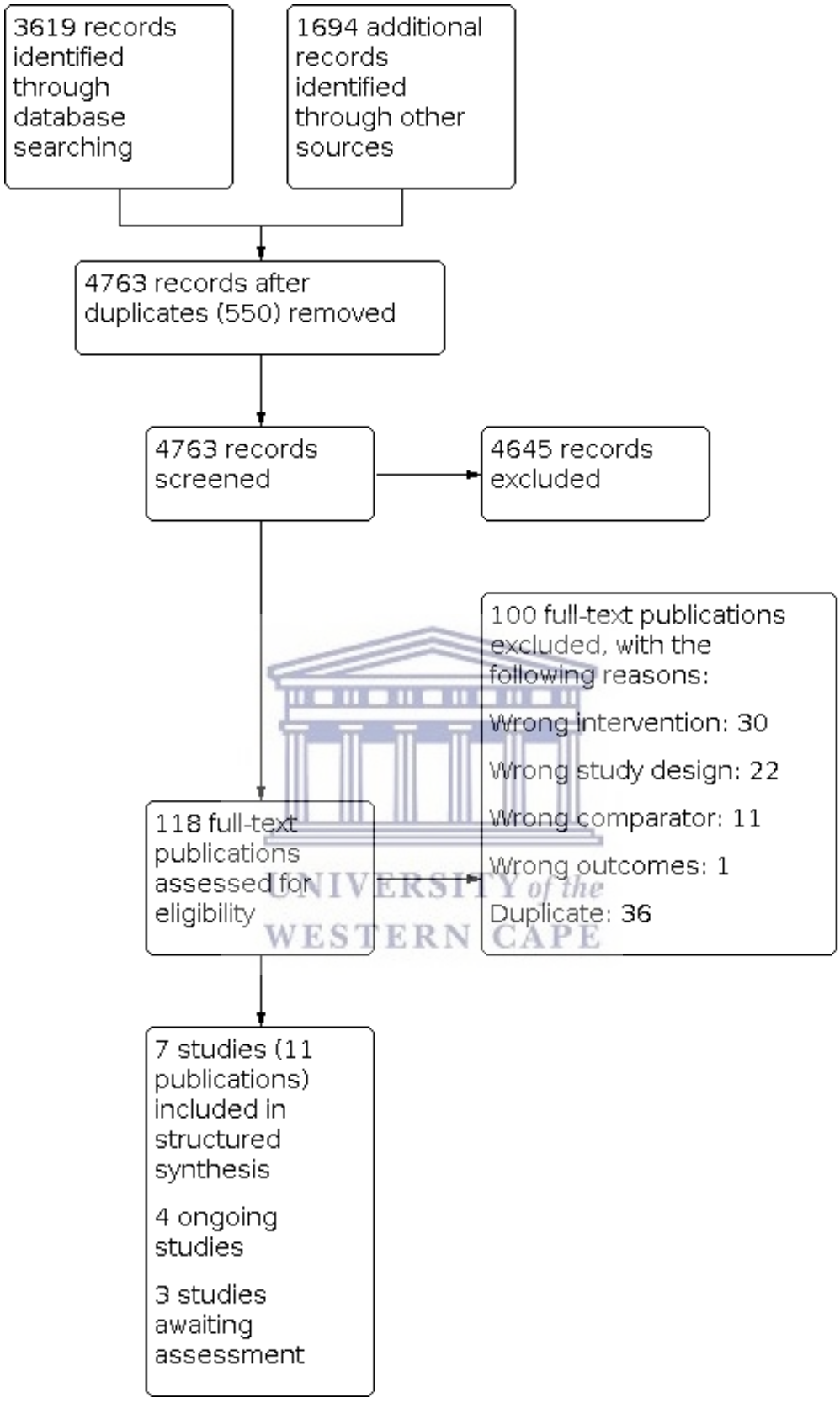
- Searched Web of Science Core Collection 1987 to 2019, Clarivate Analytics, for studies citing the included studies in this review (searched 27 September 2019);
- screened individual journals and conference proceedings;
- reviewed reference lists of all included studies and relevant systematic reviews/primary studies;
- contacted authors of relevant studies/reviews to clarify reported published information and to seek unpublished results/data; and
- contacted researchers with expertise relevant to the review topic/EPOC interventions.

Data collection and analysis

Selection of studies

We downloaded all titles and abstracts retrieved by electronic searching to Covidence, a web-based software platform for systematic review production and removed duplicates (Covidence 2019). At least two review authors (from among NO; DB; WO; EJ; MK; TD; KD) independently screened titles and abstracts for inclusion. We retrieved the full-text study reports/publication for all eligible or potentially eligible/unclear studies and at least two review authors independently screened the full text, identified studies for inclusion, and identified and recorded reasons for exclusion of the ineligible studies. We resolved any disagreements through discussion or, if required, we consulted a third review author (one of the review authors who had not originally screened the particular title, abstract or full text). We listed in Characteristics of excluded studies, with reasons for their exclusion, studies that initially appeared to meet the inclusion criteria but which we later rejected. For multiple reports of the same study, we identified a primary reference for the study and linked the other reports to this reference. We provided the information we could obtain about ongoing studies (Characteristics of ongoing studies table). We recorded the selection process in sufficient detail to complete a PRISMA flow diagram (Figure 1).

Figure 1. Study flow diagram. See also Selection of studies and Results of the search.



Data extraction and management

We used a standard data collection form, adapted from the EPOC Good Practice Data Collection Form (EPOC 2017b), and piloted on at least one study in the review, to gather study characteristics and outcome data. Two review authors per study independently extracted the following study characteristics from included studies.

- Methods: study design, number of study centres and location, study setting, withdrawals, date of study, follow-up.
- Participants: number, mean age of children, age range of children, sex of the children, socioeconomic status (country baseline income level as defined by the Human Development Index (HDI); household wealth defined as household assets or income), type of condition, diagnostic criteria, inclusion criteria, exclusion criteria, other relevant characteristics.
- Interventions: intervention components, comparison, fidelity assessment. Where multiple trial arms were reported in a single trial, we included only the relevant arms in the analyses but listed all arms in the Characteristics of included studies table.
- Outcomes: primary and secondary outcomes specified and collected, time points reported. We extracted information separately for two of the PROGRESS groups specified for subanalysis (O'Neill 2014): socioeconomic status (country baseline income level as defined by the HDI and household wealth defined as household assets or income); and sex of children.
- Notes: funding for trial, all stated conflicts of interest of trial authors, ethical approval.

Two review authors independently extracted outcome data from included studies. For Mubiru 2015, it was unclear whether the published results aligned to our outcome indicator definitions and how results were adjusted in analysis. Mubiru and colleagues provided an individual-level dataset with their publication. We sought to confirm whether the results they reported aligned to our outcome indicator definitions and to replicate their adjusted results as published, using the individual-level dataset. We found that we could not replicate the analysis because the dataset provided was incomplete. We contacted Mubiru and colleagues for clarification and requested the authors to confirm results per our outcome indicator definitions. Mubiru and colleagues did not respond. For our analyses involving Mubiru 2015, we extracted unadjusted counts from Table 3 of Mubiru 2015 and assumed the reported results aligned to our outcome indicator definitions. For Yansaneh 2014, the published results did not align to our outcome indicator definitions. We contacted Yansaneh and colleagues and requested confirmation of results per our outcome indicator definitions. Yansaneh and colleagues confirmed unadjusted event counts per our outcome indicator definitions and we used these unpublished, unadjusted event counts in our analyses involving Yansaneh 2014. For White 2018, the published results did not align to our indicator definitions. White and colleagues provided an individual-level dataset. We used unadjusted event counts recalculated from the individual level dataset to align with our outcome indicator definitions in our analyses involving White 2018. We resolved disagreements by consensus or by involving a third review author (one of the review authors who had not originally extracted from the full text). NO was not involved in data extraction for studies supported by UNICEF or the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Bhandari 2012a; Kalyango 2012a; Mubiru 2015; Yansaneh 2014, see Declarations of interest section).

Assessment of risk of bias in included studies

Two review authors (NO and TD) independently assessed risk of bias for each study using guidance from the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011) and EPOC (EPOC 2017c). NO was not involved in risk of bias evaluation for studies supported by UNICEF or the Global Fund to Fight AIDS, Tuberculosis, and Malaria (see Declarations of interest section). NO and TD resolved any disagreement by discussion or by involving a third review author (KD). We intended to apply the seven standard EPOC risk of bias criteria for ITS studies, but there were no eligible ITS studies. We assessed and presented the risk of bias for studies with a separate control group (RCTs, non-randomized trials, and CBA studies) according to the nine standard criteria suggested by EPOC (EPOC 2017c).

- Was the allocation sequence adequately generated?
- Was the allocation adequately concealed?
- Was knowledge of the allocated interventions adequately prevented during the study?
- Were incomplete outcome data adequately addressed?
- Was the study free from selective outcome reporting?
- Were baseline outcome measurements similar?
- Were baseline characteristics similar?
- Was the study adequately protected against contamination?
- Was the study adequately protected against contamination?
- Was the study free from other risks of bias?

Following EPOC guidance, we provided a summary assessment of the risk of bias for each important outcome (across domains), including all of the entries relevant to that outcome, within and across studies (EPOC 2017d). For each domain, we provided a judgement and a quotation in support of the judgement. The judgement for each outcome assessed the risk of bias as 'low risk' (low risk of bias for all key domains), as 'high risk' (high risk of bias for one or more key domains), or 'unclear risk' (unclear risk of bias for one or more key domains) (EPOC 2017d). We interpreted 'low risk' of bias to mean plausible bias that was unlikely to seriously alter the results; 'high risk of bias' to mean plausible bias that seriously weakened confidence in the results and 'unclear risk' of bias to mean plausible bias that raised some doubt about the results (Table 2; EPOC 2017d). We considered blinding separately for different key outcomes where necessary (e.g. for unblinded outcome assessment, risk of bias for mortality may be very different than for reported careseeking). Where information on risk of bias related to unpublished data or correspondence with a trialist, we note this in the 'Risk of bias' table. We included plots of 'Risk of bias' assessments in Review Manager 5 (Review Manager 2014). We resolved disagreements about risk of bias by discussion between the authors assessing risk of bias or by group discussion, if necessary. We did not provide a summary assessment of the risk of bias for a study across outcomes because we could not assume the risk of bias was the same for all outcomes in a study and generally a summary assessment of the risk of bias across outcomes was of little interest. We did not provide a summary assessment of the risk of bias for the review as a whole (across studies and outcomes) because this would require value judgements about which outcomes were critical to a decision: these judgements may vary across settings, and this review was intended to inform decisions across a variety of settings (Higgins 2011).

When considering treatment effects, we considered the risk of bias for the studies that contributed to that outcome.

Assessment of bias in conducting the systematic review

We conducted the review according to the published protocol and reported any deviations from it in the (Differences between protocol and review section.

Measures of treatment effect

Dichotomous outcomes

For RCTs, non-RCTs and CBA studies, we recorded measures of treatment effect for outcomes in each comparison group. For outcomes on treatment and careseeking, we entered the extracted or recalculated unadjusted count data into meta-analyses, using a random-effects generalised linear model to account for possible heterogeneity in the studies and calculate adjusted risk ratios (RRs) and 95% confidence intervals (CI). For outcomes on treatment and careseeking, we used the control group as the reference and estimates of relative treatment effects above 1 were in favour of the intervention. For outcomes on mortality, we used the estimated hazard ratios (HRs) from the studies. The HRs accounted for stratification factors and robust variance estimation for clustering (villages in Boone 2016) or used a frailty model to account for clustering (primary health centres in Bhandari 2012a). Both Boone 2016 and Bhandari 2012a used a Cox proportional hazard model to calculate HRs and 955 CIs. For outcomes on mortality, the control group was the reference and estimates of relative treatment effects below 1 were in favour of the intervention.

Continuous outcomes

None of the studies reported continuous outcomes.

Studies reporting multiple measures of the same outcome

None of the studies reported multiple measures of the same outcome.

Unit of analysis issues

All cRCTs adequately accounted for clustering in their analyses, therefore, further adjustments were not needed. Results from CBAs (Mubiru 2015, White 2018 and Yansaneh 2014) were analysed based on unadjusted counts (see Data extraction and management).

Dealing with missing data

We contacted study investigators and authors in order to verify key study characteristics and obtain outcome data that aligned to our outcome definitions (see Data extraction and management).

The included studies analysed their trial data on an intention-to-treat (ITT) basis, where they attempted to include all participants or clusters randomized to each group in the analyses and analysed data according to initial group allocation irrespective of whether or not participants received, or complied with, the planned intervention. We assumed this may have varied by studies and we used random-effect meta-analyses to account for this.

Assessment of heterogeneity

We first made a qualitative assessment of the extent to which the included studies were similar to each other. This included an assessment of the settings, interventions, participants and outcomes. We also examined the forest plots from the meta-analyses, visually assessing the levels of heterogeneity (in terms of the size or direction of treatment effect and by looking at the overlap between CIs around the treatment effect estimate for each included study). We computed the Q statistic and used the Chi^2 test ($P < 0.10$) to assess the presence or absence of heterogeneity of effects beyond chance alone. When observed intervention effects were more different from each other than one would expect due to chance alone, we assumed that the studies had 'clinical' or statistical heterogeneity or both.

Where we found a sufficient number of studies for a prespecified outcome, we conducted a meta-analysis. We used the I^2 statistic to quantify the level of statistical heterogeneity among the trials in each analysis. If we identified a substantial or considerable heterogeneity (approximately an I^2 statistic value of 50% to 100%), we did not pool estimates, but noted this in the text and explored this heterogeneity through the prespecified subgroup analyses. We interpreted results from meta-analyses with high levels of unexplained heterogeneity with caution.

Assessment of reporting biases

We attempted to be as comprehensive as possible in our search strategy to find and include all relevant studies and to reduce any possible publication bias.

We contacted study authors asking for missing outcome data. Where this was not possible or we received no response or data, and the missing data were thought to introduce serious bias, we explored the impact of including such studies in the overall assessment of results by a sensitivity analysis.

We used funnel plots for visual assessment of whether there was asymmetry signalling the presence of reporting bias, even if not deemed a definitive indicator of such bias. If we found more than 10 studies that reported similar outcomes, we created and examined a funnel plot to explore possible publication biases, interpreting the results with caution (Sterne 2011).

For dichotomous outcomes with intervention effects measured as RRs or odds ratios, we did not consider funnel plot calculations because funnel plots using risk differences are seldom of interest (Egger 1997). We interpreted the results of tests for funnel plot asymmetry in the light of visual inspection of the funnel plot, as the statistical results may not be representative if there are small-study effects.

Data synthesis

We provided a structured synthesis guided by the framework presented in Table 1 and text in the sections Description of the intervention and How the intervention might work. This structured synthesis included a description of the intervention mechanisms summarised across the studies in Table 1 and described narratively in Table 3.

We undertook meta-analyses where this made sense and included forest plots where appropriate (EPOC 2017g). We used random-effects meta-analysis due to evidence of heterogeneity. For dichotomous variables, we used the method proposed by Mantel 1959. For RCTs, we used the generic inverse-variance method. For non-RCTs (CBAs), we also used the generic inverse-variance method. We did not combine results from RCTs and CBAs in meta-

analyses. Where there was evidence on a particular outcome from both RCTs and CBAs, we used the evidence from the RCTs to estimate treatment effect due to lower risk of bias. We carried out all statistical analysis using Review Manager 5 (Review Manager 2014).

Subgroup analysis and investigation of heterogeneity

Our planned subgroup analyses were not possible (except for household wealth and gender for mortality and careseeking to an appropriate provider) due to insufficient data.

Sensitivity analysis

We are aware that overall risk estimates from any meta-analysis can be susceptible to outlying effect sizes, impacting on a change in statistical significance and clinical relevance and even a reversal of effectiveness of an intervention. We defined the following sensitivity analyses a priori to assess the robustness of our findings.

- Restricting analysis to published studies: this was not applicable, since all included studies were published.
- Restricting analysis to studies with a low risk of bias. For the prespecified outcomes in this review, the most important risk of bias domains were: baseline outcomes and characteristics; and completeness of outcome data. This sensitivity analysis was not possible due to only one study meeting the criteria for low risk of bias (Boone 2016). To explore the robustness of our findings according to risk of bias, we stratified analysis by RCTs and non-RCTs.
- Stratifying analysis by the number of illnesses addressed by iCCM (studies of iCCM for two or more illnesses, studies of iCCM for three or more illnesses; studies of iCCM for four or more illnesses): we performed this sensitivity analysis. See additional Table 4.

We performed the following additional sensitivity analyses not prespecified in our protocol (see Differences between protocol and review).

- To explore whether effects on our outcomes differed by illness, we conducted sensitivity analyses that stratified results by illness. See Table 5; Table 6; Table 7; Table 8; Table 9; Table 10; Table 11; Table 12; Table 13; Table 14; Table 15; Table 15; Table 16.

Summary of findings and assessment of the certainty of the evidence

We created four 'Summary of findings' tables. We summarized key findings in Summary of findings 1 and Summary of findings 2 and in additional 'Summary of findings' tables (Table 5; Table 6).

Comparison 1: iCCM versus usual facility services

Summary of findings 1 includes these primary and secondary outcomes.

- Coverage of appropriate treatment from an appropriate provider for 'any iCCM illness.'
- Quality of care as measured by adherence to recommended iCCM practice or guidelines.
- Case load or severity of illness at health facilities.
- Measures of mortality (neonatal, infant and under-five mortality).
- Adverse events.
- Coverage of careseeking to an appropriate provider of treatment services for 'any iCCM illness.'

Table 5 includes the following additional results:

- Coverage of appropriate treatment from:
  - an appropriate provider, with disease-specific results for diarrhoea, malaria, SAM, newborn sepsis and newborn local infection.
  - an iCCM provider for 'any iCCM illness' and disease-specific results for diarrhoea, malaria, SAM, newborn sepsis and newborn local infection.
- Coverage of careseeking to:
  - an appropriate provider of treatment services, with disease-specific results for diarrhoea, suspected pneumonia, malaria, SAM, newborn sepsis, newborn local infection and newborn danger signs.
  - an iCCM provider for 'any iCCM illness' and disease-specific results for diarrhoea, suspected pneumonia, malaria, SAM, newborn sepsis, newborn local infection and newborn danger signs.

Comparison 2: iCCM versus usual facility services plus CCM for malaria

Summary of findings 2 includes these primary and secondary outcomes.

- Coverage of appropriate treatment from an appropriate provider for 'any iCCM illness.'
- Quality of care as measured by adherence to recommended iCCM practice or guidelines.
- Case load or severity of illness at health facilities.
- Measures of mortality (neonatal, infant and under-five mortality).
- Adverse events.
- Coverage of careseeking to an appropriate provider of treatment services for 'any iCCM illness.'

Table 6 presents the following additional results.

- Coverage of appropriate treatment from:
  - an appropriate provider, with disease-specific results for diarrhoea, malaria, SAM, newborn sepsis and newborn local infection.
  - an iCCM provider for 'any iCCM illness' and disease-specific results for diarrhoea, malaria, SAM, newborn sepsis and newborn local infection.
- Coverage of careseeking to
  - an appropriate provider of treatment services, with disease-specific results for diarrhoea, suspected pneumonia, malaria, SAM, newborn sepsis, newborn local infection and newborn danger signs.
  - an iCCM provider for 'any iCCM illness' and disease-specific results for diarrhoea, suspected pneumonia, malaria, SAM, newborn sepsis, newborn local infection and newborn danger signs.

Two review authors (NO and TD) independently assessed the certainty of evidence for the main outcomes using the EPOC GRADE approach (EPOC 2017g). We resolved disagreements on certainty ratings by discussion and consulted a third review author when disagreement persisted. We expressed the results as one of four levels of certainty (high, moderate, low or very low). We justified all decisions to downgrade or upgrade the certainty in the various domains using footnotes and made comments to aid readers' understanding of the review where necessary. We used plain language statements to report the findings in the review (EPOC 2018). We considered whether there was any additional outcome information that could not be incorporated into meta-analyses and noted this in the comments and stated if it supported or contradicted the information from the meta-analyses.

RESULTS

Description of studies

Results of the search

Searches of databases yielded 4763 records to be screened, after duplicates were removed. Of these, we found 4645 irrelevant to the review. We obtained full texts of 118 records. Of these, we excluded 100 records. We reported reasons for excluding studies in the Characteristics of excluded studies table. We classified three records as awaiting classification (Kanté 2019a; Ma 2019a; NCT02151578), and four studies as ongoing (NCT00979797; Rabbani 2014; Taneja 2017; Whidden 2019a). Seven studies, met our inclusion criteria (Figure 1), of which three were cRCTs (Bhandari 2012a; Boone 2016; Kalyango 2012a), and four were CBA studies (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014).

Included studies

The Characteristics of included studies table describes the included studies.

Study design

Three studies were cRCTs (Bhandari 2012a; Boone 2016; Kalyango 2012a). Two of the cRCTs used appropriate methods to take clustering into account when reporting measures of treatment effect, while one presented only descriptive statistics for outcomes with no adjustment for clustering (Kalyango 2012a). Four were CBA studies (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014).

Study populations and settings

Four studies were conducted in Western Africa (Boone 2016; Munos 2016; White 2018; Yansaneh 2014). Two studies were conducted in Eastern Africa (Kalyango 2012a; Mubiru 2015). One study was conducted in Southern Asia (Bhandari 2012a).

Bhandari 2012a included children up to 12 months of age, pregnant women and primary caregivers of children aged 0 to 12 months. No exclusion criteria were reported. The study location was a mixed rural/urban environment served by 18 primary health centres in the district of Faridabad, Haryana, India. There was no information on the distance or travel time of the catchment area of the iCCM provider to the nearest health facility. The baseline neonatal mortality rate was 33 deaths per 1000 in intervention clusters and 32 deaths per 1000 in control clusters; infant mortality was 45 deaths per 1000 in intervention clusters and 44 deaths per 1000 in control clusters. Data were collected from January 2007 to April 2010.

Boone 2016 included children aged 0 to 59 months and primary caregivers of children aged 0 to 59 months. Children were excluded if they were lost to follow-up, died before 1 July 2008, died at an unknown date, had their fifth birthday on or before 1 July 2008 or were born after the final interview. Women were excluded if they died before 1 July 2008 or died at an unknown date. The location of the study was the rural districts of Tombali and Quinara, Guinea-Bissau. There was no information on the distance or travel time of the catchment area of the iCCM provider to the nearest health facility. The baseline under-five mortality rate was 135 deaths per 1000 live births (information disaggregated by intervention clusters and comparison clusters was not provided). Data were collected from July 2008 to March 2011 for mortality outcomes and an endline survey in March 2011 to June 2011 for careseeking outcomes.

Kalyango 2012a included children aged four to 59 months. Information on caregivers was not specified. There were no exclusion criteria reported. The location of the study was the rural Iganga municipality in eastern Uganda. There was no information on the distance or travel time of the catchment area of the iCCM provider to the nearest health facility. The baseline under-five mortality rate in the study area was 128 deaths per 1000 live births (information disaggregated by intervention clusters and comparison clusters was not provided). Data were collected from October 2011 to November 2011.

Mubiru 2015 included children aged zero to 59 months and primary caregivers of children aged zero to 59 months of age. There were no exclusion criteria reported. The location of the study was six rural districts (three intervention districts and 3 comparison districts) in the central region of Uganda. The three intervention districts were divided into eight districts by the government of Uganda after one year of intervention. There was no information on the distance or travel time of the catchment area of the iCCM provider to the nearest health facility. There were no exclusion criteria reported. There was no information on the baseline under-five mortality rate in the study area. Baseline data were collected in October 2010 and endline data were collected in October 2012 (intervention) and February 2013 (comparison, delayed due to the Ebola outbreak).

Munos 2016 included children aged two to 59 months of age and primary caregivers of children aged two to 59 months. There were no exclusion criteria reported. The location of the study was 16 health districts (nine intervention districts and seven comparison districts) in the Nord and Centre-Nord regions of Burkina Faso. There was no information on the distance or travel time of the catchment area of the iCCM provider to the nearest health facility. The baseline under-five mortality rate in the study area was 110 deaths per 1000 live births in the intervention districts and 114 deaths per 1000 live births in the comparison districts. Baseline data were collected in 2010 and 2011 and endline data were collected in 2013 and 2014.

White 2018 included children aged zero to 59 months and primary caregivers of children aged zero to 59 months. There were no exclusion criteria reported. The study location was rural Rivercess County, Liberia. Households targeted by the iCCM intervention were beyond 5 km from the nearest health facility. There was no

information on the baseline under-five mortality rate. Data were collected in 2015 and endline data were collected in 2016.

Yansaneh 2014 included children aged zero to 59 months and primary caregivers of children aged zero to 59 months. There were no exclusion criteria reported. The study location was four rural districts (two intervention and two comparison) in Sierra Leone. There was no information on the baseline under-five mortality rate in the study area. Baseline data were collected in June and July 2010 and endline data were collected in July and August 2012.

Interventions and comparisons

Table 1 summarises the iCCM components and inputs for each study based on EPOC taxonomy (EPOC 2015). Bhandari 2012a included 8/11 inputs, Boone 2016 included 7/11 inputs, Kalyango 2012a included 7/11 inputs, Mubiru 2015 included 7/11 inputs, Munos 2016 included 9/11 inputs, White 2018 included 10/11 inputs and Yansaneh 2014 included 7/11 inputs.

Training and deployment component: all studies reported including an input to recruit, train and retain lay health workers to provide iCCM. All studies reported including an input to implement simplified IMCI-adapted clinical guidelines for iCCM providers. Only three studies reported including training of facility-based providers on iCCM/IMCI/Integrated Management of Neonatal and Childhood Illness (IMNCI) (Bhandari 2012a; Kalyango 2012a; Munos 2016). All studies reported including an input to implement simplified IMCI-adapted clinical guidelines for iCCM providers. Only three studies reported including an input for the payment of iCCM providers such as salary, fees for service or capitation (Bhandari 2012a; Munos 2016; White 2018).

Systems component: six studies reported including an input to improve systems for referral of patients between community and facility level (Boone 2016; Kalyango 2012a; Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014). All studies reported including an input to improve the supply of iCCM drugs and equipment. Only one study reported including an input to improve health information systems and use of information communication technology for iCCM (six studies did not report on this input) (White 2018). Only three studies included an input to improve monitoring, evaluation and research for iCCM (four studies did not report on this input) (Mubiru 2015; White 2018; Yansaneh 2014). All studies included an input to improve managerial supervision of iCCM.

Communication and community mobilisation component: six studies included an input to promote good practices for health and nutrition, and generate demand for use of iCCM providers when children were ill (Bhandari 2012a; Boone 2016; Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014).

Table 3 describes narratively the inputs for each study. The comparison for all outcomes in five studies was usual facility services (Bhandari 2012a; Boone 2016; Mubiru 2015; White 2018; Yansaneh 2014). In two studies, the comparison for all outcomes was usual facility services plus CCM for malaria (Kalyango 2012a Munos 2016). We reported the effects for each outcome separately for the two comparisons in Summary of findings 1 (iCCM versus usual facility services), Summary of findings 2 (iCCM versus usual facility services plus CCM for malaria) and in Results.

Outcomes

Coverage of appropriate treatment from an appropriate provider of treatment services

Any iCCM illness

Three CBA studies (Mubiru 2015; Munos 2016; Yansaneh 2014), and one cRCT (Kalyango 2012a), reported coverage of appropriate treatment from an appropriate provider of treatment services for any iCCM illness.

Diarrhoea

Three CBA studies reported coverage of appropriate treatment by an appropriate provider of treatment services for diarrhoea, separately (Mubiru 2015; Munos 2016; Yansaneh 2014).

Malaria

Three CBA studies reported coverage of appropriate treatment by an appropriate provider of treatment services for malaria (Mubiru 2015; Munos 2016; Yansaneh 2014).

Coverage of appropriate treatment from an iCCM provider of treatment services

Any iCCM illness

One CBA study (Yansaneh 2014), and one cRCT (Kalyango 2012a), reported coverage of appropriate treatment by an iCCM provider for any of the childhood illnesses considered in this review (diarrhoea, malaria, SAM, newborn sepsis or newborn local infection).

Diarrhoea

One CBA reported coverage of appropriate treatment by an iCCM provider for diarrhoea (Yansaneh 2014).

Malaria

One CBA reported coverage of appropriate treatment by an iCCM provider for malaria (Yansaneh 2014).

Neonatal mortality

Two cRCTs reported neonatal mortality (Bhandari 2012a; Boone 2016). Bhandari 2012a/Taneja 2015 reported subgroup results for neonatal mortality by wealth quintile and gender, as well as changes in the equity gradients for these outcomes.

Infant mortality

Two cRCTs reported the effect of iCCM on infant mortality (Bhandari 2012a; Boone 2016). Bhandari 2012a/Taneja 2015 reported subgroup results for postneonatal mortality by wealth quintile and gender, as well as changes in the equity gradients for these outcomes.

Under-five mortality

One cRCT reported under-five mortality (Boone 2016).

Coverage of careseeking to an appropriate provider of treatment services

Any iCCM illness

Three cRCTs (Bhandari 2012a/Mazumder 2014; Boone 2016; Kalyango 2012a), and four CBA studies (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014), reported coverage of careseeking to an appropriate provider of treatment services for any iCCM illness.

Diarrhoea

Two cRCTs (Bhandari 2012a/Mazumder 2014; Boone 2016), and four CBA studies (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014), reported coverage of careseeking to an appropriate provider of treatment services for diarrhoea.

Suspected pneumonia

Two cRCTs (Bhandari 2012a/Mazumder 2014; Boone 2016), and four CBA studies (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014), reported coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia.

Newborn local infection

One cRCT reported coverage of careseeking to an appropriate provider of treatment services for newborn local infection (Bhandari 2012a/Mazumder 2014).

Newborn danger signs

One cRCT reported coverage of careseeking to an appropriate provider for newborn danger signs (Bhandari 2012a/Mazumder 2014).

Coverage of careseeking to an iCCM provider

Any iCCM illness

Two CBA studies (White 2018; Yansaneh 2014), and one cRCT (Kalyango 2012a), reported coverage of careseeking to an iCCM provider for any iCCM illness.

Diarrhoea

Two CBA studies (White 2018; Yansaneh 2014), and one cRCT (Kalyango 2012a), reported the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea.

Fever

Two CBA studies (White 2018; Yansaneh 2014), and one cRCT (Kalyango 2012a), reported the effect of iCCM on coverage of careseeking to an iCCM provider for fever.

Suspected pneumonia

Two CBA studies (White 2018; Yansaneh 2014), and one cRCT (Kalyango 2012a), reported the effect of iCCM on coverage of careseeking to an iCCM provider for suspected pneumonia

None of the included studies reported:

- coverage of appropriate treatment from an appropriate provider of treatment services for SAM, newborn sepsis or newborn local infection;
- coverage of appropriate treatment from an iCCM provider of treatment services for SAM, newborn sepsis or newborn local infection;
- quality of care;
- case load or severity of illness at health facilities;
- adverse events;
- coverage of careseeking to an iCCM provider for SAM, newborn sepsis, newborn local infection, or newborn danger signs.

Funding

Bhandari 2012a: WHO Geneva through a grant from United States Agency for International Development (USAID); UNICEF, New Delhi; and the GLOBVAC Program of the Research Council of Norway through grant No. 183722. The authors reported that WHO and UNICEF staff contributed importantly to the planning, analysis and reporting of the study but the funding bodies had no influence on how the data were collected, analysed or presented.

Boone 2016: Effective Intervention, a charity registered in the UK. The authors reported that the funder was on the trial steering committee but was not shown interim unmasked analysis; after the final analysis, the funder took part in interpretation of the data and writing of the report.

Kalyango 2012a: Swedish Institute for Development Agency (SIDA) and UNICEF/United Nations Development Programme (UNDP)/World Bank/WHO Special Program for Research and Training in Tropical Diseases.

Mubiru 2015: Department of Foreign Affairs Trade and Development, Canada through a grant administered by UNICEF.

Munos 2016: Bill and Melinda Gates Foundation through a grant administered by WHO.

White 2018: Direct Relief and the UBS Optimus Foundation.

Yansaneh 2014: Department of Foreign Affairs Trade and Development, Canada through a grant administered by UNICEF.

Excluded studies

We excluded 100 records. The Characteristics of excluded studies table provides details on the reasons for exclusion of each study.

- We excluded 30 studies for having the wrong intervention.
- We excluded 22 studies for having the wrong study design.
- We excluded 11 studies for having the wrong comparator.
- We excluded one for having wrong outcome.
- We excluded 36 for being duplicates.

Risk of bias in included studies

Figure 2 and Figure 3 summarise risk of bias. The Characteristics of included studies table provides details of risk of bias and methods used in each study.

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

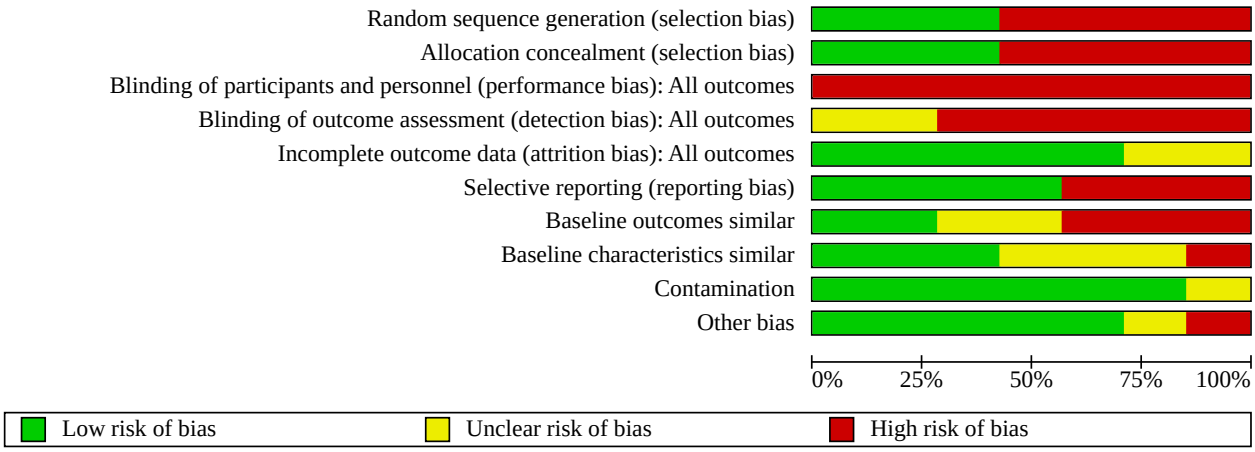
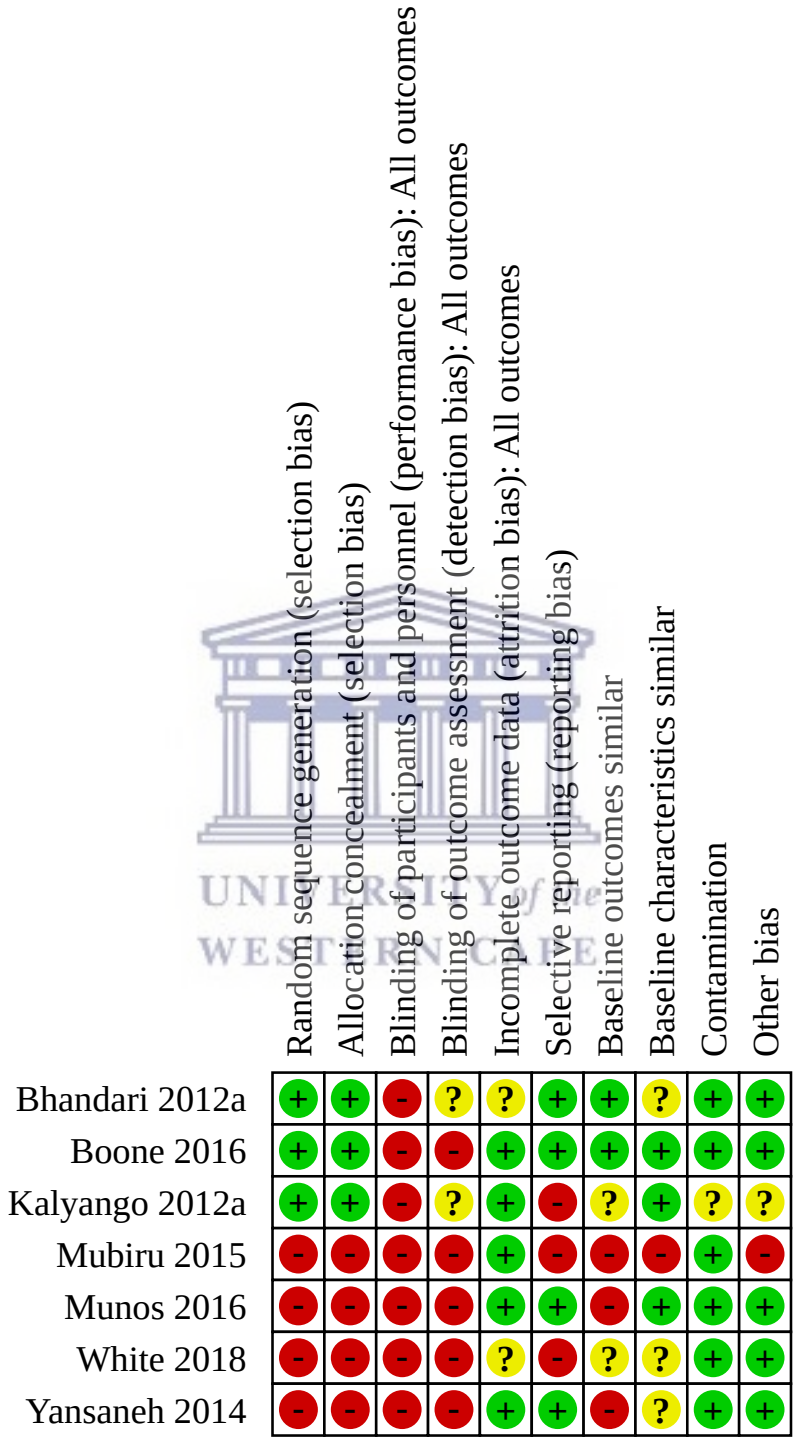


Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.



Allocation

We considered three cRCTs at low risk of bias (Bhandari 2012a; Boone 2016; Kalyango 2012a) and four CBA studies at high risk of bias (Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014) for allocation (selection bias) based on random sequence generation and allocation concealment.

Blinding

We considered all studies at high risk of bias for blinding of participants and personnel (performance bias) and five studies (one cRCT: Boone 2016; four CBA studies: Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014) at high risk of bias for blinding of outcome assessment (detection bias). We considered two cRCTs at unclear for blinding of outcome assessment (detection bias) (Bhandari 2012a; Kalyango 2012a).

Incomplete outcome data

We considered five studies at low risk for incomplete outcome data (attrition bias) (two cRCTs: Boone 2016; Kalyango 2012a; and three CBA studies: Mubiru 2015; Munos 2016; Yansaneh 2014). We considered two studies at unclear risk for incomplete outcome data (attrition bias) (one cRCT: Bhandari 2012a; and one CBA study: White 2018).

Selective reporting

We considered four studies at low risk for selective reporting (reporting bias) (two cRCTs: Bhandari 2012a; Boone 2016; and two CBA studies: Munos 2016, Yansaneh 2014). We considered three studies at high risk for selective reporting (reporting bias) (one cRCT: Kalyango 2012a; and two CBA studies: Mubiru 2015 and White 2018).

Other potential sources of bias

We considered two cRCTs at low risk of bias for baseline outcomes being similar (Bhandari 2012a; Boone 2016). We considered two studies at unclear risk for baseline outcomes being similar (one cRCT: Kalyango 2012a; and one CBA study: White 2018). We considered three CBA studies at high risk for baseline outcomes being similar (Mubiru 2015; Munos 2016; Yansaneh 2014).

We considered three studies at low risk of bias for baseline characteristics being similar (two cRCTs: Boone 2016; Kalyango 2012a; and one CBA study: Munos 2016). We considered three studies at unclear risk for baseline characteristics being similar (one cRCT: Bhandari 2012a; and two CBA studies: White 2018; Yansaneh 2014). One CBA study was at high risk for baseline characteristics being similar (Mubiru 2015).

We considered six studies at low risk of bias for contamination (two cRCTs: Bhandari 2012a; Boone 2016; and four CBA studies: Mubiru 2015; Munos 2016; White 2018; Yansaneh 2014). We considered one cRCT at unclear for risk of bias for contamination (Kalyango 2012a).

We considered five studies at low risk of other sources of bias (two cRCTs: Bhandari 2012a; Boone 2016; and three CBA studies: Munos 2016; White 2018; Yansaneh 2014). We considered one cRCT at unclear risk (Kalyango 2012a) and one CBA study high risk (Mubiru 2015) for other sources of bias.

Effects of interventions

See: **Summary of findings 1** Summary of findings: integrated community case management versus usual facility services; **Summary of findings 2** Summary of findings: integrated community case management versus usual facility services plus CCM for malaria

See Summary of findings 1 for the effects of iCCM compared to usual facility services. See Summary of findings 2 for the effects of iCCM compared to usual facility services plus CCM for malaria.

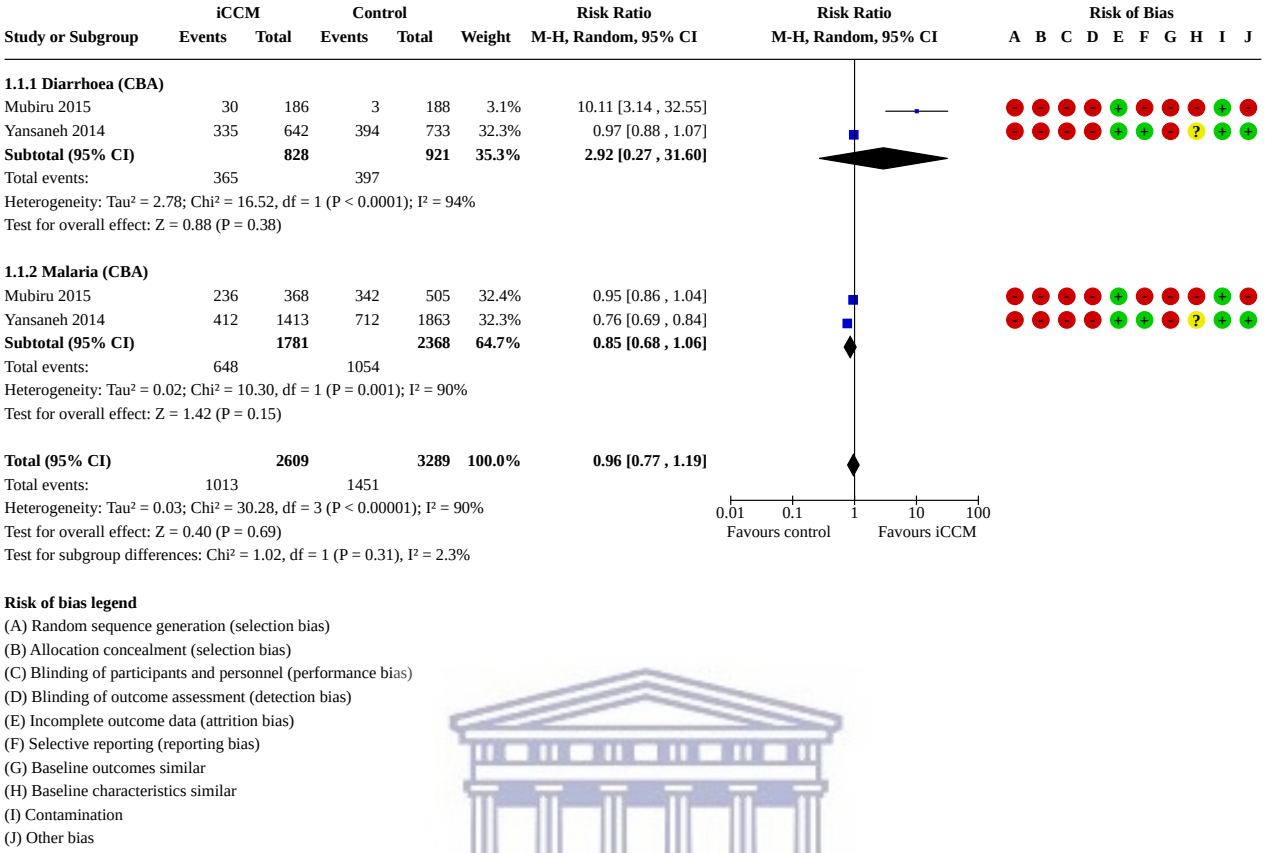
Comparison 1: iCCM versus usual facility services

Coverage of appropriate treatment from an appropriate provider

For any iCCM illness

Two CBA studies reported results for diarrhoea and malaria, totalling four results for this outcome for 'any iCCM illness') (Mubiru 2015; Yansaneh 2014). Effects were mixed (with very large effects for certain illnesses in some CBA studies and modest/no effects in others) and CIs included important effects and no effect. We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness (ORS and zinc for diarrhoea and ACTs for malaria) compared to usual facility services (RR 0.96, 95% CI 0.77 to 1.19; 2 CBA studies, 5898 children; very low-certainty of evidence; Summary of findings 1; Analysis 1.1; Figure 4; Table 5; Table 7). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome. We provided analyses by disease below.

Figure 4. Forest plot of comparison: 1 iCCM versus usual facility services, outcome: 1.1 Comparison 1 iCCM versus usual facility services: coverage of appropriate treatment by an appropriate provider (controlled before-after (CBA)).



For diarrhoea

Two CBA studies reported the effect of iCCM on coverage of appropriate treatment from an appropriate provider for diarrhoea compared to usual facility services (Mubiru 2015; Yansaneh 2014). Effects were mixed (large effect to no effect). We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for diarrhoea (ORS and zinc) (RR 2.92, 95% CI 0.27 to 31.60; 2 CBA studies, 1749 children; very low-certainty evidence; Analysis 1.1; Figure 4; Table 5; Table 7).

Both CBA studies diagnosed diarrhoea symptomatically and treated it with ORS and zinc. Coverage of appropriate treatment from an appropriate provider for diarrhoea was measured as the receipt of both ORS and zinc. We recalculated unadjusted results for Mubiru 2015 and Yansaneh 2014 (see Data extraction and management). Our recalculated effects for Mubiru 2015, based on the unadjusted published numerators and denominators, indicated a large effect (RR 10.11, 95% CI 3.14 to 32.55) of iCCM on this outcome. Our recalculated results for Yansaneh 2014, based on unpublished, unadjusted numerators and denominators that were reviewed and approved by Yansaneh, indicated no effect of iCCM on this outcome (RR 0.97, 95% CI 0.88 to 1.07). The reasons for the modest negative effect (or null effect, considering the 95% CIs) of iCCM on this outcome in Yansaneh 2014 are unclear but the authors indicated that the effect may have been dampened by interventions that targeted both intervention and control districts during the study period, including the national Free Health Care Initiative (FHCI), and suboptimal deployment and targeting of iCCM providers (community health volunteers (CHVs)) in the intervention district.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For malaria

Two CBA studies reported the effect of iCCM on coverage of appropriate treatment from an appropriate provider for malaria (Mubiru 2015; Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for malaria (ACTs) (RR 0.85, 95% CI 0.68 to 1.06; 2 CBA studies; 4149 children; very low-certainty evidence; Analysis 1.1; Figure 4; Table 5; Table 7).

In Mubiru 2015, iCCM providers diagnosed malaria with an RDT and treated with ACT, whereas in Yansaneh 2014, iCCM providers diagnosed malaria symptomatically (i.e. RDTs were not used) and treated with ACT. This may have inflated the effect of iCCM on coverage of appropriate treatment from an appropriate provider for malaria in Yansaneh 2014. We recalculated unadjusted results for Mubiru 2015 and Yansaneh 2014 (see Data extraction and management). Our recalculated effects for Mubiru 2015, based on the unadjusted published numerators and denominators,

indicated a very modest negative effect (RR 0.95, 95% CI 0.86 to 1.04), with CIs that included no effect. Our recalculated results for Yansaneh 2014, based on unpublished, unadjusted numerators and denominators that were reviewed and approved by Yansaneh, indicated a moderate negative effect (RR 0.76, 95% CI 0.69 to 0.84). The reasons for the moderate negative effect for this outcome in Yansaneh 2014 are unclear but the authors indicated that the effect may have been dampened by a national stockouts ACTs – but this would require the national stockout of ACTs to have disproportionately impacted intervention districts compared to comparison districts – and interventions that targeted both intervention and control districts during the study period, including the national FHCI, as well as suboptimal deployment and targeting of iCCM providers (CHVs) in the intervention districts. We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for SAM compared to usual facility services.

For newborn sepsis

No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for newborn sepsis compared to usual facility services.

For newborn local infection

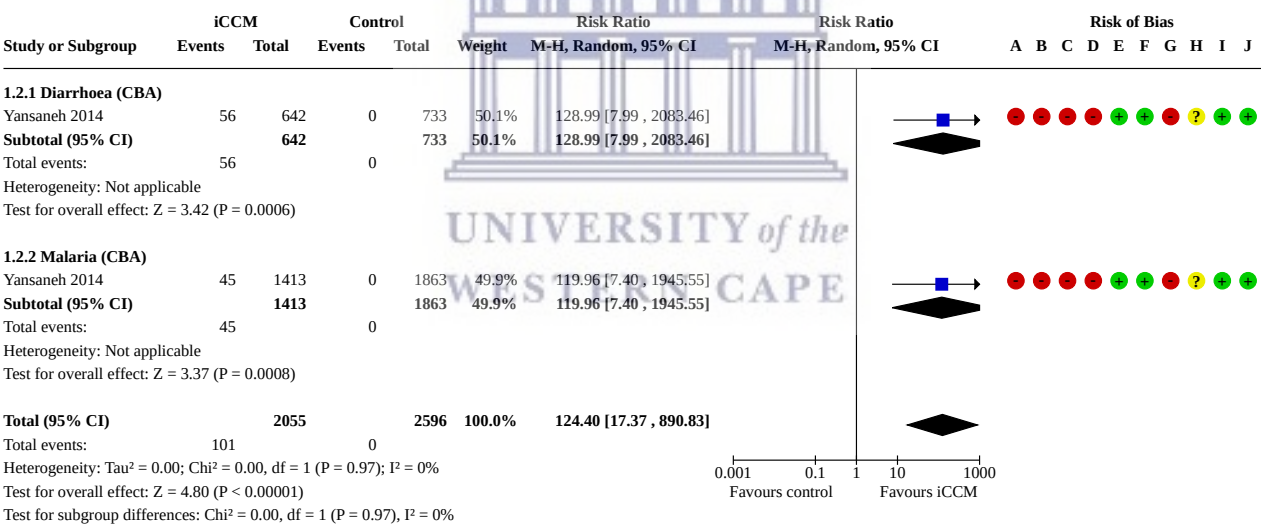
No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for newborn local infection compared to usual facility services.

Coverage of appropriate treatment from an iCCM provider

For any iCCM illness

One CBA study reported the effect of iCCM on coverage of appropriate treatment from an iCCM provider for any iCCM illness (Yansaneh 2014). The CBA reported results for diarrhoea and malaria, totalling two results for 'any illness.' We are uncertain of the effect of iCCM on coverage of appropriate treatment from an iCCM provider for any iCCM illness compared to usual facility services (1 CBA study, 4651 children; very low-certainty evidence (downgraded for serious risk of bias due to the study being a CBA, and one level for indirectness and serious imprecision); Analysis 1.2; Figure 5; Table 5; Table 8). We provided an analysis by disease below. The results from this CBA for 'any illness' and for the specific diseases below should be considered in light of the cRCT in Uganda, which indicated coverage of appropriate treatment from an iCCM provider for any iCCM illness was 40% higher with iCCM (malaria and pneumonia) compared to usual facility services plus CCM for malaria (see results for Comparison 2 below) (Kalyango 2012a).

Figure 5. Forest plot of comparison: 1 iCCM versus usual care, outcome: 1.4 Comparison 1 iCCM versus usual care: coverage of appropriate treatment by an iCCM provider (controlled before-after (CBA)).



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

For diarrhoea

One CBA study reported the effect of iCCM on coverage of appropriate treatment from an iCCM provider for diarrhoea (Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of appropriate treatment from an iCCM provider for diarrhoea (ORS and zinc) compared to usual facility services (1 CBA study, 1375 children; very low-certainty evidence (downgraded for serious risk of bias due to the study being a CBA, and one level for indirectness and serious imprecision); Analysis 1.2; Figure 5; Table 5; Table 8). However, in absolute terms, coverage in the intervention group was less than 10% and may have been attenuated by the small effect of iCCM on careseeking for diarrhoea compared to usual facility services (reported below).

For malaria

One CBA study reported the effect of iCCM on coverage of appropriate treatment from an iCCM provider for malaria (Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of appropriate treatment from an iCCM provider for malaria (ACTs) compared to usual facility services (1 CBA study, 3276 children; very low-certainty evidence (downgraded for serious risk of bias due to the study being a CBA, and one level for indirectness and serious imprecision); Analysis 1.2; Figure 5; Table 5; Table 8). However, in absolute terms, coverage in the intervention group was still less than 10%. Given the important effect of iCCM on careseeking for fever (reported below), it is likely that stockouts among iCCM providers – as reported in by the authors in Yansaneh 2014 – attenuated the effect of iCCM on appropriate treatment from an iCCM provider for malaria compared to usual facility services.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of appropriate treatment from an iCCM provider for SAM compared to usual facility services.

For newborn sepsis

No studies reported effects of iCCM on coverage of appropriate treatment from an iCCM provider for newborn sepsis compared to usual facility services.

For newborn local infection

No studies reported effects of iCCM on coverage of appropriate treatment from an iCCM provider for newborn local infection compared to usual facility services.

Quality of care

No studies reported effects of iCCM on quality of care compared to usual facility services.

Case load or severity of illness at health facilities

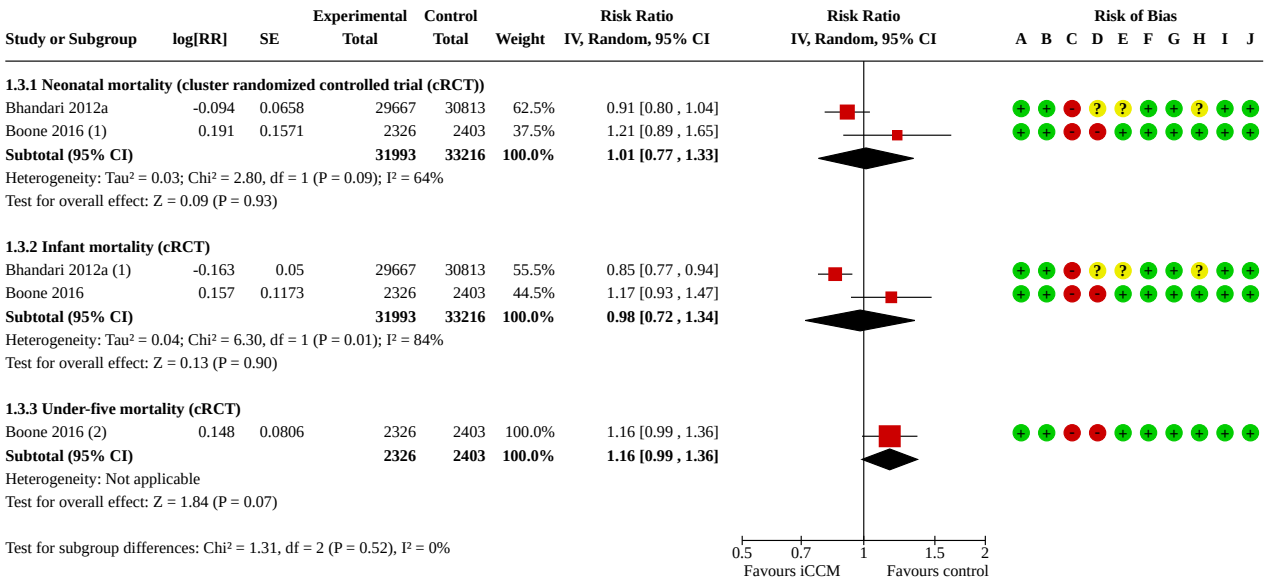
No studies reported effects of iCCM on case load or severity of illness at health facilities compared to usual facility services.

Measures of mortality

Neonatal mortality

Two cRCTs reported effects of iCCM on neonatal mortality (Bhandari 2012a; Boone 2016). These studies suggest that iCCM may have little or no effect on neonatal mortality compared to usual facility services (HR 1.01, 95% CI 0.77 to 1.33; 2 trials, 65,209 children; low-certainty evidence (downgraded due to indirectness and serious imprecision); Boone 2016; Summary of findings 1; Analysis 1.3; Figure 6; Table 5; Table 9). Appendix 2 provides further details regarding heterogeneity and information pertinent to the interpretation of the estimated effect on neonatal mortality.

Figure 6.



A subgroup analysis in Bhandari 2012a found that neonatal mortality may be 20% lower in the intervention subgroup that delivered at-home compared to usual facility services (cluster-adjusted HR 0.80, 95% CI 0.68 to 0.93), but may be 6% higher in the intervention subgroup that delivered at a health facility compared to usual facility services (cluster-adjusted HR 1.06, 95% CI 0.91 to 1.23) with CIs that included no effect for the latter.

Bhandari 2012a (linked paper Taneja 2015) reported no effect of iCCM on inequity in neonatal mortality by wealth quintile compared to usual facility services (difference in equity gradient 0.5, 95% CI –2.0 to 2.9) and no effect on inequity in neonatal mortality by gender compared to usual facility services (difference in equity gradient –0.1, 95% CI –8.7 to 8.4; Table 10).

Infant mortality

Two cRCTs reported effects of iCCM on infant mortality (Bhandari 2012a; Boone 2016). Due to inconsistent effects (large effect in favour of the intervention to no effect), indirectness and serious imprecision, we concluded that we are uncertain of the effect of iCCM on infant mortality compared to usual facility services (HR 0.98, 95% CI 0.72 to 1.34; 2 trials, 60,480 children; very low-certainty evidence (downgraded due to inconsistency, indirectness and serious imprecision); Summary of findings 1; Analysis 1.3; Figure 6; Table 5; Table 9). Appendix 2 provides further details regarding heterogeneity and information pertinent to the interpretation of the estimated effect on infant mortality.

The subgroup effect noted above in Bhandari 2012a for neonatal mortality persisted for infant mortality (lower infant mortality among home deliveries, cluster-adjusted HR 0.77, 95% CI 0.69 to 0.87; lower infant mortality to no effect for facility-based deliveries, cluster-adjusted HR 0.98, 95% CI 0.87 to 1.10) (Bhandari 2012a).

Bhandari 2012a (linked paper Taneja 2015) reported an important effect of iCCM on inequity in infant mortality by wealth quintile compared to usual facility services, favouring the very poor (difference in equity gradient 2.2, 95% CI 0 to 4.4), but no effect on inequity in infant mortality by gender compared to usual facility services (difference in equity gradient 1.7, 95% CI –3.2 to 6.6; Table 10).

Under-five mortality

One cRCT reported under-five mortality (Boone 2016). Due to indirectness and serious imprecision of the estimated effect, we concluded that we are uncertain of the effect of iCCM on under-five mortality compared to usual facility services (HR 1.16, 95% CI 0.99 to 1.36; 1 trial, 4729 children; very low-certainty evidence (downgraded for indirectness, and serious imprecision); Summary of findings 1; Analysis 1.3; Figure 6; Table 5; Table 9). Appendix

2 provides further information pertinent to the interpretation of the estimated effect on under-five mortality.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

Adverse events

No studies reported effects of iCCM on adverse events.

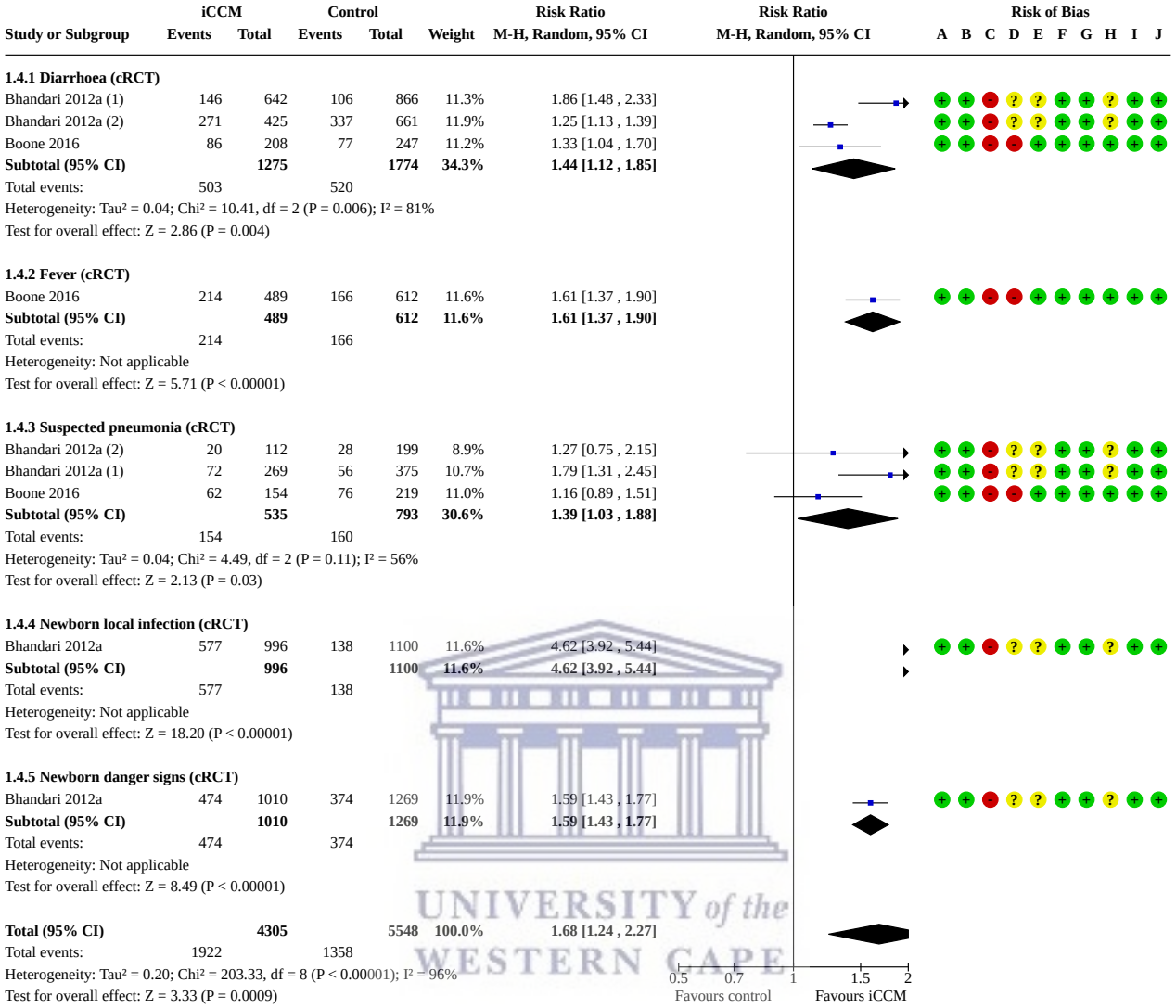
Coverage of careseeking to an appropriate provider

For any iCCM illness

Two cRCTs (Boone 2016; Bhandari 2012a/Mazumder 2014), and three CBA studies (Mubiru 2015; White 2018; Yansaneh 2014), assessed coverage of careseeking to an appropriate provider of treatment services for any iCCM illness, compared to usual facility services. Following our protocol, we reported the estimate of effect based on the cRCTs, due to lower risk of bias.

iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness by 68% compared to usual facility services (RR 1.68, 95% CI 1.24 to 2.27; 2 trials, 9853 children; moderate-certainty evidence; based on the total across subgroups; Summary of findings 1; Analysis 1.4; Figure 7; Table 11). The effects across the cRCTs were consistent, with moderate to important effects in favour of the intervention, depending on disease (Table 11). The effect for this outcome is consistent with the effect (in favour of the intervention) of iCCM on careseeking to an iCCM provider (Analysis 1.6, described below). The effects of the three CBA studies (RR 1.29, 95% CI 1.08 to 1.53, see the total across subgroups) is consistent with that from the cRCTs, and indicates coverage of careseeking to an appropriate provider of treatment services for any illness may be 29% higher with iCCM compared to usual facility services. The effects across studies ranged from no effect to an effect of 259% in favour of the intervention, depending on disease (Analysis 1.5; Figure 8; Table 11).

Figure 7. Forest plot of comparison: 1 iCCM versus usual care, outcome: 1.6 Comparison 1 iCCM versus usual care: coverage of careseeking to an appropriate provider of treatment services (cluster randomized controlled trial (cRCT)).



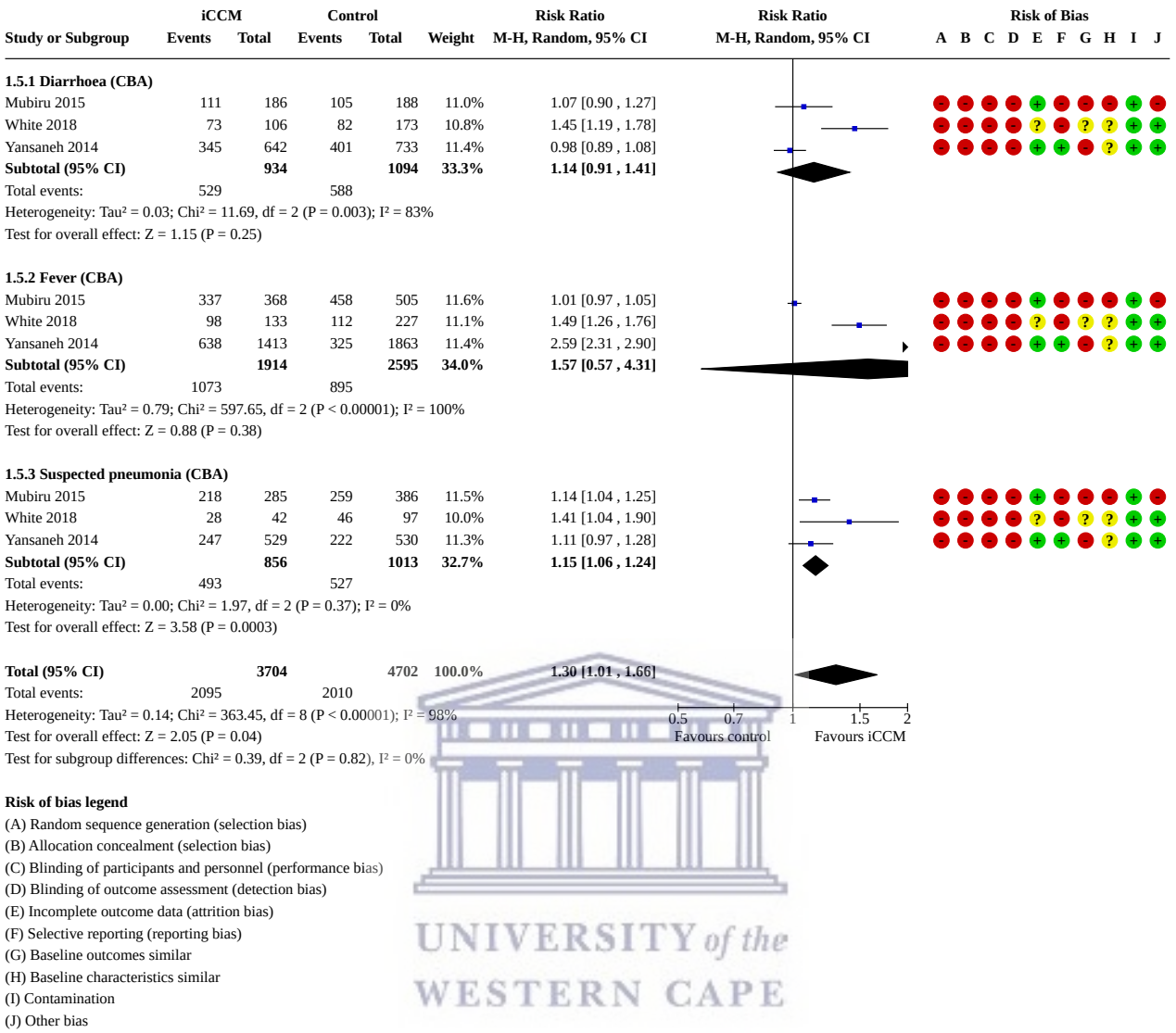
Footnotes

(1) Among children 6 months of age
(2) Among children 12 months of age

Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

Figure 8. Forest plot of comparison: 1 iCCM versus usual care, outcome: 1.7 Comparison 1 iCCM versus usual care: coverage of careseeking to an appropriate provider of treatment services (controlled before-after (CBA)).



Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome (see below for equity effects on careseeking to an appropriate provider of treatment services for newborn danger signs).

For diarrhoea

For coverage of careseeking to an appropriate provider of treatment services for diarrhoea compared to usual facility services, we found two cRCTs (Boone 2016; Bhandari 2012a/ Mazumder 2014) and three CBA studies (Mubiru 2015; White 2018; Yansaneh 2014). Data from the cRCTs suggested that iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for diarrhoea by 44%, compared to usual facility services (RR 1.44, 95% CI 1.12 to 1.85; 2 trials, 3049 children; moderate-certainty evidence; Analysis 1.4; Figure 7; Table 5; Table 11). The effects across cRCTs were generally consistent, ranging from an effect of 25% to 86% in favour of the intervention (Table 11).

Findings from the three CBA studies (RR 1.14, 95% CI 0.91 to 1.41) are consistent with the effect (in favour of the intervention) from the cRCTs (Analysis 1.5; Figure 8; Table 11). We recalculated unadjusted results for Mubiru 2015, White 2018, and Yansaneh 2014 (see Data extraction and management). Mubiru 2015 did not explain the marginal effect on careseeking to an appropriate provider of treatment services for diarrhoea but noted that other studies had reported low coverage of careseeking to an appropriate provider for diarrhoea. The recalculated effect from Yansaneh 2014 indicated no effect. The reasons for no effect in Yansaneh 2014 are unclear but the authors indicated that the impact may been dampened by interventions that targeted both intervention and control districts during the study period, including the national FHCI and suboptimal deployment and targeting of iCCM providers (CHVs) in the intervention district.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For fever

For coverage of careseeking to an appropriate provider of treatment services for fever compared to usual facility services, we fund one cRCT (Boone 2016) and three CBA studies (Mubiru 2015; White 2018; Yansaneh 2014). Data from the cRCT indicated iCCM may improve coverage of careseeking to an appropriate provider of treatment services for fever by 61% compared to usual health services (RR 1.61, 95% CI 1.37 to 1.90; 1 trial, 1101 children; low-certainty evidence; Analysis 1.4; Figure 7; Table 5; Table 11).

The effect assessed in the four CBA studies (RR 1.57, 95% CI 0.57 to 4.31) was consistent with the effect from the cRCT (in favour of the intervention) but the CIs included no effect (Analysis 1.4; Figure 7; Table 5; Table 11). We recalculated unadjusted results for Mubiru 2015, White 2018, and Yansaneh 2014 (see Data extraction and management). The CIs for the recalculated effect for Mubiru 2015 included no effect. The effect for White 2018 was 49% and the recalculated effect for Yansaneh 2014 was 258%, in favour of the intervention. In Mubiru 2015, iCCM providers diagnosed malaria with an RDT and treated confirmed malaria cases with ACTs. In White 2018 and Yansaneh 2014, iCCM providers diagnosed malaria symptomatically (i.e. RDTs were not used) and treated suspected cases based on symptoms with ACTs. This may have inflated the effects of iCCM on this outcome in Yansaneh 2014 and White 2018.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For suspected pneumonia

For coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia compared to usual facility services, we found two cRCTs (Boone 2016; Bhandari 2012a/Mazumder 2014) and three CBA studies (Mubiru 2015; White 2018; Yansaneh 2014). Following our protocol, we reported the estimate of effect based on the cRCT due to lower risk of bias. iCCM probably improves coverage of careseeking to an appropriate provider for suspected pneumonia by 39% compared to usual facility services (RR 1.39, 95% CI 1.03 to 1.88; 2 trials, 1328 children; moderate-certainty of evidence; Analysis 1.4; Figure 7; Table 5; Table 11). The effects across the two studies were consistent and in favour of the intervention (Table 11).

The effect assessed in the four CBA studies (RR 1.13, 95% CI 1.06 to 1.20) was consistent with the effect based on the cRCTs (in favour of the intervention) (Analysis 1.4; Figure 7; Table 5; Table 11). We recalculated unadjusted results for Mubiru 2015, White 2018, and Yansaneh 2014 (see Data extraction and management). The recalculated effect for Mubiru 2015 was 15% in favour of the intervention. The effect for White 2018 was 40% in favour of the intervention. The CIs for the recalculated effect for Yansaneh 2014 included no effect and the reasons for this were unclear. The authors indicated that the effect may have been dampened by interventions that targeted both intervention and control districts during the study period, including the national FHCI and suboptimal deployment and targeting of iCCM providers (CHVs) in the intervention district.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of careseeking to an appropriate provider of treatment services for SAM compared to usual facility services.

For newborn sepsis

No studies reported effects of iCCM on coverage of careseeking to an appropriate provider of treatment services for newborn sepsis compared to usual facility services.

For newborn local infection

For coverage of careseeking to an appropriate provider of treatment services for newborn local infection, we found one cRCT (Bhandari 2012a/Mazumder 2014). iCCM may improve coverage of careseeking to an appropriate provider of treatment services for newborn local infection by 462% compared to usual facility services (RR 4.62, 95% CI 3.92 to 5.45; 1 trial, 2906 children; low-certainty evidence; Analysis 1.4; Figure 7; Table 5; Table 11). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For newborn danger signs

For coverage of careseeking to an appropriate provider of treatment services for newborn danger signs, we found one cRCT (Bhandari 2012a/Mazumder 2014). iCCM may improve coverage of careseeking to an appropriate provider of treatment services for newborn danger signs by 59% compared to usual facility services (RR 1.59, 95% CI 1.43 to 1.77; 1 trial, 2279 children; low-certainty evidence; Analysis 1.4; Figure 7; Table 5; Table 11).

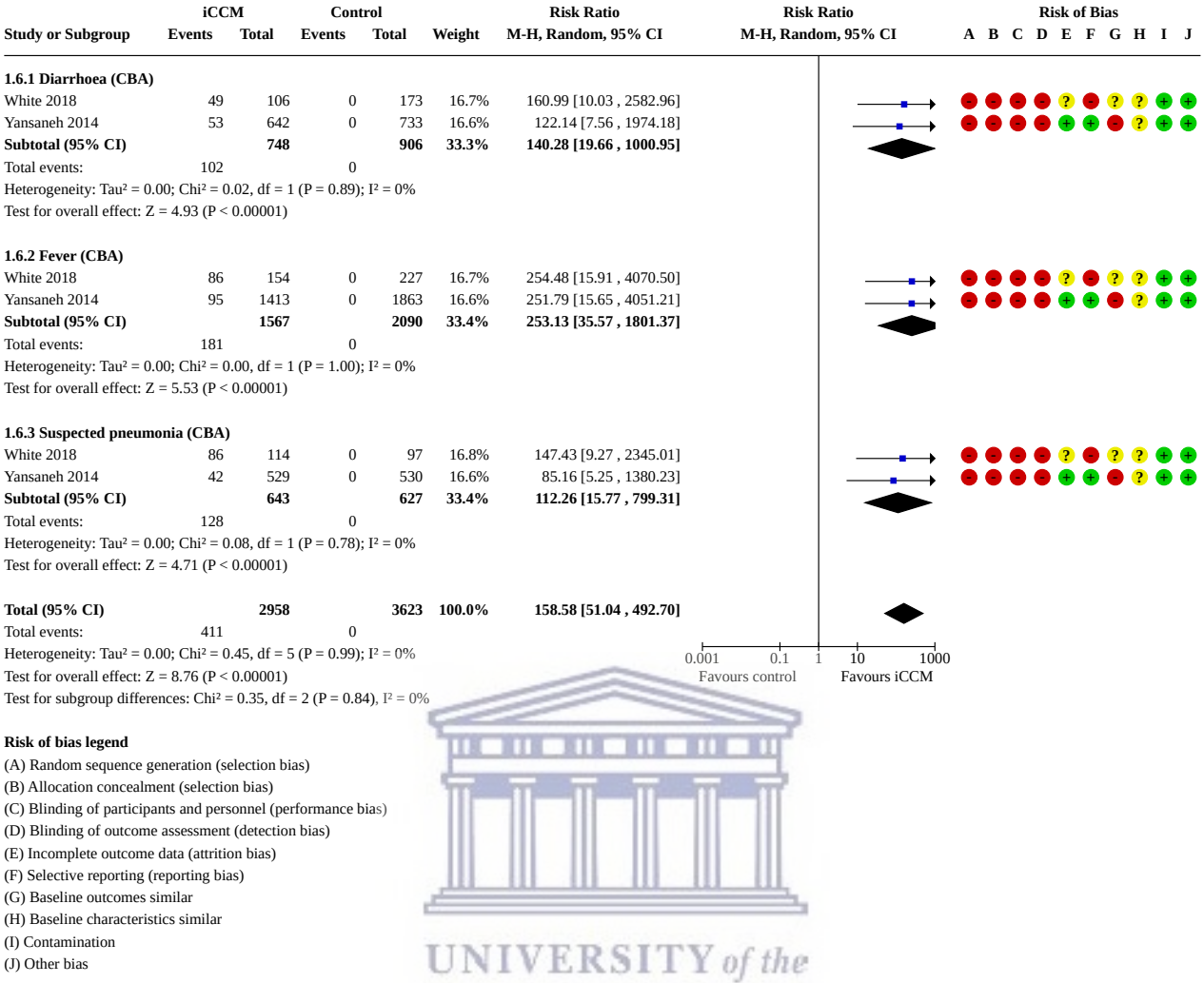
Bhandari 2012a (linked paper Taneja 2015) reported no effect of iCCM on inequity in coverage of careseeking to an appropriate provider of treatment services for newborn danger signs by wealth quintile (difference in equity gradient 0.6, 95% CI −1.6 to 2.8). However, the study reported an important effect on inequity in coverage of careseeking to an appropriate provider of treatment services for newborn danger signs by gender, favouring girls (difference in equity gradient −9.3, 95% CI −18.2 to −0.4; Table 12).

Coverage of careseeking to an iCCM provider

For any iCCM illness

Two CBA studies reported the effect of iCCM on coverage of careseeking to an iCCM provider for any iCCM illness compared to usual facility services (White 2018; Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for any iCCM illness compared to usual facility services (2 CBA studies, 6581 children; very low-certainty evidence; based on the total across subgroups (downgraded for serious risk of bias due to the studies being CBAs, and one level for serious imprecision); Analysis 1.6; Figure 9; Table 5; Table 13). We recalculated unadjusted results for White 2018 and Yansaneh 2014 (see Data extraction and management).

Figure 9. Forest plot of comparison: 1 iCCM versus usual facility services, outcome: 1.6 Comparison 1 iCCM vs usual facility services: coverage of careseeking to an iCCM provider (controlled before-after (CBA)).



For diarrhoea

Two CBA studies reported the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea compared to usual facility services (White 2018; Yansaneh 2014). No cRCTs reported this outcome for this comparison. Due to risk of bias and serious imprecision, we are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea compared to usual facility services (2 CBA studies, 1654 children; very low-certainty evidence (downgraded for serious risk of bias due to the studies being CBAs, and one level for serious imprecision); Analysis 1.6; Figure 9; Table 5; Table 13). We recalculated unadjusted results for White 2018 and Yansaneh 2014 (see Data extraction and management).

For fever

Two CBA studies reported the effect of iCCM on coverage careseeking to an iCCM provider for fever compared to usual facility services (White 2018; Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for fever compared to usual facility services (2 CBA studies, 3657 children; very low-certainty evidence (downgraded for serious risk of bias due to the studies being CBAs, and one level for serious imprecision); Analysis 1.6; Figure 9; Table 5; Table 13). We recalculated unadjusted results for White 2018 and Yansaneh 2014 (see Data extraction and management).

For suspected pneumonia

Two CBA studies reported the effect of iCCM on coverage careseeking to an iCCM provider for suspected pneumonia compared to usual facility services (White 2018; Yansaneh 2014). We are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for suspected pneumonia compared to usual facility services (2 CBA studies, 1270 children; very low-certainty evidence (downgraded for serious risk of bias due to the studies being CBAs, and one level for serious imprecision); Analysis 1.6; Figure 9; Table 5; Table 13). We recalculated unadjusted results for White 2018 and Yansaneh 2014 (see Data extraction and management).

For severe acute malnutrition

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for SAM compared to usual facility services.

For newborn sepsis

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn sepsis compared to usual facility services.

For newborn local infection

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn local infection compared to usual facility services.

For newborn danger signs

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn danger signs compared to usual facility services.

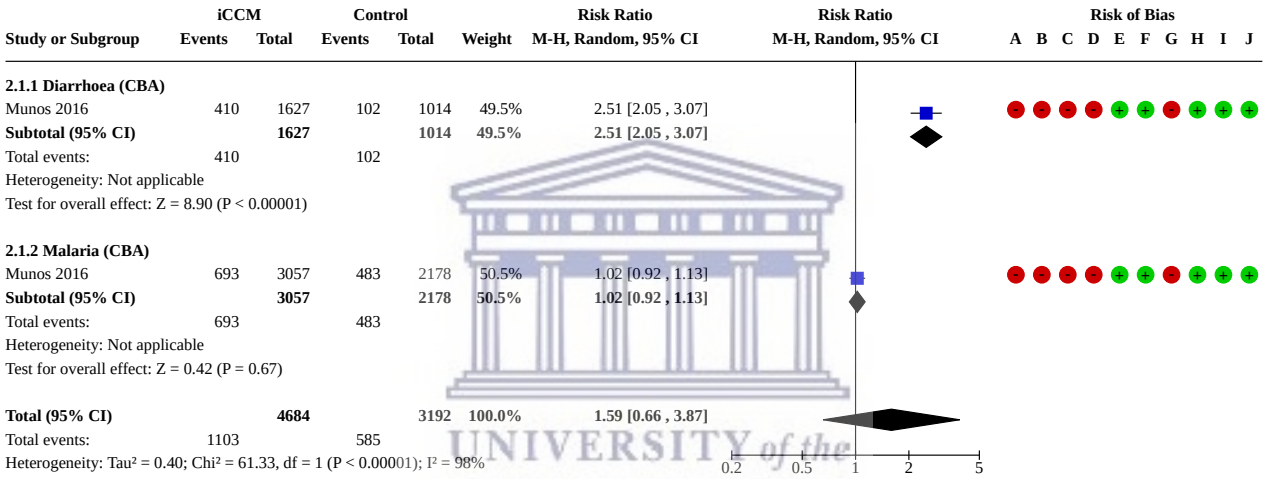
Comparison 2: iCCM versus usual facility services plus CCM for malaria

Coverage of appropriate treatment from an appropriate provider

For any iCCM illness

For the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness compared to usual facility services plus CCM for malaria, one CBA study reported results for diarrhoea and malaria, totalling two results for the outcome 'any illness' (see disease-specific results below) (Munos 2016). We are uncertain of the effect of iCCM on coverage of appropriate treatment by an appropriate provider for any iCCM illness (ORS and zinc for diarrhoea and ACTs for malaria) compared to usual facility services plus CCM for malaria (1 CBA study, 7876 children; very low-certainty of evidence). We reported results from the study in Summary of findings 2; Analysis 2.1; Figure 10; and Table 14.

Figure 10. Forest plot of comparison: 2 iCCM versus usual facility services plus CCM for malaria, outcome: 2.1 Comparison 2 iCCM versus usual facility services plus CCM for malaria: coverage of appropriate treatment by an appropriate provider (controlled before-after (CBA)).



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For diarrhoea

For coverage of appropriate treatment from an appropriate provider for diarrhoea compared to usual facility services plus CCM for malaria, we found one CBA study (Munos 2016). We are uncertain of the effect of iCCM on coverage of appropriate treatment by an appropriate provider for diarrhoea (ORS and zinc) compared to usual facility services plus CCM for malaria (1 CBA study, 2641 children; very low-certainty evidence). We reported results in Table 6; Analysis 2.1; Figure 10; and Table 14.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For malaria

For coverage of appropriate treatment from an appropriate provider for malaria compared to usual facility services plus CCM for malaria, we found one CBA study (Munos 2016). We were uncertain of the effect of iCCM on coverage of appropriate treatment by an appropriate provider for malaria (ACTs) compared to usual facility services plus CCM for malaria (1 CBA study, 5235 children; very low-certainty evidence). We reported results in Table 6; Analysis 2.1; Figure 10; and Table 14.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for SAM compared to usual facility services plus CCM for malaria.

For newborn sepsis

No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for newborn sepsis compared to usual facility services plus CCM for malaria.

For newborn local infection

No studies reported effects of iCCM on coverage of appropriate treatment from an appropriate provider for newborn local infection compared to usual facility services plus CCM for malaria.

Coverage of appropriate treatment from an iCCM provider

For any iCCM illness

No studies reported effects of iCCM on coverage of appropriate treatment by an iCCM provider for any iCCM illness compared to usual facility services plus CCM for malaria.

For diarrhoea

No studies reported effects of iCCM on coverage of appropriate treatment by an iCCM provider for diarrhoea compared to usual facility services plus CCM for malaria.

For malaria

No studies reported effects of iCCM on coverage of appropriate treatment by an iCCM provider for malaria compared to usual facility services plus CCM for malaria.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of appropriate treatment by an iCCM provider for SAM compared to usual facility services plus CCM for malaria.

For newborn sepsis

No studies reported effects of iCCM on coverage of appropriate treatment from an iCCM provider for newborn sepsis compared to usual facility services plus CCM for malaria.

For newborn local infection

No studies reported effects of iCCM on coverage of appropriate treatment from an iCCM provider for newborn local infection compared to usual facility services plus CCM for malaria.

Quality of care

No studies reported effects of iCCM on quality of care compared to usual facility services plus CCM for malaria.

Case load or severity of illness at health facilities

No studies reported effects of iCCM on case load or severity of illness at health facilities compared to usual facility services plus CCM for malaria.

Measures of mortality

No studies reported effects of iCCM on case load or severity of illness at health facilities compared to usual facility services plus CCM for malaria.

Adverse events

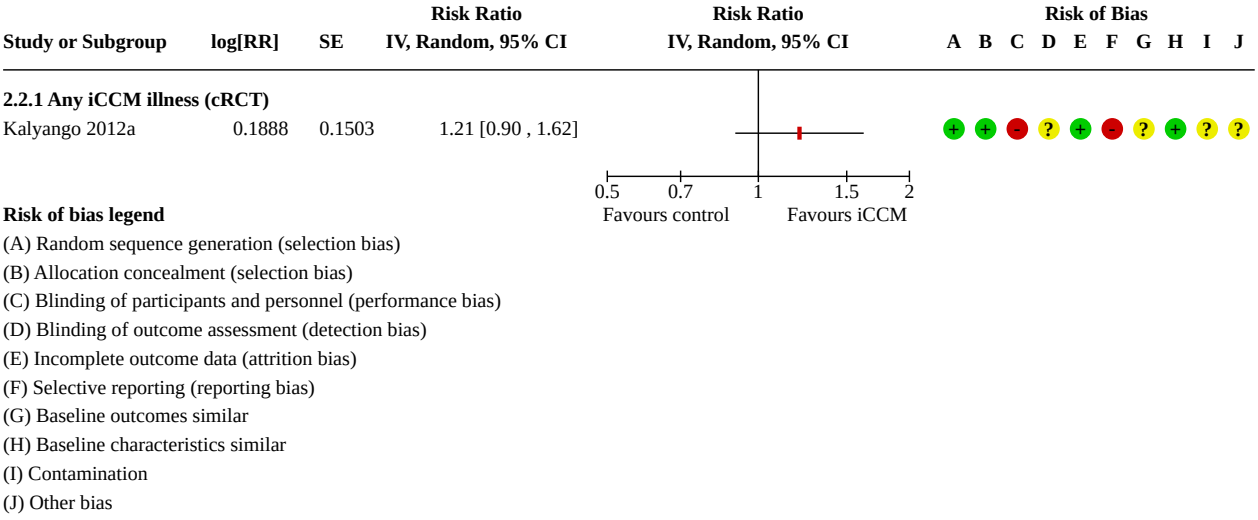
No studies reported effects of iCCM on adverse events compared to usual facility services plus CCM for malaria.

Coverage of careseeking to an appropriate provider

For any iCCM illness

For coverage of careseeking to an appropriate provider of treatment services for any iCCM illness compared to usual facility services plus CCM for malaria, we found one cRCT (Kalyango 2012a) and one CBA (Munos 2016). Following our protocol, we reported the estimate of effect based on the cRCT due to lower risk of bias. Based on the cRCT, iCCM may have little or no effect on careseeking to an appropriate provider of treatment services for any iCCM illness compared to usual facility services plus CCM for malaria (RR 1.06, 95% CI 0.97 to 1.17; 1 trial, 811 children; low-certainty evidence; Summary of findings 2; Analysis 2.2; Figure 11; Table 15). The effect based on the CBA is inconsistent with the effect based on the cRCT, suggesting an important effect in favour of the intervention (RR 1.24, 95% CI 1.01 to 1.53; Analysis 2.3; Figure 12; Table 15).

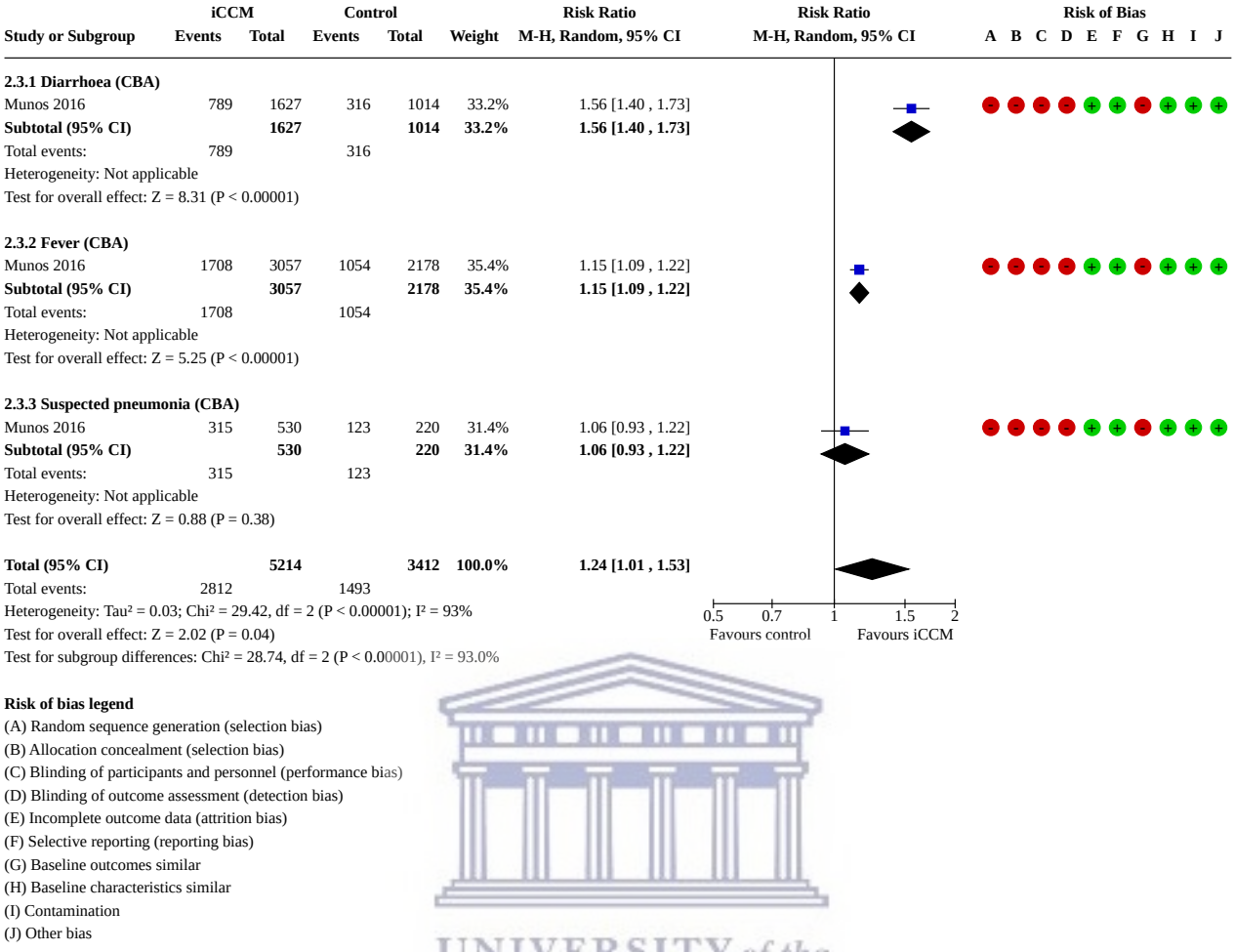
Figure 11. Forest plot of comparison: 2 iCCM versus usual facility services plus CCM for malaria, outcome: 2.2 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (cRCT).



Risk of bias legend

(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

Figure 12. Forest plot of comparison: 2 iCCM versus usual facility services plus CCM for malaria, outcome: 2.4 Comparison 2 iCCM vs usual facility services plus CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (controlled before-after (CBA)).



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

We performed a sensitivity analysis comparing the effects of iCCM for two diseases, iCCM for three diseases or iCCM for four diseases on coverage of careseeking to an appropriate provider of treatment services for any iCCM illness compared to usual facility services with or without CCM for malaria. The effects of iCCM on coverage of careseeking to an appropriate provider were larger for iCCM for four diseases compared to iCCM for two diseases and larger for iCCM for three diseases compared to iCCM for two diseases (however, 95% CIs overlapped for the latter comparison). The effect was larger for iCCM for four diseases compared to iCCM for three diseases; however, the 95% CIs overlapped (Table 4).

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome and comparison.

For diarrhoea

One CBA reported the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for diarrhoea compared to usual facility services plus CCM for malaria (Munos 2016). We are uncertain of the effect of iCCM on careseeking to an appropriate provider of treatment services for diarrhoea compared to usual facility services plus CCM for malaria (RR 1.56, 95% CI 1.40 to 1.73; 1 study, 2641 children; very low-certainty evidence; Table 6; Analysis 2.3; Figure 12; Table 15).

For fever

One CBA reported the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for fever compared to usual facility services plus CCM for malaria (Munos 2016). Certainty of the evidence was very low, precluding meta-analysis. Due to risk of bias of the CBA and indirectness, we are uncertain of the effect of iCCM on careseeking to an appropriate provider of treatment services for fever compared to usual facility services plus CCM for malaria (RR 1.15, 95% CI 1.09 to 1.22; 1 study, 5235 children; very low-certainty evidence; Table 6; Analysis 2.3; Figure 12; Table 15).

For suspected pneumonia

One CBA reported the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia compared to usual facility services plus CCM for malaria (Munos 2016). We are uncertain of the effect of iCCM on careseeking to an appropriate provider of treatment services for fever compared to usual facility services plus CCM for malaria (RR 1.21, 95% CI 0.90

to 1.62; 1 study, 750 children; very low-certainty evidence; Table 6 ; Analysis 2.3; Figure 12; Table 15).

For severe acute malnutrition

No studies reported effects of iCCM on coverage of careseeking to an appropriate provider of treatment services for SAM compared to usual facility services plus CCM for malaria.

For newborn sepsis

No studies reported effects of iCCM on coverage of careseeking to an appropriate provider of treatment services for newborn sepsis compared to usual facility services plus CCM for malaria.

For newborn local infection

No studies reported effects of iCCM on coverage of careseeking to an appropriate provider of treatment services for newborn local infection compared to usual facility services plus CCM for malaria.

For newborn danger signs

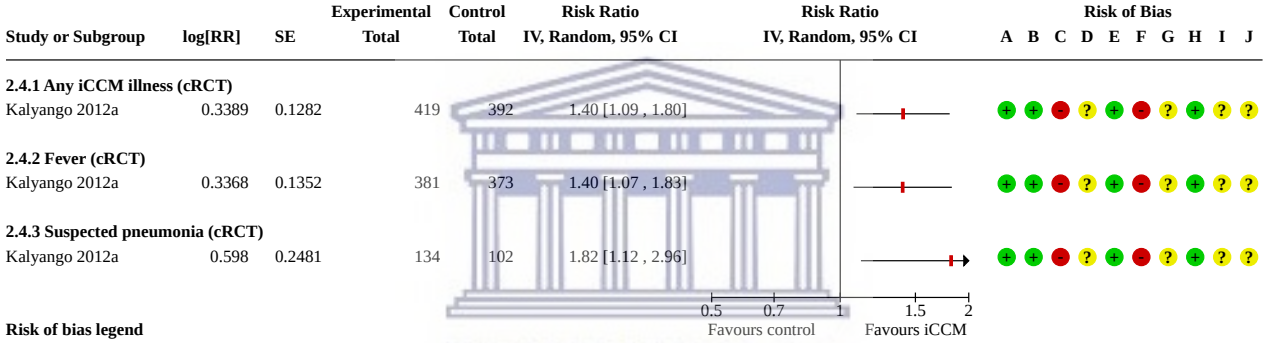
No studies reported effects of iCCM on coverage of careseeking to an appropriate provider for newborn danger signs compared to usual facility services plus CCM for malaria.

Coverage of careseeking to an iCCM provider

For any iCCM illness

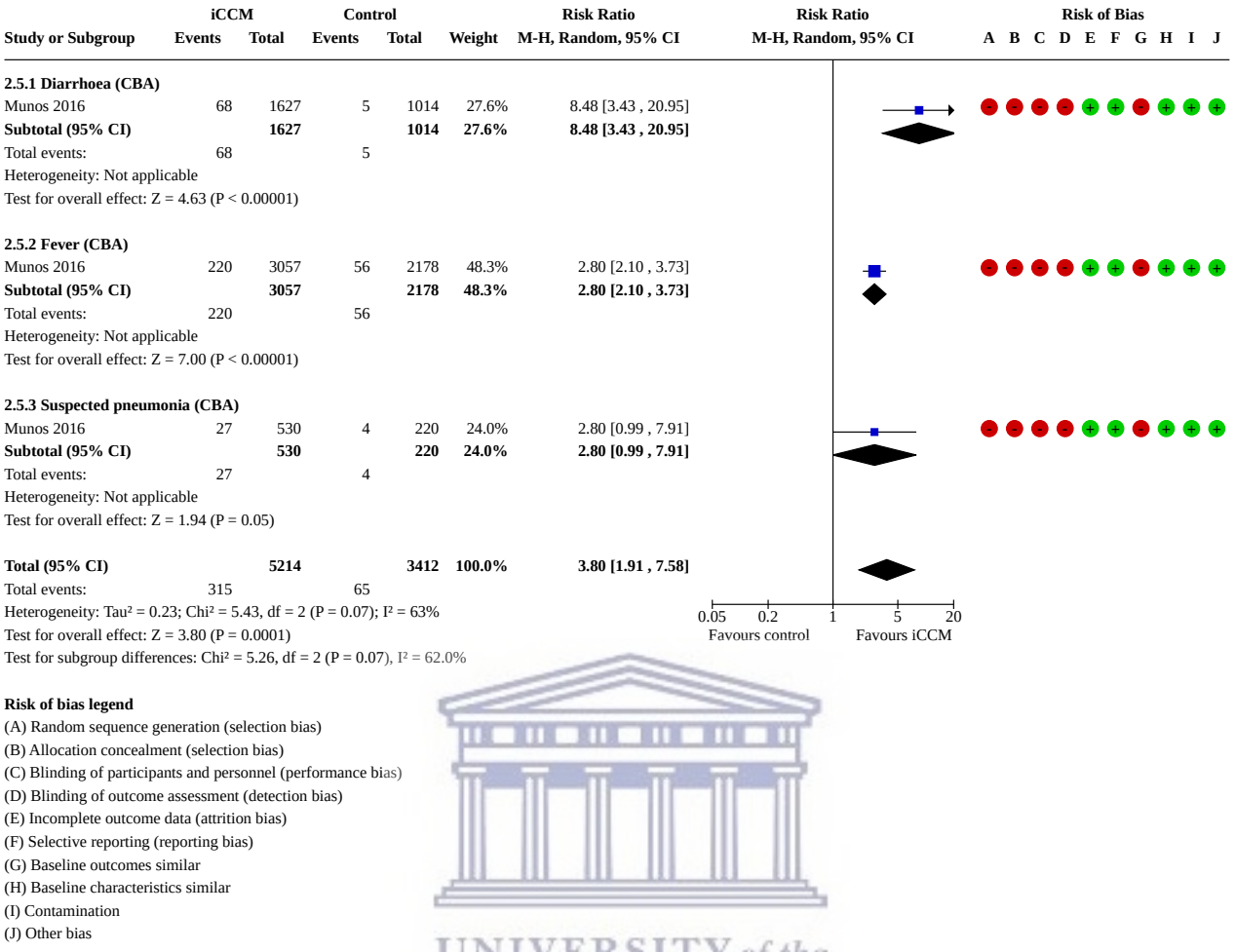
One cRCT (Kalyango 2012a), and one CBA (Munos 2016), reported the effect of iCCM on coverage of careseeking to an iCCM provider for any iCCM illness compared to usual facility services plus CCM for malaria. Based on the cRCT, iCCM may improve coverage of careseeking to an iCCM provider for any iCCM illness by 40% compared to usual facility services plus CCM for malaria (RR 1.40, 95% CI 1.09 to 1.80; 1 trial, 811 children; low-certainty evidence; Analysis 2.4; Figure 13; Table 6; Table 16). The effect based on the CBA (RR 3.80, 95% CI 1.91 to 7.58) is consistent with an effect in favour of the intervention (Analysis 2.5; Figure 14; Table 16). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

Figure 13. Forest plot of comparison: 2 iCCM versus usual facility services plus CCM for malaria, outcome: 2.3 Comparison 2 iCCM vs usual facility services plus CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (cluster randomized controlled trial (cRCT)).



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

Figure 14. Forest plot of comparison: 2 iCCM versus usual facility services plus CCM for malaria, outcome: 2.6 Comparison 2 iCCM versus usual facility services plus CCM for malaria: coverage of careseeking to an iCCM provider (controlled before-after (CBA)).



Risk of bias legend
(A) Random sequence generation (selection bias)
(B) Allocation concealment (selection bias)
(C) Blinding of participants and personnel (performance bias)
(D) Blinding of outcome assessment (detection bias)
(E) Incomplete outcome data (attrition bias)
(F) Selective reporting (reporting bias)
(G) Baseline outcomes similar
(H) Baseline characteristics similar
(I) Contamination
(J) Other bias

For diarrhoea

One CBA reported the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea compared to usual facility services plus CCM for malaria (Munos 2016). We are uncertain of the effect iCCM may have on coverage of careseeking to an iCCM provider for diarrhoea compared to usual facility services plus CCM for malaria (RR 8.48, 95% CI 3.43 to 20.95; 1 study, 2641 children; very low-certainty evidence; Analysis 2.5; Figure 14; Table 6; Table 16). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For fever

One cRCT (Kalyango 2012a) and one CBA (Munos 2016) reported the effect of iCCM on coverage of careseeking to an iCCM provider for fever compared to usual facility services plus CCM for malaria. Based on the cRCT, iCCM may improve coverage of careseeking to an iCCM provider for fever by 40% compared to usual facility services plus CCM for malaria (RR 1.40, 95% CI 1.07 to 1.83); 1 trial, 754 children; low-certainty evidence; Analysis 2.4; Figure 13; Table 6; Table 16; Figure 14). The effect based on the CBA (RR 2.80, 95% CI 2.10 to 3.73) is consistent with an effect in favour of the intervention (Analysis 2.5; Figure 14; Table 16). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For suspected pneumonia

One cRCT (Kalyango 2012a) and one CBA (Munos 2016) reported the effect of iCCM on coverage of careseeking to an iCCM provider for suspected pneumonia compared to usual facility services plus CCM for malaria. Based on the cRCT, iCCM may improve coverage of careseeking to an iCCM provider for suspected pneumonia by 82% compared to usual facility services plus CCM for malaria (RR 1.82, 95% CI 1.12 to 2.96; 1 trial, 236 children; low-certainty evidence; Analysis 2.4; Figure 13; Table 6; Table 16). The effect based on the CBA (RR 2.80, 95% CI 0.99 to 7.91) is consistent with an effect in favour of the intervention; however, the CIs included no effect (Analysis 2.5; Figure 14; Table 16). We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For severe acute malnutrition

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for SAM compared to usual facility services plus CCM for malaria.

For newborn sepsis

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn sepsis compared to usual facility services plus CCM for malaria.

For newborn local infection

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn local infection compared to usual facility services plus CCM for malaria.

For newborn danger signs

No studies reported effects of iCCM on coverage of careseeking to an iCCM provider for newborn danger signs compared to usual facility services plus CCM for malaria.

DISCUSSION

Summary of main results

The iCCM components and inputs were fairly consistent across the seven studies with notable variation for the training and deployment component (e.g. on payment of iCCM providers) and the system component (e.g. on improving information systems and monitoring and evaluation) (Table 1; Table 3). It is notable that few studies included interventions for the payment of iCCM providers such as salary, fees for service, capitation or training of facility-based providers on iCCM/IMCI/IMNCI as part of the training and deployment component, given WHO recommendations on remunerating CHWs (which include iCCM providers) with a "financial package commensurate with the job demands, complexity, number of hours, training and roles that they undertake" and ensuring CHWs receive supportive supervision from trained supervisors (WHO 2018). It is also notable that few studies included systems inputs (e.g. for improving information systems and monitoring and evaluation), given WHO recommendations on data collection and use that underscore the importance of this type of system support for CHW programmes (WHO 2018).

When compared to usual facility services, iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness. However, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness. iCCM may have little or no effect on neonatal mortality and we are uncertain of the effect on infant mortality or under-five mortality.

Overall completeness and applicability of evidence

The evidence provided through the studies identified is relevant the review question but, due to uncertainty of the evidence, it does not sufficiently address the objective of the review. Given the very low- to moderate-certainty evidence for all reported outcomes, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, evidence was not reported for three primary outcomes: quality of care, case load or severity of illness at health facilities, and adverse events – research is needed on these outcomes.

When applying the meta-analysis findings to current policies and practice, the following issues need to be considered. First, the contexts of the included studies, by virtue of being studies, do not translate directly to real-world conditions. The rigour of design and strength of support to implementation of iCCM under study conditions may be more robust than what may be feasible under real-world conditions at scale. Second, iCCM is a complex intervention and there was important variation in some of the components and inputs included across studies, particularly with regard to inputs for training and deployment (e.g. on payment of iCCM providers) and strengthening the health system. Additionally, there was important variation regarding inclusion of interventions for improving newborn health. For instance, Bhandari 2012a included training of iCCM providers to provide iCCM in the community and training for other providers in health facilities on IMNCI; postnatal home visits and convening of women's groups by lay health workers, as well as a number of system-strengthening inputs. While this complexity made it infeasible to disentangle the effects of one component or input from another, it underscores the need for policy makers and programme managers to engage with this complexity and consider multiple components and inputs – including ones aimed at broader health systems strengthening. Third, although all included studies occurred in contexts where iCCM is expected to be beneficial – LMICs with high under-five mortality and inadequate access to facility-based services – there were important differences in contextual setting. Bhandari 2012a was the only included study conducted outside of Africa; thus, the evidence base from settings outside Africa is sparse. Additionally, Bhandari 2012a was set in a mixed rural/urban area of northern India. However, despite these differences in contextual setting, the effects between Bhandari 2012a and the comparable cRCTs (Boone 2016; Kalyango 2012a) from SSA were broadly similar. Differences in effect for neonatal mortality and infant mortality between Bhandari 2012a and Boone 2016 are most likely explained by differences in intervention components and inputs (e.g. Boone 2016 included a broader range of systems inputs such as incentives for lay health workers, had a broader iCCM package (including for newborns), had women's groups conducted by lay health workers trained on iCCM and had facility-based providers trained on IMNCI) rather than contextual setting, given that there were no important differences in effect between these studies for careseeking to an appropriate provider of treatment services (Summary of findings 1).

Certainty of the evidence

We used the GRADE approach to assess the certainty of the evidence. The certainty of the evidence was very low to low for coverage of appropriate treatment; low to moderate for coverage of careseeking; and very low to low for measures of mortality. See Summary of findings 1; Summary of findings 2; Table 5; and Table 6 for GRADE judgements.

Potential biases in the review process

One review author (NPO) has worked as a Health Specialist for UNICEF at its headquarters in New York, USA. UNICEF was involved in the development of iCCM with WHO; UNICEF has advocated for countries to adopt iCCM; and UNICEF has provided funding and technical support in numerous countries for iCCM implementation, monitoring, evaluation and research. NPO was

involved in providing technical support in numerous countries for iCCM monitoring, evaluation, and implementation research. NPO works as a Health Specialist, Public Health and M&E, for the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) in Geneva, Switzerland. GFATM has funded the implementation of iCCM and CCM in numerous countries. NPO was not involved in data extraction for studies supported by UNICEF or the GFATM.

Two studies were identified after our search and shortly prior to submission of the draft review to Cochrane EPOC (Kanté 2019a; Ma 2019a). We identified four studies as ongoing (Maru 2018b; Rabbani 2014; Taneja 2017; Whidden 2019a/Whidden 2019). These studies may be eligible and will be considered for inclusion when we update this review. It is unlikely that we missed any eligible studies due the exhaustive nature of our search strategy and familiarity with the research topic.

Agreements and disagreements with other studies or reviews

Systematic reviews have been undertaken and published on single-disease CCM – that is, CCM for diarrhoea (Das 2013), CCM for malaria (Okwundu 2013; Ruizendaal 2014; Sazawal 2003), and pneumonia (Das 2013; Druetz 2013; Ruizendaal 2014; Sazawal 2003) – among children under-five in LMICs. Two of these reviews used the GRADE approach for assessing certainty of the evidence (Das 2013; Okwundu 2013). In addition, one systematic review using GRADE reviewed the effect of proactive case detection by lay health workers (an approach whereby lay health workers proactively visit households to identify ill children) on infant mortality, under-five mortality, child morbidity, coverage of appropriate treatment by an appropriate provider and coverage of careseeking to an appropriate provider compared to usual health services, including "conventional community-based healthcare delivery" by lay health workers (i.e. without proactive case detection by lay health workers) (Whidden 2019b).

We calculated an effect in favour of iCCM for coverage of appropriate treatment by an iCCM provider compared to usual facility services plus CCM for malaria (low-certainty evidence; Table 6) and this effect, in favour of the intervention, is consistent with the effects reported by Das 2013 (CCM for diarrhoea), Okwundu 2013 (CCM for malaria) and Whidden 2019b (proactive case detection by lay health workers).

For infant mortality, we found inconsistent effects and concluded that we are uncertain of the effect of iCCM on infant mortality compared to usual facility services (low-certainty evidence), whereas Gera 2016, in a systematic review of facility and community-based IMNCI and Whidden 2019b (proactive case detection by lay health workers), reported effects in favour of the intervention (low-certainty evidence). For under-five mortality, the effect in our review was based on one cRCT (Boone 2016), and we concluded that iCCM may have little or no effect on under-five mortality (low-certainty evidence), whereas as Gera 2016 (IMNCI) found an effect in favour of the intervention, with 95% CIs that included no effect (low-certainty evidence) and Whidden 2019b found an effect in favour of the intervention but concluded that it is uncertain whether proactive case detection reduces under-five mortality due to the low-certainty evidence. Two reviews found effects in favour of the intervention for under-five mortality (moderate-certainty evidence) (Das 2013 on CCM for diarrhoea and Okwundu 2013 on CCM for malaria).

A "scoping review" of the training, supervision and quality of care of iCCM that did not use GRADE reported evidence of positive effects on quality of care in large iCCM programmes where multifaceted interventions including training, supervision and supply chain management were implemented (Bosch-Capblanch 2014). No included studies in our review reported quality of care. One systematic review assessed the evidence for the effect of integrating CCM for malaria with other interventions, including CCM for pneumonia, on outcomes for CCM for malaria – in particular, quality of care and facilitators and barriers to high-quality CCM for malaria (Smith Paintain 2014). Smith Paintain 2014 did not use GRADE and was focused on the effects of iCCM on malaria outcomes, not outcomes across diseases as in this review. They found that integrating additional interventions with case management services at community level for malaria did not reduce the quality of the malaria services in contexts where training and supervision were maintained but quality of pneumonia case management was lower and variable (Smith Paintain 2014). Our included studies did not report on quality of care; however, we did a sensitivity analysis comparing the effects of iCCM for two diseases, iCCM for three diseases or iCCM for four diseases compared to usual facility services with or without CCM for malaria. The results suggested that the effects of iCCM on careseeking to an appropriate provider were larger for iCCM with four diseases compared to iCCM for two diseases and larger for iCCM with three diseases compared to two diseases (however, 95% CIs overlapped for the latter). There was no difference in effect between iCCM for four diseases compared to iCCM for three diseases (Table 4). Further research is required to determine whether, or at what point and in which contexts, there may be decreases or improvements in quality of care as more diseases are added to the iCCM package.

The effects we calculated for coverage of careseeking to an appropriate provider of treatment services are consistent with the effects in favour of CCM (moderate-certainty evidence) reported by Das 2013 (CCM for diarrhoea). Lewin 2010, a systematic review on the effects of lay health workers on various health outcomes and interventions compared to usual care, included three cRCTs (none of which were met our inclusion criteria) that reported the effect of lay health workers on careseeking behaviour. Although the three studies did not include iCCM, the evidence from Lewin 2010 is relevant to our review given the similarity of the intervention and outcome reviewed. Lewin 2010 concluded that lay health workers may increase careseeking compared to usual care (RR 1.33, 95% CI 0.86 to 2.05), an effect similar to that found in this review, but the certainty of evidence was low.

AUTHORS' CONCLUSIONS

Implications for practice

Integrated community case management (iCCM) is a complex intervention and there was important variation in the components and inputs included across studies, particularly with regard to inputs for training and deployment (e.g. training of facility-based providers, payment of iCCM providers) and strengthening the health system (e.g. health information systems and monitoring and evaluation). Additionally, there was important variation regarding inclusion of interventions for improving newborn health. For instance, Bhandari 2012a included training of iCCM providers to provide iCCM in the community and training for other providers in health facilities on Integrated Management of Neonatal and Childhood Illness (IMNCI); postnatal home visits and convening of

women's groups by lay health workers trained on iCCM, as well as a number of system strengthening inputs. While this complexity made it infeasible to disentangle the effects of one component or input from another, it underscores the need for policy makers and programme managers to engage with this complexity. The low to modest effects of iCCM found in this review underscore the importance of ensuring all components and inputs of iCCM are adequately addressed in the given context.

As low- and middle-income countries strive to achieve universal health coverage and put into practice their (renewed) commitments to primary health care made at the Global Conference on Primary Health Care in Astana, Kazakhstan in 2018, many will consider the role of iCCM. The evidence presented here underscores the importance of moving beyond training and deployment to valuing iCCM providers, strengthening health systems and engaging community systems. Depending on the context, this could mean adding remuneration of iCCM providers with a financial package commensurate with their work; a greater focus on training and support to facility-based providers to ensure children with severe illness who are referred from iCCM providers receive quality care; expanding the iCCM package to include newborn care; a greater focus on the systems component of iCCM, including referral systems, supply chain, supervision systems, information systems, and monitoring and evaluation; and a greater focus on the social mobilization and community engagement component of iCCM (e.g. engaging women's groups as in the systematic review; Prost 2013).

Although all included studies occurred in contexts where iCCM is expected to be beneficial – LMICs with high under-five mortality and inadequate access to facility-based services – there were important differences in contextual settings. Bhandari 2012a was the only included study conducted outside of Africa; thus, the evidence base from settings outside Africa is sparse. Additionally, Bhandari 2012a was set in a mixed rural/urban area of northern India. However, despite these differences in contextual setting, the effects between Bhandari 2012a and the comparable cluster-randomized controlled trials (Boone 2016; Kalyango 2012a) from SSA were broadly consistent and, where they were inconsistent (e.g. neonatal and infant mortality), this was most likely due to differences in inputs across studies rather than differences in contextual settings.

Implications for research

This is the first systematic review of iCCM – that is, as an integrated approach for the management of diarrhoea, pneumonia, malaria (in malaria-affected areas), acute malnutrition or newborn infection (or combinations of these conditions) at the community level by lay health workers. Given the very low-to-moderate certainty of evidence for reported outcomes, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, there was no evidence for three primary outcomes: quality of care, case load or severity of illness at health facilities and adverse events – research is needed on these outcomes.

None of the three iCCM components had complete information for all inputs across all included studies.

Information on five of 11 iCCM inputs across the three iCCM components was complete for all included studies.

- Intervention to recruit, train and retain lay health workers to provide iCCM.
- Implementation of simplified integrated management of childhood illness (IMCI)-adapted clinical guidelines for iCCM providers.
- Interventions to improve systems for referral of patients between community and facility level.
- Interventions to improve the supply of iCCM drugs and equipment.
- Interventions to improve managerial supervision of iCCM.

For the following iCCM inputs, one or more included studies did not provide sufficient information to judge whether the study included the input or not.

- Interventions to recruit, train and retain other types of health workers (e.g. doctors, nurses, midwives) to provide integrated case management services for children under-five (iCCM/IMCI/Integrated Management of Neonatal and Childhood Illness).
- Interventions for the payment of iCCM providers such as salary, fees for service, capitation.
- Interventions to improve health information systems and use of information communication technology for iCCM.
- Interventions to improve monitoring, evaluation and research for iCCM.
- Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill.

Information on these inputs (and potential effect modifiers) in future studies would help policy makers and programme managers. In addition to these areas, further research is needed on the following.

- Whether the modality/approach to iCCM service delivery modifies the effect of iCCM on outcomes. One systematic review assessed the effect of proactive case detection by lay health workers on infant mortality, under-five mortality, child morbidity, coverage of appropriate treatment by an appropriate provider and coverage of careseeking to an appropriate provider compared to usual health services, including "conventional community-based healthcare delivery" (i.e. without a proactive case detection approach by lay health workers) (Whidden 2019b). We summarized the results in Agreements and disagreements with other studies or reviews. It is not clear whether all studies included iCCM. One study awaiting classification assessed the effect of home visits by lay health workers trained on iCCM on coverage of appropriate treatment by an appropriate provider for diarrhoea and malaria, as well as prevalence of diarrhoea and malaria (Ma 2019a). Each lay health worker was to visit 20 households per month, ensuring each household in a catchment area of 40 households received one household visit every two months. Ma 2019a will be considered for inclusion when this review is updated. Further research on whether different modalities/approaches to iCCM as described in Ma 2019a and Whidden 2019b modify the effect of iCCM on outcomes is needed.
- Whether the population-to-iCCM provider ratio modifies the effect of iCCM on outcomes. Few included studies provided information on this possible effect modifier.

- Whether distance or travel time to an iCCM provider modifies the effect of iCCM on outcomes. No included studies provided information on this possible effect modifier.
- Whether women's groups and other community-based health clubs/groups for the promotion of good practices for health and nutrition and generating demand for use of iCCM providers when children are ill modify the effect of iCCM on outcomes. Two studies included information on this input, but it remains unclear whether the effect of iCCM on outcomes is modified (Bhandari 2012a; Boone 2016). One review found women's groups with participatory learning and action may reduce maternal and newborn mortality (Prost 2013).
- Whether the effect of iCCM may be sustained. It is unclear on the basis of the included studies whether the effects of iCCM may be sustained due to the limited follow-up time of the studies.
- The effect of iCCM on timeliness of careseeking to an appropriate provider and timeliness of appropriate treatment by an appropriate provider. These outcomes were not part of our original protocol but will be explored in updates to this review.
- The reasons for low coverage of careseeking to iCCM providers for diarrhoea and low coverage of appropriate treatment for diarrhoea by iCCM providers and mechanisms to improve these outcomes through iCCM.
- The effect of iCCM on outcomes in urban/peri-urban settings. Bhandari 2012a provided encouraging evidence for policy makers interested in adapting iCCM to mixed rural/urban or peri-urban environments; however, additional studies on the effect of iCCM in these contexts is warranted before overall conclusions can be drawn.
- Whether and how policy transfer mechanisms influence the effect of iCCM on outcomes.

This review fills an important information gap relevant to evidence-based decision making of the general public, practitioners, policy makers and researchers in low- and middle-income countries. Future research could aim to identify effective ways to improve iCCM design, implementation, monitoring and evaluation within the context of broader primary health care and community health systems, considering all of the iCCM components and inputs and with particular attention to key gaps identified in the studies included in this review (e.g. training for facility-based providers, inputs within the systems component and inputs within the social mobilization and community engagement component); identify which constellations of iCCM inputs work best in which contexts; identify how iCCM inputs may need to be adapted to address evolving needs such as in urban and peri-urban contexts; identify which approaches to improving iCCM inputs are most effective in which contexts; and identify which modalities (e.g. proactive case detection versus passive case detection) for iCCM implementation work best in which contexts; and quality of care of iCCM providers.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Bhandari 2012a

Study characteristics	
Methods	**Design:** cluster-randomized controlled trial **Unit of randomization:** catchment areas of 18 primary health centres
Participants	**Inclusion criteria:** children up to 12 months of age in the catchment areas of the 18 primary health centres included in study **Exclusion criteria:** none reported
Interventions	**Intervention** • Training lay health workers (existing cadre of ASHAs to provide iCCM for diarrhoea, malaria (in high-risk areas), pneumonia (ARI) and malnutrition among children aged 0–59 months • Recruiting and training other types of health workers (providers at public and private sector health facilities) to provide IMNCI • Providing incentives for lay health workers for home visits (Anganwadi workers), women's group meetings (ASHAs) and sick child contacts (ASHAs) • Providing iCCM providers with drugs and equipment • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers (ASHAs) • Implementing referral of children with severe disease to health facilities • Training Anganwadi workers to conduct postnatal home visit • Training ASHAs on conducting women's group meetings • Implementing women's group meetings • Implementing postnatal home visits by Anganwadi workers and convening women's groups by ASHAs based on the training above • Training supervisors of lay health workers (Anganwadi workers and ASHAs) on effective supervision • Providing supervision to lay health workers (Anganwadi workers and ASHAs); frequency, content and approach of supervision not reported **Comparison** • Usual facility services
Outcomes	**Mortality**

Bhandari 2012a *(Continued)*

- Neonatal mortality (deaths between birth and day 28 of life) and inequity gradient thereof
- Mortality beyond the first 24 hours of birth (deaths between day 2 and day 28 of life)
- Infant mortality (deaths between birth and day 365 of life) and inequity gradient thereof
- Perinatal mortality (stillbirths and deaths between birth and day 7 of life)
- Postneonatal mortality (deaths between day 29 and day 365 of life) and inequity gradient thereof

Nutrition

- Wasting
- Stunting

Coverage of health services

- Immunization coverage and inequity gradient thereof

Healthy practices by caregiver

- Newborn care practices and inequity gradient thereof
- Care seeking behaviour and inequity gradient thereof
- Complementary feeding and inequity gradient thereof

Notes	**Objective:** to evaluate the Indian IMNCI programme, which integrates improved treatment of illness for children with home visits for newborn care, inform its scale-up. **Location:** catchment areas of 18 primary health centres in a mixed rural/urban environment within the district of Faridabad, Haryana, India with a population of 1.1 million (10,694–72,059 per primary health centre). **Funding source:** WHO Geneva through a grant from USAID; UNICEF, New Delhi; GLOBVAC Program of the Research Council of Norway through grant No. 183722. The authors reported that WHO and UNICEF staff contributed importantly to the planning, analysis and reporting of the study but the funding bodies had no influence on how the data were collected, analyzed or presented.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "We divided the clusters into three strata containing six clusters each according to their baseline neonatal mortality rate. An independent epidemiologist generated 10 stratified randomisation schemes to allocate the clusters to intervention or control groups. We excluded three of these schemes, which had large differences in neonatal mortality rate, proportion of home births, proportion of mothers who had never been to school, and population size. We selected one of the remaining seven allocation schemes by a computer generated random number." P. 2.
Allocation concealment (selection bias)	Low risk	An independent epidemiologist generated 10 stratified randomization schemes to allocate the clusters to intervention or control groups.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Surveillance teams, research assistants and independent teams conducted data collection per the description below from the study. The study indicated the surveillance teams were blinded. Unclear whether the research assistants or independent teams were blinded.

Bhandari 2012a *(Continued)*

		Quote: "Data were collected by a team of 110 study field workers who were not involved with IMNCI implementation. The workers visited the allocated households every month to identify new pregnancies and inquire about the outcome of previously identified pregnancies. All households with live births were visited on day 29 and at ages 3, 6, 9, and 12 months to document the vital status of the infant. The surveillance team comprised workers who resided in or near to the areas allocated to them. The surveillance team was not told the intervention status of the community they were visiting. The follow-up procedures were identical in all the clusters. A separate team of research assistants interviewed a randomly selected sub-sample of mothers at 29 days to ascertain newborn care practices and exposure to the intervention. An independent team visited each household with a death as soon as possible to do a verbal autopsy, a technique for ascertaining the probable cause of death used in settings lacking vital registration and medical certification of deaths." P. 3. Despite the above measures, the residual risk of detection bias was unclear. The research assistants and independent teams may not have been blinded. Since the surveillance teams were selected from or near the areas allocated to them, they may have ascertained which arm they were working in through their daily interactions with the population. Similarly, even if blinded, the research assistants and independent teams may have ascertained which arm they were in from interactions with participants.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Quote: "almost all recruited live born infants were followed for the newborn period (97.8%), only 75.4% were followed for six months and 52.6% until the end of infancy". P. 4. Comment: 15,899/29,782 in intervention clusters and 16,055/30,920 had known vital status at 12 months.
Selective reporting (reporting bias)	Low risk	No evidence of selective reporting.
Baseline outcomes similar	Low risk	Baseline outcomes were similar.
Baseline characteristics similar	Unclear risk	There were some differences in baseline characteristics. Quote: "Intervention areas were less accessible, had a lower proportion of births in health facilities, and had families with lower economic status but higher literacy." Comment: these differences would have favoured control areas. The authors reported controlling for these differences in analysis.
Contamination	Low risk	The 18 clusters were contiguous; however, the risk of contamination was likely low, owing to the large size of clusters and the way health service delivery was organized.
Other bias	Low risk	No other apparent source of bias was detected.

Boone 2016

Study characteristics	
Methods	**Design:** cluster-randomized controlled trial **Unit of randomization:** villages

Boone 2016 *(Continued)*

Participants	**Inclusion criteria:** Women: main residence was in 1 of the clusters; woman's reported age 15–49 years; was primary caregiver of a child aged < 5 years in baseline survey (note: age range for eligible women in protocol was 12–49 years but was reported as 15–49 years in study); resident in 1 of the enumerated households per village; gave consent; village (*tabanca*) leader gave consent Children: aged < 5 years at randomization; resided permanently with an eligible woman at time of baseline survey; her/his name was recorded during baseline survey; born to an eligible woman after randomization, or was born after the baseline survey and before randomization and was alive at time of randomization; if mother/caregiver gave consent; if village (*tabanca*) leader gave consent **Exclusion criteria:** women: death before 1 July 2008 or died at an unknown date; children: lost to follow-up, died before 1 July 2008, died at an unknown date, had 5th birthday on or before 1 July 2008, or born after final interview
Interventions	**Intervention** • Recruiting and training lay health workers (CHW) to provide iCCM for diarrhoea, moderate ARIs and fever (presumptive malaria) among children aged 2–59 months • Recruitment and training of lay health workers (health promoters) to organize and facilitate community health clubs • Recruitment and training of traditional birth attendants to provide home-based counselling and care for pregnant women and newborn babies • Recruitment and training of community health nurses to train and supervise iCCM providers and traditional birth attendants • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers (CHWs) • Implementing referral of children under 2 months of age and children with severe disease to health facilities • Providing iCCM providers with iCCM drugs and equipment • Providing iCCM providers with supervision; frequency twice per month (content and approach not reported) • Providing mobile clinic services twice per month by community health nurses • Organizing and facilitating community health clubs by trained health promoters • Providing home-based counselling and care for pregnant women and newborn babies by traditional birth attendants **Comparison** • Usual facility services
Outcomes	**Mortality** • Under-5 mortality rate • Infant mortality rate • Neonatal mortality rate **Coverage of careseeking to an 'appropriate provider'of treatment services** • Coverage of careseeking to an appropriate provider of treatment services for diarrhoea • Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia • Coverage of careseeking to an appropriate provider of treatment services for fever
Notes	**Objective:** to assess whether a community-based intervention package in the absence of health system strengthening activities could generate a rapid and cost-effective reduction in under-5 mortality in these regions. **Location:** geographical clusters (individual villages or groups of villages) within the rural districts of Tombali and Quinara in Guinea-Bissau.

Boone 2016 *(Continued)*

Funding source: effective Intervention, a charity registered in the UK. The authors reported that the funder was on the trial steering committee but was not shown interim unmasked analysis; after the final analysis, the funder took part in interpretation of the data and writing of the report.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Cluster randomization, no individual randomization. Clusters selected through computerized random number generator. Quote: "In August, 2007, after completion of the baseline survey, all clusters were randomly allocated by the trial statistician (VM) at the London School of Hygiene & Tropical Medicine within these six strata, to either the intervention group or the control group using a computerised random number generator."
Allocation concealment (selection bias)	Low risk	Allocation was concealed prior to assignment. Quote: "Allocation was performed centrally at London School of Hygiene & Tropical Medicine (i.e. away from recruitment centers) on all clusters after the baseline (i.e. after enrolment) using a computerized random number generator."
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessment. Quote: "Field data collection and statistical analysis were not masked; data entry was masked."
Incomplete outcome data (attrition bias) All outcomes	Low risk	Only 7/11,509 children enrolled in the trial were lost to follow-up. Reasons for excluding certain children from the analysis are clearly given, loss to follow-up, dearth, having their 5th birthday before start of trial, born after final interview.
Selective reporting (reporting bias)	Low risk	All relevant outcomes (i.e. relevant per our protocol) in the methods section of the study – and in the protocol – were reported in the results section. Annotations from e331-e332. Quote: "The primary outcome was the proportion of children younger than 5 years who died during the study period. Secondary outcomes were neonatal and infant mortality, age at and cause of child deaths, treatment practices for sick children, mother's or primary caregiver's knowledge of childhood diseases and safe delivery, child morbidity (prevalence of fever, diarrhoea, and respiratory infections), maternal mortality, age at and cause of maternal deaths, and indicators of safe birthing practices. Cost-effectiveness was not calculated because of the lack of effect on child deaths." The authors stated that some outcomes will be published elsewhere (P. e334) but we found these outcomes are not among our primary or secondary outcomes.
Baseline outcomes similar	Low risk	Baseline under-5 mortality was similar. Figure 1 indicates that in the control arm there were 899 children under 5 years who had their 5th birthday on or before 1 July 2008 (start of the intervention in the intervention arm) and among these, 89 died before 1 July 2008 (89/899 × 1000 = 98.9 deaths per 1000 live births). In the intervention arm, there were 864 children under 5 years who had

Boone 2016 *(Continued)*

		their 5th birthday on or before 1 July 2008 and among these 84 died before 1 July 2008 (84/864 × 1000 = 97.2 deaths per 1000 live births).
Baseline characteristics similar	Low risk	Baseline characteristics were similar.
Contamination	Low risk	Clusters were separated by a minimum of 4 km to minimize risk of contamination.
Other bias	Low risk	No other apparent source of bias was detected.

Kalyango 2012a

Study characteristics	
Methods	**Design:** cluster-randomized controlled trial **Unit of randomization:** groups of villages (parishes)
Participants	**Inclusion criteria:** children aged 6–59 months in study villages who received treatment from CHWs for any illness; identified from CHW registers, traced to their homes and enrolled in study. All enrolled children were included in the analysis for treatment outcomes. Only children with pneumonia symptoms were included in the analysis for prompt and appropriate antibiotics for pneumonia symptoms **Exclusion criteria:** none reported
Interventions	**Intervention** • Recruiting and training lay health workers (CHWs) to provide iCCM for malaria and pneumonia (ARI) among children aged 4–59 months • Recruiting and training other types of health workers to provide IMNCI • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers • Implementing referral of children under 4 months of age and children with severe disease to health facilities • Providing iCCM providers with drugs and equipment • Training supervisors of lay health workers (iCCM for intervention and CCM for control) • Providing supervision to lay health workers (iCCM for intervention and CCM for control); frequency monthly (content and approach not reported) **Comparison** • Usual facility services + CCM for malaria
Outcomes	**Coverage of appropriate treatment**: • Coverage of appropriate treatment (antibiotics) for pneumonia • Coverage of appropriate treatment (antibiotics) for pneumonia by an iCCM provider • Coverage of appropriate treatment (antibiotics) for pneumonia within 24 hours **Coverage of careseeking to an 'appropriate provider'of treatment services** • Careseeking for children with suspected pneumonia to an iCCM provider • Careseeking for children with fever to an iCCM provider • Coverage of careseeking to an appropriate provider of treatment services for any illness • Coverage of careseeking to an iCCM provider as first source of treatment for any illness

Kalyango 2012a *(Continued)*

Notes	**Objective:** to determine the effect of integrated malaria and pneumonia management, compared to malaria only management by CHWs, on receiving prompt and appropriate antibiotics for pneumonia symptoms. **Location:** Eastern Uganda, Iganga Municipality. **Funding source:** SIDA and UNICEF/UNDP/World Bank/WHO Special Program for Research and Training in Tropical Diseases.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Quote: "Randomization was done by a statistician that was independent of the study using stratified block randomization. Iganga-Mayuge HDSS has 65 villages which make up 26 parishes that were divided into eight urban and 18 rural clusters (parishes). The clusters from the rural area were further grouped into three strata based on the population size of children less than five years: i) 190–320, ii) 321– 390, and iii) 391 and above, resulting in six clusters in each of these strata. The clusters from the urban area were grouped into two strata based on population sizes of iv) 280–430, and v) 431 and above. Random numbers were generated in blocks of six for the rural clusters and in blocks of four for the urban clusters."
Allocation concealment (selection bias)	Low risk	Quote: "Randomization was done by a statistician that was independent of the study using stratified block randomization."
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Data collectors were not blinded; however, they were independent of the intervention. It is not clear whether being independent would have mitigated the risk of detection bias due to not being blinded.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Quote: "All children enrolled on day 1 were assessed on day 4."
Selective reporting (reporting bias)	High risk	Mortality was the primary outcome measure of the registered trial (ISRCTN52966230), but this outcome has never been published.
Baseline outcomes similar	Unclear risk	Baseline outcomes (careseeking and quality of care) were not assessed. The history of children with illness at baseline was similar between arms, with the exception of the % of children with fast breathing per respiration count by field assistants on day 1 – which was higher in the intervention arm compared to the control arm. This may have had an effect on outcomes for careseeking and quality of care. Imbalances in the number of children treated per arm could have resulted in a loss of power, possibly dampening any effect of the intervention.
Baseline characteristics similar	Low risk	Baseline characteristics were similar except for higher % rural population in control clusters.

Kalyango 2012a *(Continued)*

Contamination	Unclear risk	There were no buffer zones between the intervention clusters and control clusters and caregivers from the control clusters may have accessed care in the intervention clusters, possibly dampening any positive effect of the intervention.
Other bias	Unclear risk	No other apparent source of bias.

Mubiru 2015

Study characteristics	
Methods	**Design:** controlled before-after study **Unit of randomization:** none
Participants	**Inclusion criteria:** children aged < 5 years, heads of households and caregivers of children aged < 5 years, and women of reproductive age (15–49 years of age) in intervention and comparison districts **Exclusion criteria:** none reported
Interventions	**Intervention** • Training lay health workers – existing VHT members – to provide iCCM for diarrhoea, malaria and pneumonia (ARI) among children aged 0–59 months • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers (VHT members) • Providing lay health workers (VHT members) with incentives, including transport refund and meals during quarterly meetings • Implementing referral of children with severe disease to health facilities • Providing iCCM providers with iCCM drugs and equipment • Providing iCCM providers (VHT members) with supervision; frequency of supervision provided as part of the intervention not reported; however. the study monitored the percent of VHT members who received quarterly supervision; content and approach to supervision not reported • Implementing radio spots promoting careseeking • Training community leaders to sensitize communities about the work of iCCM providers (VHT members) **Comparison** • Usual facility services
Outcomes	**Mortality** • Under-5 mortality **Coverage of appropriate treatment by an appropriate provider** • Coverage of appropriate treatment (ACT) for malaria (study took fever as presumed malaria) from an appropriate provider • Coverage of appropriate treatment (antibiotics) for pneumonia from an appropriate provider • Coverage of appropriate treatment (ORS and zinc) for diarrhoea from an appropriate provider **Coverage of careseeking to an 'appropriate provider' of treatment services** • Coverage of careseeking for treatment services for fever • Coverage of careseeking to an appropriate provider of treatment services for fever • Coverage of careseeking for fever within 24 hours • Coverage of careseeking for treatment services for suspected pneumonia • Coverage of careseeking for treatment services for suspected pneumonia

Mubiru 2015 *(Continued)*

- Coverage of careseeking for suspected pneumonia within 24 hours
- Coverage of careseeking for diarrhoea
- Coverage of careseeking to an appropriate provider of treatment services for diarrhoea

Notes	**Objective:** to evaluate the effects of iCCM on care seeking behaviour and treatment, 2 years after it has been introduced. **Implementation date:** July 2010 to December 2012. **Location:** 3 districts (Masaka, Mpigi and Wakiso) which in 2011 were divided into 8 districts by the government of Uganda (Wakiso, Mpigi, Butambala, Gomba, Masaka, Lwengo, Bukomansimbi and Kalungu). The majority of participants (≥ 67%) lived in rural areas. **Funding source:** Department of Foreign Affairs Trade and Development Canada through a grant administered by UNICEF.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Controlled before-after study, with no random sequence generation.
Allocation concealment (selection bias)	High risk	Controlled before-after study, with no allocation concealment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Blinding of outcome assessors not described in paper.
Incomplete outcome data (attrition bias) All outcomes	Low risk	The number of participating households was increased (from 2080 to 8000) between baseline and endline assessment. The response rate in both assessments were high: 99% (2076/2080) of eligible households participated at baseline and 97% (7734/8000) of eligible households participated at endline.
Selective reporting (reporting bias)	High risk	The outcomes listed in the objective of the paper were presented in the tables. However, grey literature indicates under-5 mortality was an original objective and that this was collected. The paper substantiated this by indicating a birth history was collected; however, the outcomes on mortality were not reported.
Baseline outcomes similar	High risk	There were some differences in baseline outcomes. • Higher prevalence of careseeking for fever, ARI and diarrhoea in the control. • Higher % of careseeking within 24 hours (timeliness of careseeking) in the control. • Higher % of appropriate treatment for fever and diarrhoea in the control. • Higher prevalence of fever, ARI and diarrhoea in the control which may have affected careseeking and treatment.
Baseline characteristics similar	High risk	There were some differences in baseline characteristics. • Higher % rural population in control areas.

Mubiru 2015 *(Continued)*

		• Higher mean household size in control areas. • Lower % of "least poor" households based on a household asset index in control areas. • Higher % of caregivers with no education in control areas.
Contamination	Low risk	Low risk of contamination due to districts being the unit of analysis and size of districts. VHTs in control areas were not trained on iCCM or provided with commodities for treatment.
Other bias	High risk	6/11 authors had UNICEF affiliations and UNICEF advocates iCCM. The endline survey in the control areas occurred in the dry season whereas the baseline survey for control areas and both the baseline survey and endline survey for the intervention areas were in the rainy season. Ebola may have affected implementation of iCCM, particularly for fever, in the intervention areas.

Munos 2016

Study characteristics	
Methods	**Design:** controlled before-after study **Unit of randomization:** none
Participants	**Inclusion criteria:** all women aged 15–49 years and children aged less than 5 years in the sampled households were eligible for the baseline and endline surveys **Exclusion criteria:** none reported
Interventions	**Intervention** • Training lay health workers – existing cadres of ASBC – to provide iCCM for diarrhoea, malaria, pneumonia (ARI) and malnutrition among children aged 2–59 months. • Training facility-based health workers on IMCI; emergency obstetric and newborn care; emergency triage and treatment • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers (ASBC) • Implementing referral of children under 2 months of age and children with severe disease to health facilities • Providing payment for iCCM providers (ASBC were provided with iCCM drugs and could sell these drugs to community members at a markup to provide a small financial "motivation" for their work) • Providing iCCM providers with iCCM drugs and equipment • Providing iCCM providers with supervision; frequency bimonthly for where iCCM for malaria and diarrhoea was implemented (it is unclear whether the authors used "bimonthly" to mean once every 2 months or twice every month); monthly where iCCM for malaria, diarrhoea and pneumonia was implemented; content and approach to supervision not reported **Comparison** Usual facility services + CCM for malaria in comparison districts. The comparison districts implemented similar interventions with the exception of iCCM. The study noted: "The facility component of the RSU ["Rapid Scale-Up"] used project funds to support activities such as integrated management of childhood illness (IMCI); emergency obstetric and newborn care; emergency triage and treatment training for clinicians; and acquisition of commodities, such as delivery tables and bag and mask kits for hospitals, which were expected to reduce maternal, newborn, and under-5 mortality. Funds were also used to support outreach activities such as child health days and insecticide-treated bednet (ITN) distribution campaigns. Because similar activities were ongoing throughout the country, the evaluation focused primarily on the implementation of iCCM, which was the one novel aspect of the project that

Munos 2016 *(Continued)*

	might be expected to accelerate changes in coverage and mortality in the project districts, relative to other areas of the country."
Outcomes	**Coverage of appropriate treatment (*study did not report on what type of provider or whether treatment was provided by an appropriate provider)** • Coverage of treatment for fever with ACT • Coverage of treatment for suspected pneumonia with antibiotics • Coverage of treatment for diarrhoea with ORS (*coverage of treatment with zinc was reported separately from coverage of treatment with ORS) **Coverage of careseeking to an 'appropriate provider'of treatment services** • Coverage of careseeking to an appropriate provider of treatment services for diarrhoea • Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia • Coverage of careseeking to an appropriate provider of treatment services for fever **Coverage of careseeking to a CHW (ASBC)** • Coverage of careseeking to a CHW (ASBC) for diarrhoea • Coverage of careseeking to a CHW (ASBC) for suspected pneumonia • Coverage of careseeking to a CHW (ASBC) for fever
Notes	**Objective:** to assess whether the programme objectives were met and to assess the impact of the RSU strategy relative to ongoing activities in the rest of the country. **Implementation date:** intervention implementation 2009–2014. Evaluation baseline in 2010 and endline in 2014. **Location:** 9 health districts comprising the Nord and Centre-Nord regions of the country. These regions were selected purposively by the Ministry of Health on the basis of high under-5 mortality levels, capacity to absorb the project funds, and relative lack of investment by health and development partners. The independent evaluation team had no input in the selection of the programme regions. **Funding source:** Bill and Melinda Gates Foundation through a grant administered by WHO.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Before-after study design, programme areas selected purposively by Ministry of Health. A set of 7 health districts was matched to the 9 intervention districts.
Allocation concealment (selection bias)	High risk	Non-randomized study with no allocation concealment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants or personnel.
Blinding of outcome assessment (detection bias) All outcomes	High risk	No blinding of outcome assessors.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Baseline and endline household surveys. Similar sample sizes of households achieved for the 2 survey rounds.

Munos 2016 *(Continued)*

Selective reporting (reporting bias)	Low risk	All stated outcomes were reported.
Baseline outcomes similar	High risk	Careseeking in programme areas higher at baseline.
Baseline characteristics similar	Low risk	Baseline characteristics appeared similar.
Contamination	Low risk	Only 2 districts had borders adjacent to comparison districts.
Other bias	Low risk	No other apparent source of bias.

White 2018

Study characteristics	
Methods	**Design:** controlled before-after study **Unit of randomization:** none
Participants	**Inclusion criteria:** children aged < 5 years and women aged 18–49 years within selected households located beyond 5 km from the nearest health facility **Exclusion criteria:** households and respondents who did not participate or were not available were not replaced
Interventions	**Intervention** • Recruiting and training lay health workers – CHW – to provide iCCM for diarrhoea, malaria, pneumonia (ARI) and malnutrition, including an active case finding approach. iCCM providers were also trained on community engagement, household registration, community mapping and how to conduct household visits, focusing on child health – with the expectation that they would visit every household in their catchment area at least once per month • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers, including an active case finding approach • Providing iCCM providers a monthly cash incentive of USD 70 for approximately 20 hours of work per week, additional compensation for training (daily subsistence allowance and travel expenses) • Providing iCCM providers with iCCM drugs and equipment • Providing iCCM providers and their supervisors with paper and mobile health tools to assist in workflow, help guide clinical decision-making and collect programmatic data • Providing iCCM providers with visual job aids to enable the correct assessment, diagnosis and treatment of children aged < 5 years correctly • Providing iCCM providers with supervision (CHW leaders were recruited, trained and paid (USD 220 per month) to provide weekly supervision; and Community Clinical Supervisors were recruited – from nurses, physician assistants and midwives – trained and paid (USD 313 per month) to provide monthly supervision) **Comparison** Usual facility services in the 3 control districts in Rivercess County: Doedain, population 13,051; Jo River, population 13,900; Timbo, population 19,776. As context the study indicated that gCHV were trained to provide iCCM in both intervention and control districts but actual provision of iCCM by gCHVs was minimal (i.e. careseeking to gCHVs was < 3% at baseline and 0% at endline in both intervention and control districts, see Table 3, page 1257). In terms of health services, the main difference between the intervention and control districts was the intervention described in the study

White 2018 *(Continued)*

Outcomes	**Objective:** to assess whether the programme increased treatment of fever, diarrhoea and ARI compared with a control area during the 1-year implementation period. **Implementation date:** August 2015 to July 2016. **Location:** the study was set in 6 districts of Rivercess County, Liberia. Rivercess County had a population of about 71,000 and was the poorest county in Liberia, with 71.3% of its population within the lowest wealth quintile of the country. Rivercess County also had among the lowest treatment rates for childhood illness and the highest proportion of women describing distance to health facility as a barrier to accessing health care. 3/6 districts were intervention districts (Central C, population 8303; Jowein, population 8921; Yarnee, population 7568) and the remaining 3 districts were control districts. **Funding source:** Direct Relief and the UBS Optimus Foundation.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Controlled before-after study, with no random sequence generation. Districts were purposefully selected.
Allocation concealment (selection bias)	High risk	Controlled before-after study, with no allocation concealment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Blinding of outcome assessors not described in the paper.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	Response rates were high: quote: "97.2% in 2015 and 98.4% in 2016 resulting in 455 and 539 surveys, respectively. Within eligible households, 82.2% of listed women participated in 2015 and 84.5% in 2016 (549 and 604 surveys); information about 97.5% of listed children was provided in 2015 and 99.3% in 2016, (340 and 492 surveys). Less than 3% of data items were missing." There was no indication of systematic differences between arms.
Selective reporting (reporting bias)	High risk	Assessing the effect of the intervention on under-5 mortality was a primary outcome and data were collected. The authors provided the following explanation: quote: "Although we collected data on early childhood mortality rates in both surveys, we were underpowered to detect mortality differences in the timeframe observed." P. 1258.
Baseline outcomes similar	Unclear risk	Risk was unclear. Baseline outcomes were not balanced between intervention and control groups per Table C in Appendix E (online supplementary material). Baseline coverage was higher in the control group for careseeking to an appropriate provider for any illness; careseeking to an appropriate provider for fever; careseeking to an appropriate provider for ARI; and ORT treatment for children with diarrhoea. The authors used a difference-in-difference approach adjusted by inverse probability weighting to deal with this type of imbalance; however, the residual risk of bias was unclear.

White 2018 *(Continued)*

Baseline characteristics similar	Unclear risk	Risk was unclear. The author's stated, "Overall, the samples were similar (Table 1); however, households in the intervention areas were farther from the nearest health facility than were those in the control areas at both time points. More households in the intervention group were in mining communities and more respondents in the intervention areas completed the survey in English than in the control group. In all groups, IPT weighting produced approximate balance, as seen by decreased standardized differences from the baseline control group. We present full IPT weighting balance diagnostics and an IPT-weighted version in Appendix C, Table A (available as a supplement to the online version of this article at http://www.ajph.org)." P. 1254. Furthermore, the authors stated, "Our study had several limitations. First, community mapping for the 2015 sampling frame was incomplete, which challenged the comparability of the baseline and follow-up samples. We used 2 approaches to improve balance between groups and time points: (1) IPT-weighted modeling and (2) regression adjustment. Results were similar with both approaches … After we applied IPT weights, no covariates had sufficiently different before-to-after differences between the intervention and control areas to explain the observed effect on childhood treatment (discussed in Appendix C, available as a supplement to the online version of this article at http://www. ajph.org). However, IPT weighting only corrects shifts in measured confounders, so unmeasured confounders may remain." P. 1257.
Contamination	Low risk	Prior to the study (and through a mechanism not related to the study) a cadre of volunteer lay health workers called gCHVs had been trained on iCCM and deployed to implement it in both the intervention and control districts. The authors stated, "In response to Liberia's poor maternal and child health outcomes, Last Mile Health, a nongovernmental organization, partnered with the Liberia Ministry of Health to implement a CHW programme, which included an iCCM component, in 2 counties in Liberia." (P. 1252). This was the intervention described in the study. The authors indicated that, "This program built upon Liberia's existing "general community health volunteer" programme, which included iCCM but lacked systematic supervision, supply chain systems, and monetary incentives." (P. 1252). These volunteer gCHVs continued to implement iCCM in both the intervention and control districts however implementation was weak, if not negligible, as indicated by the authors in their statement and as evidenced by the results of careseeking at baseline and endline (Table 3, P. 1257). At baseline 2.3% of caregivers in the intervention districts and 2.7% of caregivers in control districts sought treatment from gCHVs. At endline, 2.7% of caregivers in intervention districts and 0% of caregivers in control districts sought treatment from gCHVs in control districts. Since implementation was weak, the effect in terms of coverage negligible, and the fact that gCHVs were in both intervention and control districts, the risk of contamination by the gCHVs is low. The authors also indicated that their study informed the "development of a national-scale, government-led program called the National Community Health Assistant (CHA) Program, which uses a cadre of workers called CHAs performing similar duties as the CHWs in this study, which was launched by the Ministry of Health in 2016." (P. 1252). The risk of the CHA contaminating the study is low since it was launched in the areas targeted by the study only after the study was completed.
Other bias	Low risk	No other risks of bias were detected.

Yansaneh 2014

Study characteristics

Yansaneh 2014 *(Continued)*

Methods	**Design:** controlled before-after study **Unit of randomization:** none
Participants	**Inclusion criteria:** consenting children aged 0–59 months and caregivers of children aged 0–59 months residing in selected households with ≥ 1 child aged 0–59 months. Consenting caregivers provided information on disease prevalence, care seeking and treatment for children under-5 in the 2 weeks prior to the surveys **Exclusion criteria:** none reported
Interventions	**Intervention** • Recruiting and training lay health workers – CHV – to provide iCCM for diarrhoea, malaria and pneumonia among children aged < 5 and referral of children aged < 5 years with severe illness to health facilities • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers • Providing iCCM providers with non-monetary incentives such as community recognition, community help with household tasks of CHVs such as farming and exemption from community labour such as building or repairing roads and bridges • Providing iCCM providers with iCCM drugs and equipment • Providing iCCM providers and their supervisors with paper and mobile health tools to assist in workflow, help guide clinical decision-making, and collect programmatic data. • Providing iCCM providers with visual job aids to enable data collection and reporting • Providing iCCM providers with supervision; frequency monthly with direct observation of case management **Comparison** • Usual facility services
Outcomes	**Mortality** 2-week period prevalence (proportion of children with ICCM symptoms (diarrhoea, presumed malaria, presumed pneumonia, or a combination) 2 weeks prior to the survey **Coverage of appropriate treatment** Appropriate treatment by symptom (proportion of ill children who received appropriate treatment for their symptom (antimalarials including ACT for malaria, antibiotics including cotrimoxazole for pneumonia, and ORS and zinc for diarrhoea) per Ministry of Health and Sanitation of Sierra Leone, UNICEF and WHO guidelines) **Careseeking** Careseeking (proportion of children ill for whom care was sought) Careseeking from an appropriate provider (proportion of children ill in the previous 2 weeks for whom care was sought from healthcare professional such as a nurse, doctor or a trained CHV) Use of traditional treatment by symptom (having treatment besides syrups and tablets provided by allopathic healthcare workers) in the previous 2 weeks
Notes	**Objective:** to examine whether CHVs induced significant changes in careseeking and treatment of ill children aged < 5 years 2 years after their deployment in 2 underserved districts of Sierra Leone **Implementation date:** August 2010 to August 2012 **Location:** rural, poorest quintile districts of Sierra Leone. Kambia and Pujehun districts (intervention); Kailahun and Tonkolili districts (control)

Yansaneh 2014 *(Continued)*

Funding sources: Department of Foreign Affairs Trade and Development Canada through a grant administered by UNICEF.

Other: results for Yansaneh for outcomes in this review were based on unpublished results, recalculated using data provided by Yansaneh. Results had to be recalculated to align with standard definitions for out outcomes. The recalculated results used in this review were reviewed and confirmed by Yansaneh.

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Controlled before-after study, with no random sequence generation. Districts were purposefully selected.
Allocation concealment (selection bias)	High risk	Controlled before-after study, with no allocation concealment.
Blinding of participants and personnel (performance bias) All outcomes	High risk	No blinding of participants and personnel. Lay health workers would have known if they received additional training and this may have biased their performance. Allocation was by village and parents may have known that the health workers at their primary health centre had received additional training and this may have biased their care seeking behaviour or responses to questionnaires, or both.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Blinding of outcome assessors not described in the paper.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Response rates were high (94% at baseline and 96% at endline) and there no indication of systematic differences between arms.
Selective reporting (reporting bias)	Low risk	Outcomes were reported for all stated study outcomes.
Baseline outcomes similar	High risk	There were important differences in baseline outcomes, including: • higher % careseeking to an appropriate provider for diarrhoea in control areas; • higher % careseeking to an appropriate provider for suspected pneumonia in control areas.
Baseline characteristics similar	Unclear risk	Baseline characteristics were similar, with the exception of: • lower % of households with > 6 people in control areas; • lower % of households reporting being polygamous in control areas; • lower % of households reporting Islam as the household religion in control areas; • lower % of households reporting Mende as the household ethnicity in control areas.
Contamination	Low risk	Intervention areas (districts) and control areas (districts) were geographically separated, minimizing the risk of contamination.
Other bias	Low risk	3/9 authors have UNICEF affiliations and UNICEF advocates iCCM. Ebola may have affected implementation of iCCM, particularly for fever, e.g. causing a

Yansaneh 2014 *(Continued)*	shift away from using RDTs to implementing WHO's "no touch" policy, in the intervention areas.

ACT: artemisinin-based combination therapy; ARI: acute respiratory infection; ASBC: Agents de Santé à Base Communautaire; ASHA: Accredited Social Health Activists; CCM: community case management; gCHV: general community health volunteer; CHV: community health volunteer; CHW: community health worker; iCCM: integrated community case management; IMCI: integrated management of childhood illness; IMNCI: Integrated Management of Neonatal and Childhood Illness; ORS: oral rehydration salts; RDT: rapid diagnostic test; SIDA: Swedish Institute for Development Agency; UNDP: United Nations Development Programme; UNICEF: United Nations Children's Fund; USAID: United States Agency for International Development; VHT: village health team; WHO: World Health Organization.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Akter 2015	Wrong intervention
Alvarez-Morán 2018	Wrong comparator
Amouzou 2016a	Duplicate study
Amouzou 2016b	Duplicate study
Amouzou 2016c	Wrong comparator
Anand 2004	Wrong study design
Awoonor-Williams 2013	Wrong intervention
Bang 1990	Wrong intervention
Bang 1994	Wrong intervention
Bang 1999	Wrong intervention
Bang 2005	Wrong intervention
Baqui 2009	Wrong intervention
Bari 2011	Wrong intervention
Bhandari 2012b	Duplicate study
Bhandari 2012c	Duplicate study
Bhandari 2012d	Duplicate study
Bhandari 2012e	Duplicate study
Bhandari 2012f	Duplicate study
Bhutta 2011	Wrong intervention
Biemba 2016a	Duplicate study
Biemba 2016b	Duplicate study

Study	Reason for exclusion
Biemba 2016c	Wrong comparator
Brenner 2011	Wrong intervention
Brenner 2017a	Duplicate study
Brenner 2017b	Duplicate study
Brenner 2017c	Wrong study design
Callaghan-Koru 2013	Wrong study design
Chinbuah 2012	Duplicate study
Chinbuah 2013	Wrong intervention
Curtale 1995	Wrong study design
Dani 2017	Wrong intervention
Degefie 2017a	Duplicate study
Degefie 2017b	Wrong comparator
Ebuehi 2010	Wrong study design
Edward 2007	Wrong intervention
Fiedler 2008	Wrong intervention
Findley 2013	Wrong intervention
Ghimire 2010	Wrong study design
Gill 2011	Wrong intervention
Guenther 2017	Wrong study design
Habib 2013	Wrong intervention
Hamer 2012	Wrong comparator
Huque 2016	Wrong study design
ICDDR 2009a	Duplicate study
ICDDR 2009b	Duplicate study
IPPF 1989	Wrong study design
Iyer 2011	Wrong comparator
Jarolimova 2018	Wrong study design
Johnson 2016a	Duplicate study

Study	Reason for exclusion
Johnson 2016b	Duplicate study
Johnson 2016c	Duplicate study
Johnson 2016d	Duplicate study
Kafle 2013	Wrong intervention
Kallander 2012	Wrong intervention
Kalyango 2012b	Duplicate study
Kanté 2019b	Duplicate study
Lal 2015	Wrong intervention
Langston 2014	Wrong comparator
Littrell 2013	Wrong study design
Ma 2017	Duplicate study
Ma 2019b	Duplicate study
Maru 2018a	Duplicate study
Maru 2018b	Wrong comparator
Matovu 2014	Wrong study design
Mazumder 2014a	Duplicate study
Mazumder 2014b	Duplicate study
Menon 1990	Wrong intervention
Mugeni 2014	Wrong study design
Mukanga 2012a	Duplicate study
Mukanga 2012b	Wrong study design
Nanyonjo 2015	Wrong study design
NCT00513500	Duplicate study
NCT03371186	Duplicate study
Nzayirambaho 2013	Wrong intervention
Ogundele 2015	Wrong study design
Oliphant 2014	Wrong study design
Onono 2018	Wrong study design

Study	Reason for exclusion
Qazi 2017	Wrong comparator
Rahman 2016	Wrong intervention
Ratnayake 2017	Wrong study design
Rowe 2009	Wrong intervention
Seidenberg 2012	Wrong comparator
Siribie 2015	Wrong outcome
Sirima 2009a	Duplicate study
Sirima 2009b	Duplicate study
Soofi 2017a	Wrong intervention
Soofi 2017b	Wrong intervention
Tagbor 2011	Wrong intervention
Taneja 2015	Duplicate study
Teferi 2014a	Wrong study design
Teferi 2014b	Wrong study design
Tikmani 2016	Wrong intervention
Tine 2011	Wrong intervention
Tiono 2008a	Duplicate study
Tiono 2008b	Wrong intervention
Uganda 2009	Wrong study design
Uwemedimo 2018	Wrong study design
Yeboah-Antwi 2010a	Duplicate study
Yeboah-Antwi 2010b	Duplicate study
Yeboah-Antwi 2010c	Wrong comparator

Characteristics of studies awaiting classification *[ordered by study ID]*

Kanté 2019a

Methods	**Design:** cluster-randomized trial, including continuous health and demographic surveillance through the Health and Health and Demographic Surveillance System of the Ifakara Institute **Unit of randomization:** village

Kanté 2019a *(Continued)*

Participants	**Inclusion criteria:** population in intervention and control villages **Exclusion criteria:** none stated
Interventions	**Intervention** • Training lay health workers (CHW) to provide iCCM for diarrhoea, malaria (in high-risk areas), pneumonia (ARI) and malnutrition among children aged 2–59 months. CHWs were also trained on a broader package of promotive, preventive and curative interventions across the life cycle, including for neonates, postneonates, infancy and childhood, adolescence and adulthood • Providing incentives for lay health workers (CHW were paid an annual salary in Tanzanian Shillings amounting to USD 1348.21) • Providing iCCM providers (CHW) with drugs and equipment • Implementing simplified IMCI-adapted clinical guidelines for iCCM providers (CHW) • Implementing referral of children aged < 2 months and children with severe disease to health facilities • Training supervisors (Council Health Management Team, consisting of project field co-ordinator, village authorities and health workers posted in a nearby health facility) of iCCM providers (CHWs) on supportive supervision • Providing supervision (Council Health Management Team) to iCCM providers (CHWs); frequency, content and approach of supervision not reported **Comparison** Usual facility services
Outcomes	**Mortality** • Neonatal mortality (deaths between birth and day 28 of life) • Infant mortality (deaths between birth and day 365 of life) • Under-5 mortality (deaths between birth and age 5 years) Note: data for other outcomes were collected but not reported in the publication, including maternal mortality ratio and adult mortality rates, childhood morbidity, cause of death distribution for children under-5 years, life years gained, coverage of health services (e.g. rates of antenatal care, skilled attendance at birth, facility delivery, postnatal care, immunization, treatment with ORS, antimalarial medicines, and antibiotics and contraceptive prevalence) the total fertility rate, parental health-seeking behaviours during child illness, and other parental health behaviours such as prevalence of immediate and exclusive breastfeeding.
Notes	**Objective:** to evaluate the childhood survival impact of deploying paid CHWs to provide doorstep preventive, promotional and curative antenatal, newborn, child, and reproductive health care in 3 rural Tanzanian districts. **Location:** 3 districts, including Ifakara and Ulanga districts – 2 rural, remote and poor districts of Morogoro region of southwestern Tanzania – 500 km by road from Dar-es-Salaam in communities covered by the Ifakara Health Institute and Rufiji district in Coast region, about 150 km by road from Dar-es-Salaam. The economies of the 3 districts are dominated by farming, fishing and petty trade. The population was approximately 380,000 people, residing in 101 villages in 2015. Prior to intervention, the main causes of childhood mortality were malaria (7.8 deaths per 1000 person-years), ARIs including pneumonia (2.8 deaths per 1000 person-years) and prematurity and low birthweight (1.9 deaths per 1000 person-years) and other preventable causes such as diarrhoeal diseases, birth injuries and asphyxia, anaemia and malnutrition. **Funding source:** the US-based Doris Duke Charitable Foundation (DDCF) and Comic Relief in the UK financed the trial. Advisors to the DDCF commented on the study design prior to implementation.

Ma 2019a

Methods	**Design:** cluster-randomized controlled trial **Unit of randomization:** village
Participants	Children aged < 5 years of age and caregivers in households located in the trial catchment area that had ≥ 1 child under 5 years of age. In households with > 1 child, the youngest child was recruited. Following the baseline, children were not excluded from subsequent surveys if they had their 5th birthday before the surveys were implemented.
Interventions	**Intervention** • Training lay health workers (CHVs) to provide household visits 2 per month to all households in their catchment and to provide key messages on disease prevention and healthy behaviours during household visits; identify children with diarrhoea and treat them with ORS; identify febrile children and test them for malaria using an RDT and refer RDT-positive children to health facilities for treatment Based on this intervention the study would not meet inclusion criteria for this review due to "wrong intervention" (only CHVs only treated diarrhoea); however, we will assess for inclusion at the next update of this review. **Comparison** • Usual facility services
Outcomes	Primary outcomes • 14-day prevalence of diarrhoea at 6 months and 12 months among children aged < 5 years • 14-day prevalence of malaria among at 6 months and 12 months among children aged < 5 years Secondary outcomes • Coverage of diarrhoea treatment (oral rehydration therapy) among children aged < 5 years with diarrhoea • Coverage of RDT for malaria among children aged < 5 years with fever • Coverage of family planning practices of caregivers Based on the above outcomes the study would not meet the inclusion criteria for this review; however, we will assess for inclusion at the next update of this review.
Notes	**Objective:** to assess the effect of a CHV intervention on reducing diarrhoea and fever prevalence in children aged < 5 years, and the participants were followed up at 6 months and 12 months after the intervention started. Associations of CHVs' home visit coverage and intensity with the primary outcomes, 14-day diarrhoea and fever prevalence, were also examined. **Location:** 40 communities (20 intervention communities, 20 control communities) in the Volta region, Ghana. **Funding source:** Korea International Cooperation Agency (KOICA) under the "Project for Improving Maternal and Child Healthcare in Volta Region, Ghana (P2013-001921). The authors stated: "The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript."

NCT02151578

Methods	**Design:** cluster-randomized controlled trial

NCT02151578 *(Continued)*	
	Unit of randomization: clusters (villages)
Participants	**Inclusion criteria:** children aged 6–59 months of age living in of the study clusters (villages), no history of allergy to any of the study drugs, history of fever or body temperature ≥ 38.5 °C **Exclusion criteria:** signs of severity/complications like impaired consciousness, convulsions, fast breathing, etc.
Interventions	3 intervention arms **Intervention 1: HMM** At the community level, the CHW/ key opinion leader trained and equipped to provide the antimalarial drug (arthemeter/lumefantrine) to any child with fever ("hot body") without any other signs of complications like impaired consciousness, convulsions, etc **Intervention 2: HMMP** At the community level, the CHW/key opinion leader trained and equipped to provide the antimalarial drug (arthemeter/lumefantrine) or antibiotic (cotrimoxazole) to any child with fever ("hot body") without any other signs of complications like impaired consciousness, convulsions, etc. The treatment decision making for the CHWs/key opinion leaders based on the algorithm **Comparison: nothing at home level (usual health facility services)** No intervention at community level. The study drugs (arthemeter/lumefantrine and cotrimoxazole) available at the health facility drug stores level and prescribed exclusively to sick children attending to the health facility for careseeking. No CHW/key opinion leader selected in those clusters **Comparisons performed:** HMM compared to usual health services; HMMP compared to usual health services; HMM compared to HMMP
Outcomes	**Primary outcomes:** number of deaths in children aged 6–59 months; annual crude mortality rate in children aged 0–6 months **Other outcomes measured:** specific mortality preceded by acute febrile illness of children aged 6–59 months – severe malaria cases at community level; adverse events at community level consecutive to the administration of the cotrimoxazole and arthemeter/lumefantrine
Notes	**Objective:** to test the hypothesis that an integrated approach of home and community management of malaria and pneumonia may increase the proportion of children receiving prompt treatment; improve child survival as measured by a reduction of the under-5 mortality rate. **Location:** 111 clusters of a rural district in Burkina Faso where malaria and pneumonia are 2 major causes of under-5 mortality. **Funding source:** the record on ClinicalTrials.gov indicates the following sponsors and collaborators but it is not clear whether these are the same as the funding source: WHO. **Notes:** according to the record on Clinical.Trials.gov (clinicaltrials.gov/ct2/show/study/NCT02151578), the study started in January 2009 and final data collection for primary outcomes occurred in June 2012. The study was completed in September 2012. Results have not been posted on ClinicalTrials.gov or published elsewhere (to our knowledge).

ARI: acute respiratory infection; ASHA: Accredited Social Health Activists; CCM: community case management; CHV: community health volunteer; CHW: community health worker; HMM: home management of malaria; HMMP: home management of malaria and pneumonia; iCCM: integrated community case management; IMCI: integrated management of childhood illness; ORS: oral rehydration therapy; RDT; rapid diagnostic test; WHO: World Health Organization.

Characteristics of ongoing studies *[ordered by study ID]*

NCT00979797

Study name	Community-Integrated Management of Childhood Illness (IMCI) programme evaluation **Official title:** an assessment of public health effectiveness of approaches to promote key family and community behaviours for child survival
Methods	**Design:** cluster-randomized controlled trial **Unit of randomization:** Upazilas (subdistricts)
Participants	**Inclusion criteria:** children aged < 5 years and women aged 15–49 years in areas with facility-based IMCI in place **Exclusion criteria:** children aged > 5 years; women aged < 15 and > 49 years
Interventions	**Intervention** • Community-based IMCI in the intervention upazillas will be implemented through the district health system while in the comparison upazillas existing services will continue, including facility-based IMCI **Comparison** • Usual health facility services, including facility-based IMCI
Outcomes	**Primary outcomes:** under-5 mortality; coverage of appropriate careseeking for childhood illness; coverage of exclusive breastfeeding; nutritional status (weight-for-age) **Other outcomes measured:** antenatal and postnatal care; deliveries by trained birth attendants; essential newborn care (drying and wrapping, delayed bathing, breastfeeding; complementary feeding; quality of care provided by health workers
Starting date	July 2009
Contact information	International Centre for Diarrhoeal Disease Research, Bangladesh
Notes	**Objective:** the proposed 4-year randomized study will attempt to test the hypothesis that community-based child health interventions in conjunction with facility-based IMCI will improve childcare practices, nutritional status and child survival. The objectives of this research are: • to measure the effectiveness of the community-based interventions in improving selected childcare practices in the community; • to measure the effectiveness of the community-based interventions in improving child nutritional status and in reducing child morbidity and mortality; • to document the process of implementation of community-based interventions at scale to promote selected key family and community practices related to child health; • to undertake cost-effectiveness analysis of the interventions. **Location:** 14 Upazilas (subdistricts) in Bangladesh. **Funding source:** the record on ClinicalTrials.gov indicates the following sponsors and collaborators but it is not clear whether these are the same as the funding source: International Centre for Diarrhoeal Disease Research, Bangladesh; Directorate General for Health Services, Ministry of Health, Bangladesh; Johns Hopkins Bloomberg School of Public Health; World Health Organization; UNICEF. **Notes:** according to the record on ClinicaTrials.gov (clinicaltrials.gov/ct2/show/record/NCT00979797), the study started in July 2009 and final data collection for primary outcomes occurred in December 2013. The record indicates, "Results information has been submitted to Clini-

NCT00979797 *(Continued)*

	calTrials.gov by the sponsor or investigator, but is not yet publicly available (or "posted") on ClinicalTrials.gov. The submitted information may not be available if it is pending Quality Control (QC) Review by the National Library of Medicine (NLM) or if issues identified during QC review are being addressed or corrected by the sponsor or investigator. NLM's limited QC review assesses for apparent errors, deficiencies, or inconsistencies. NLM staff do not verify the scientific validity or relevance of the submitted information." The results were submitted to ClinicalTrials.gov on 2 June 2018 and results returned after quality control review on 28 December 2018.

Rabbani 2014

Study name	Improving community case management of diarrhoea and pneumonia in district Badin, Pakistan through a cluster randomised study – the NIGRAAN trial protocol
Methods	Cluster-randomized trial

Participants	• LHSs
	• LHWs
	• Caregivers of children aged < 5 years in the population of the study sites
	  • Community caregiver/parent/guardian permanently residing in the household falling under the geographical scope/coverage area of the LHW enrolled into the study
	  • Community caregiver residing in a household that has ≥ 1 child under 5 years of age

Interventions	**Intervention** • Training to build LHS knowledge and skills, clinical mentorship and written feedback to LHWs of LHWs already trained on iCCM for diarrhoea and pneumonia **Comparison** • Usual health services, including iCCM for diarrhoea and pneumonia. Based on this comparison, the study would not meet inclusion criteria of this review due to "wrong comparator" (the control has iCCM, the difference between the intervention clusters and control clusters being the addition of the enhanced supervisory strategies;" however, we will assess inclusion at the next update of this review
Outcomes	Primary outcome • Improvement in CCM practices of diarrhoea and pneumonia Secondary outcomes • Improved knowledge, skills and supervisory processes among LHSs for CCM of pneumonia and diarrhoea in children aged < 5 years • Improvement in LHW knowledge, skills and performance as a result of structured supportive supervision by LHSs • Improved knowledge of community caregivers through interactions with LHWs and LHSs during community management of children with diarrhoea and pneumonia Based on outcomes reported in the protocol, it is unclear whether this study would meet inclusion criteria for this review; however, we will assess inclusion at the next update of this review.
Starting date	November 2014; scheduled to end 9–12 months after start
Contact information	Fauziah Rabbani; contact information not provided. Contact possible through a link in the online version of the article doi.org/10.1186/s13012-014-0186-9

Rabbani 2014 *(Continued)*

Notes	**Objective:** to improve CCM of childhood diarrhoea and pneumonia by health workers (LHWs and LHSs) and community caregivers (e.g. mothers) through strengthened supervision and mentorship by LHSs **Location:** District Badin, Pakistan **Funding:** WHO, Geneva, Department of Maternal, Newborn, Child and Adolescent Health

Taneja 2017

Study name	Enhanced community case management to increase access to pneumonia treatment
Methods	Cluster-randomized controlled trial
Participants	Infants aged 7–59 days with fast breathing and children aged 2–59 months with chest indrawing pneumonia without hypoxaemia Exclusion criteria: non-consent, danger signs, hypoxaemia
Interventions	Enhanced iCCM for diarrhoea and pneumonia, with the addition of pulse oximetry by LHWs (ASHA) for the latter Quote: "The study is a cluster randomized open label non inferiority trial where subcentres will be randomized into intervention and control. Infants aged 7–59 days with fast breathing and absence of danger signs and hypoxaemia and children aged 2–59 months with chest indrawing and absence of danger signs and hypoxaemia will be treated with amoxicillin by ASHAs in the intervention clusters and referred to health facilities in the control cluster. Cases identified by ASHAs will be assessed and all enrolled children will be followed up on days 1, 2, 4 and 7. An independent team will assess outcomes on days 6 and 14 post identification of case. Acceptability and feasibility of using pulse oximetry will be examined."
Outcomes	Primary outcomes • Death between day 1 and day 14 of enrolment • Persistence of fast breathing in infants aged 7–59 days or persistence of chest indrawing in children aged 2–59 months at day 6 of enrolment • Child hospitalized for any reason or has any indication of hospitalizations at day 6 of enrolment • Development of serious adverse effect during the treatment period Secondary outcomes • Evaluating the accuracy of pulse oximetry used by ASHA against standardized measurement by a trained supervisor • Evaluating the impact of use of pulse oximetry on referral and treatment outcomes
Starting date	1 February 2017; end date 31 July 2018
Contact information	Dr Sunita Taneja; sunita.taneja@sas.org.in
Notes	**Objective:** to assess the effect of enhanced iCCM for diarrhoea and pneumonia treatment on mortality, treatment outcomes, accuracy of pulse oximetry used by ASHA and referral and treatment outcomes **Location:** India (subnational location not specified) **Comparison:** usual health services without enhanced iCCM **Funding:** WHO, Geneva

Whidden 2019a

Study name	Proactive community case management and child survival: protocol for a cluster randomised controlled trial
Methods	Unblinded, cluster-randomized controlled trial
Participants	Children aged < 5 years and their caregivers
Interventions	**Intervention** • Proactive iCCM: LHWs (CHWs) conduct daily proactive case-finding home visits and deliver doorstep counsel, care, referral and follow-up "In clusters assigned to the intervention arm, CHW(s) will be trained and deployed to conduct proactive case finding, door-to-door home visits for at least 2 hours each day, 6 days a week, with the goal of visiting each household at least two times each month. During the home visit, CHWs will screen all household members for recent illness or symptoms and provide services at the home, including follow-up for sick children and adults, pregnant women, newborns and postpartum mothers. In addition to home visits, ProCCM CHWs will provide care at their community health site for at least 2 hours a day, 6 days per week, according to a calendar shared with the community. At the health site, CHWs will provide the same services as those offered by CHWs in the control arm to care-seeking patients." P. 4. **Comparison** • Usual health services, including iCCM by CHWs at fixed sites within communities
Outcomes	Primary outcome • Under-5 mortality: deaths among children aged < 5 years per 1000 person-years at risk of mortality Secondary outcomes • Infant mortality (deaths per 1000 live births among children aged 0–11 months) • Newborn mortality (deaths per 1000 live births among children aged 0–28 days) • Pregnancy-related mortality ratio (number of deaths among women while pregnant or within 42 days of delivery or termination per 100,000 live births per year) if there is sufficient and robust data to do so. • Receipt of ORS and zinc within 24 hours of diarrhoea onset among children aged < 5 years • Receipt of diagnostic testing or effective treatment (or both) for malaria within 24 hours of fever onset among children aged < 5 years • Evaluation by a qualified provider within 24 hours of symptom onset among children aged < 5 years with cough or fast breathing (or both) • Receipt of ≥ 3 doses of sulphadoxine–pyrimethamine as intermittent preventive treatment during a woman's most recent pregnancy **Comparison** • Usual health services, including iCCM by CHWs at fixed sites within communities
Starting date	Baseline: December 2016 to February 2017 Implementation: February 2017
Contact information	Caroline Whidden; cwhidden@musohealth.org
Notes	**Objective:** to generate evidence on the efficacy, cost-effectiveness and equity of door-to-door proactive case detection by CHWs on access to care and child mortality. P. 1.

Whidden 2019a *(Continued)*

Location: 69 village clusters (intervention arm) and 68 village clusters (control arm) in Bankass health district of the Mopti region in Mali.

Funding source: resources received by Muso though unrestricted funding as well as dedicated research funding from Child Relief International Foundation, Grand Challenges Canada, Johnson & Johnson Foundation and USAID Development Innovation Ventures. Child Relief International Foundation serves as the nonlegal sponsor of the trial." P. 8.

Other notes: original protocol published as: Whidden 2019a at ClinicalTrials.gov: NCT02694055; subsequently the protocol was published as: Whidden C, Treleaven E, Liu J, et al. Proactive community case management and child survival: protocol for a cluster randomised controlled trial BMJ Open 2019;9:e027487. doi: 10.1136/bmjopen-2018-027487.

ASHA: Accredited Social Health Activists; CCM: community case management; CHW: community health worker; iCCM: integrated community case management; IMCI: integrated management of childhood illness; LHS: lady health supervisor; LHW: lady health worker; ORS: oral rehydration salts; UNICEF: United Nations Children's Fund; USAID: United States Agency for International Development; WHO: World Health Organization.

DATA AND ANALYSES

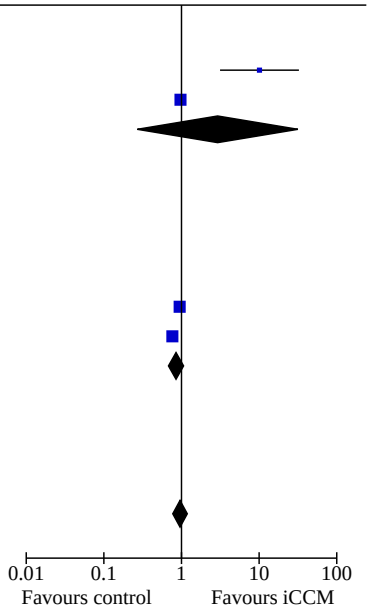
Comparison 1. iCCM versus usual facility services

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.1 Comparison 1 iCCM vs usual facility services: coverage of appropriate treatment by an appropriate provider (CBA)	2	5898	Risk Ratio (M-H, Random, 95% CI)	0.96 [0.77, 1.19]
1.1.1 Diarrhoea (CBA)	2	1749	Risk Ratio (M-H, Random, 95% CI)	2.92 [0.27, 31.60]
1.1.2 Malaria (CBA)	2	4149	Risk Ratio (M-H, Random, 95% CI)	0.85 [0.68, 1.06]
1.2 Comparison 1 iCCM vs usual facility services: coverage of appropriate treatment by an iCCM provider (CBA)	1	4651	Risk Ratio (M-H, Random, 95% CI)	124.40 [17.37, 890.83]
1.2.1 Diarrhoea (CBA)	1	1375	Risk Ratio (M-H, Random, 95% CI)	128.99 [7.99, 2083.46]
1.2.2 Malaria (CBA)	1	3276	Risk Ratio (M-H, Random, 95% CI)	119.96 [7.40, 1945.55]
1.3 Comparison 1 iCCM vs usual facility services: mortality (cRCT)	2		Risk Ratio (IV, Random, 95% CI)	Subtotals only
1.3.1 Neonatal mortality (cluster randomized controlled trial (cRCT))	2	65209	Risk Ratio (IV, Random, 95% CI)	1.01 [0.77, 1.33]
1.3.2 Infant mortality (cRCT)	2	65209	Risk Ratio (IV, Random, 95% CI)	0.98 [0.72, 1.34]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1.3.3 Under-five mortality (cRCT)	1	4729	Risk Ratio (IV, Random, 95% CI)	1.16 [0.99, 1.36]
1.4 Comparison 1 iCCM vs usual facility services: coverage of careseeking to an appropriate provider of treatment services (cRCT)	2	9853	Risk Ratio (M-H, Random, 95% CI)	1.68 [1.24, 2.27]
1.4.1 Diarrhoea (cRCT)	2	3049	Risk Ratio (M-H, Random, 95% CI)	1.44 [1.12, 1.85]
1.4.2 Fever (cRCT)	1	1101	Risk Ratio (M-H, Random, 95% CI)	1.61 [1.37, 1.90]
1.4.3 Suspected pneumonia (cRCT)	2	1328	Risk Ratio (M-H, Random, 95% CI)	1.39 [1.03, 1.88]
1.4.4 Newborn local infection (cRCT)	1	2096	Risk Ratio (M-H, Random, 95% CI)	4.62 [3.92, 5.44]
1.4.5 Newborn danger signs (cRCT)	1	2279	Risk Ratio (M-H, Random, 95% CI)	1.59 [1.43, 1.77]
1.5 Comparison 1 iCCM vs usual facility services: coverage of careseeking to an appropriate provider of treatment services (CBA)	3	8406	Risk Ratio (M-H, Random, 95% CI)	1.30 [1.01, 1.66]
1.5.1 Diarrhoea (CBA)	3	2028	Risk Ratio (M-H, Random, 95% CI)	1.14 [0.91, 1.41]
1.5.2 Fever (CBA)	3	4509	Risk Ratio (M-H, Random, 95% CI)	1.57 [0.57, 4.31]
1.5.3 Suspected pneumonia (CBA)	3	1869	Risk Ratio (M-H, Random, 95% CI)	1.15 [1.06, 1.24]
1.6 Comparison 1 iCCM vs usual facility services: coverage of careseeking to an iCCM provider (CBA)	2	6581	Risk Ratio (M-H, Random, 95% CI)	158.58 [51.04, 492.70]
1.6.1 Diarrhoea (CBA)	2	1654	Risk Ratio (M-H, Random, 95% CI)	140.28 [19.66, 1000.95]
1.6.2 Fever (CBA)	2	3657	Risk Ratio (M-H, Random, 95% CI)	253.13 [35.57, 1801.37]
1.6.3 Suspected pneumonia (CBA)	2	1270	Risk Ratio (M-H, Random, 95% CI)	112.26 [15.77, 799.31]

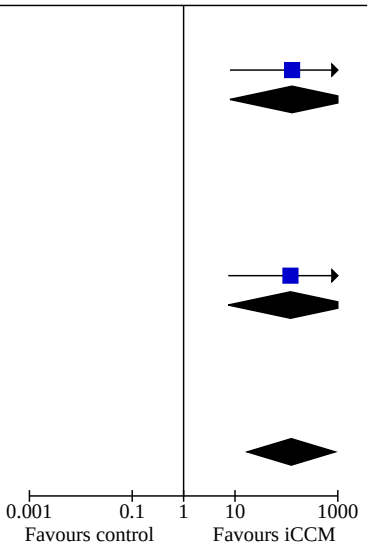
Analysis 1.1. Comparison 1: iCCM versus usual facility services, Outcome 1: Comparison 1 iCCM vs usual facility services: coverage of appropriate treatment by an appropriate provider (CBA)

Study or Subgroup	iCCM Events	iCCM Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
1.1.1 Diarrhoea (CBA)						
Mubiru 2015	30	186	3	188	3.1%	10.11 [3.14 , 32.55]
Yansaneh 2014	335	642	394	733	32.3%	0.97 [0.88 , 1.07]
Subtotal (95% CI)		**828**		**921**	**35.3%**	**2.92 [0.27 , 31.60]**
Total events:	365		397			
Heterogeneity: Tau² = 2.78; Chi² = 16.52, df = 1 (P < 0.0001); I² = 94%						
Test for overall effect: Z = 0.88 (P = 0.38)						
1.1.2 Malaria (CBA)						
Mubiru 2015	236	368	342	505	32.4%	0.95 [0.86 , 1.04]
Yansaneh 2014	412	1413	712	1863	32.3%	0.76 [0.69 , 0.84]
Subtotal (95% CI)		**1781**		**2368**	**64.7%**	**0.85 [0.68 , 1.06]**
Total events:	648		1054			
Heterogeneity: Tau² = 0.02; Chi² = 10.30, df = 1 (P = 0.001); I² = 90%						
Test for overall effect: Z = 1.42 (P = 0.15)						
Total (95% CI)		**2609**		**3289**	**100.0%**	**0.96 [0.77 , 1.19]**
Total events:	1013		1451			
Heterogeneity: Tau² = 0.03; Chi² = 30.28, df = 3 (P < 0.00001); I² = 90%						
Test for overall effect: Z = 0.40 (P = 0.69)						
Test for subgroup differences: Chi² = 1.02, df = 1 (P = 0.31), I² = 2.3%						



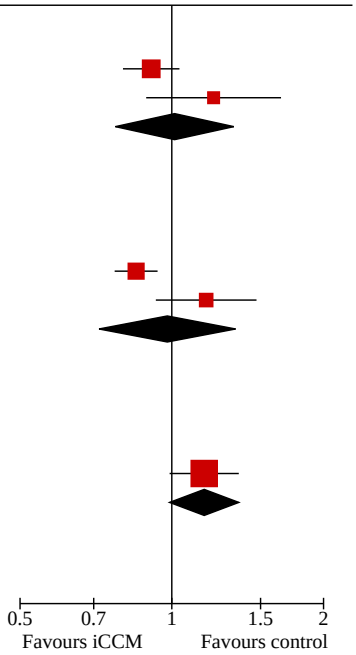
Analysis 1.2. Comparison 1: iCCM versus usual facility services, Outcome 2: Comparison 1 iCCM vs usual facility services: coverage of appropriate treatment by an iCCM provider (CBA)

Study or Subgroup	iCCM Events	iCCM Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
1.2.1 Diarrhoea (CBA)						
Yansaneh 2014	56	642	0	733	50.1%	128.99 [7.99 , 2083.46]
Subtotal (95% CI)		**642**		**733**	**50.1%**	**128.99 [7.99 , 2083.46]**
Total events:	56		0			
Heterogeneity: Not applicable						
Test for overall effect: Z = 3.42 (P = 0.0006)						
1.2.2 Malaria (CBA)						
Yansaneh 2014	45	1413	0	1863	49.9%	119.96 [7.40 , 1945.55]
Subtotal (95% CI)		**1413**		**1863**	**49.9%**	**119.96 [7.40 , 1945.55]**
Total events:	45		0			
Heterogeneity: Not applicable						
Test for overall effect: Z = 3.37 (P = 0.0008)						
Total (95% CI)		**2055**		**2596**	**100.0%**	**124.40 [17.37 , 890.83]**
Total events:	101		0			
Heterogeneity: Tau² = 0.00; Chi² = 0.00, df = 1 (P = 0.97); I² = 0%						
Test for overall effect: Z = 4.80 (P < 0.00001)						
Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.97), I² = 0%						



Analysis 1.3. Comparison 1: iCCM versus usual facility services, Outcome 3: Comparison 1 iCCM vs usual facility services: mortality (cRCT)

Study or Subgroup	log[RR]	SE	Experimental Total	Control Total	Weight	Risk Ratio IV, Random, 95% CI
1.3.1 Neonatal mortality (cluster randomized controlled trial (cRCT))						
Bhandari 2012a	-0.094	0.0658	29667	30813	62.5%	0.91 [0.80 , 1.04]
Boone 2016 (1)	0.191	0.1571	2326	2403	37.5%	1.21 [0.89 , 1.65]
Subtotal (95% CI)			**31993**	**33216**	**100.0%**	**1.01 [0.77 , 1.33]**
Heterogeneity: Tau² = 0.03; Chi² = 2.80, df = 1 (P = 0.09); I² = 64%						
Test for overall effect: Z = 0.09 (P = 0.93)						
1.3.2 Infant mortality (cRCT)						
Bhandari 2012a (1)	-0.163	0.05	29667	30813	55.5%	0.85 [0.77 , 0.94]
Boone 2016	0.157	0.1173	2326	2403	44.5%	1.17 [0.93 , 1.47]
Subtotal (95% CI)			**31993**	**33216**	**100.0%**	**0.98 [0.72 , 1.34]**
Heterogeneity: Tau² = 0.04; Chi² = 6.30, df = 1 (P = 0.01); I² = 84%						
Test for overall effect: Z = 0.13 (P = 0.90)						
1.3.3 Under-five mortality (cRCT)						
Boone 2016 (2)	0.148	0.0806	2326	2403	100.0%	1.16 [0.99 , 1.36]
Subtotal (95% CI)			**2326**	**2403**	**100.0%**	**1.16 [0.99 , 1.36]**
Heterogeneity: Not applicable						
Test for overall effect: Z = 1.84 (P = 0.07)						
Test for subgroup differences: Chi² = 1.31, df = 2 (P = 0.52), I² = 0%						

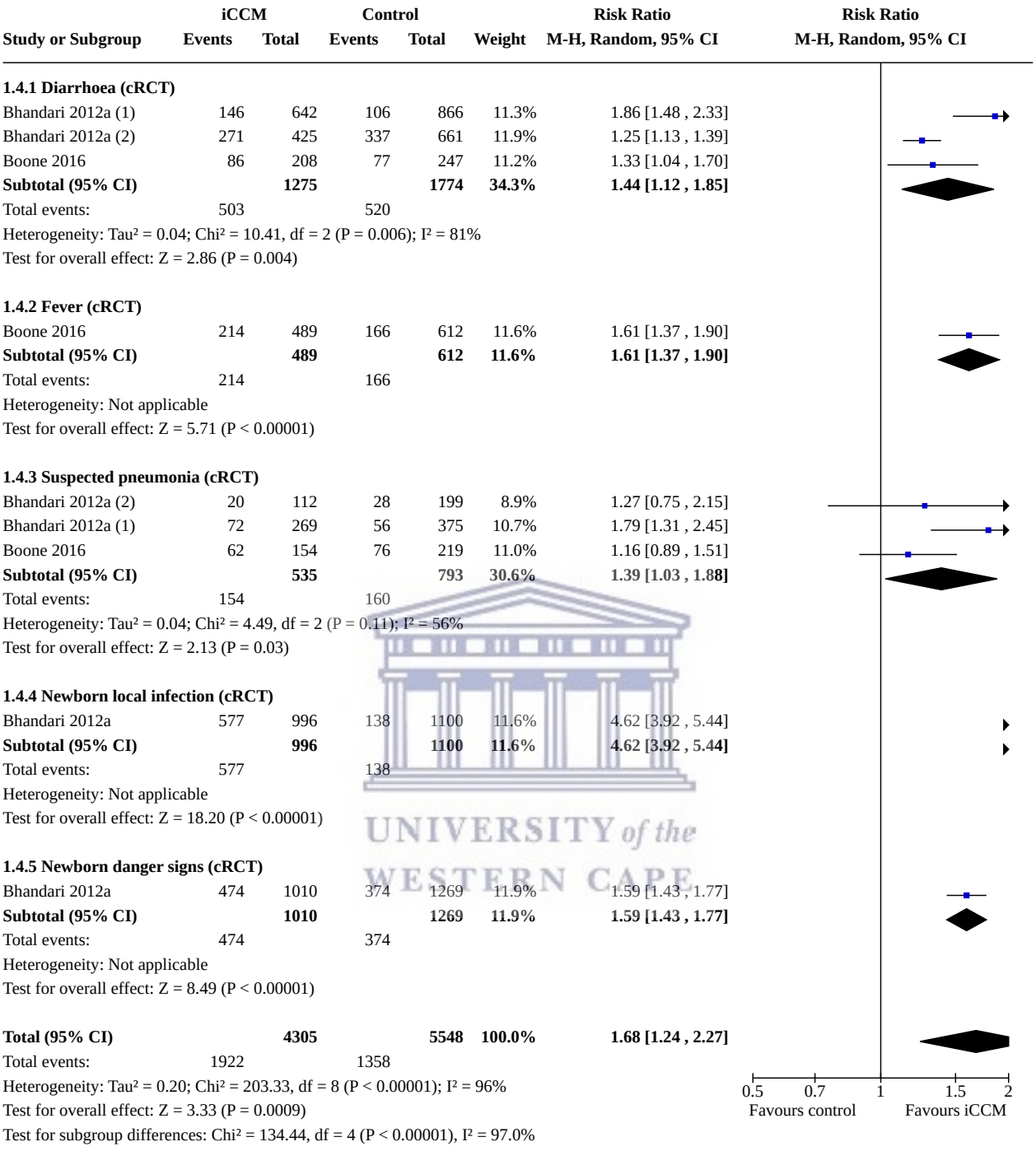


Footnotes

(1) Please note that these are all Hazard Ratios rather than risk ratios

(2) Please note that this is a Hazard Ratios rather than a risk ratio

Analysis 1.4. Comparison 1: iCCM versus usual facility services, Outcome 4: Comparison 1 iCCM vs usual facility services: coverage of careseeking to an appropriate provider of treatment services (cRCT)

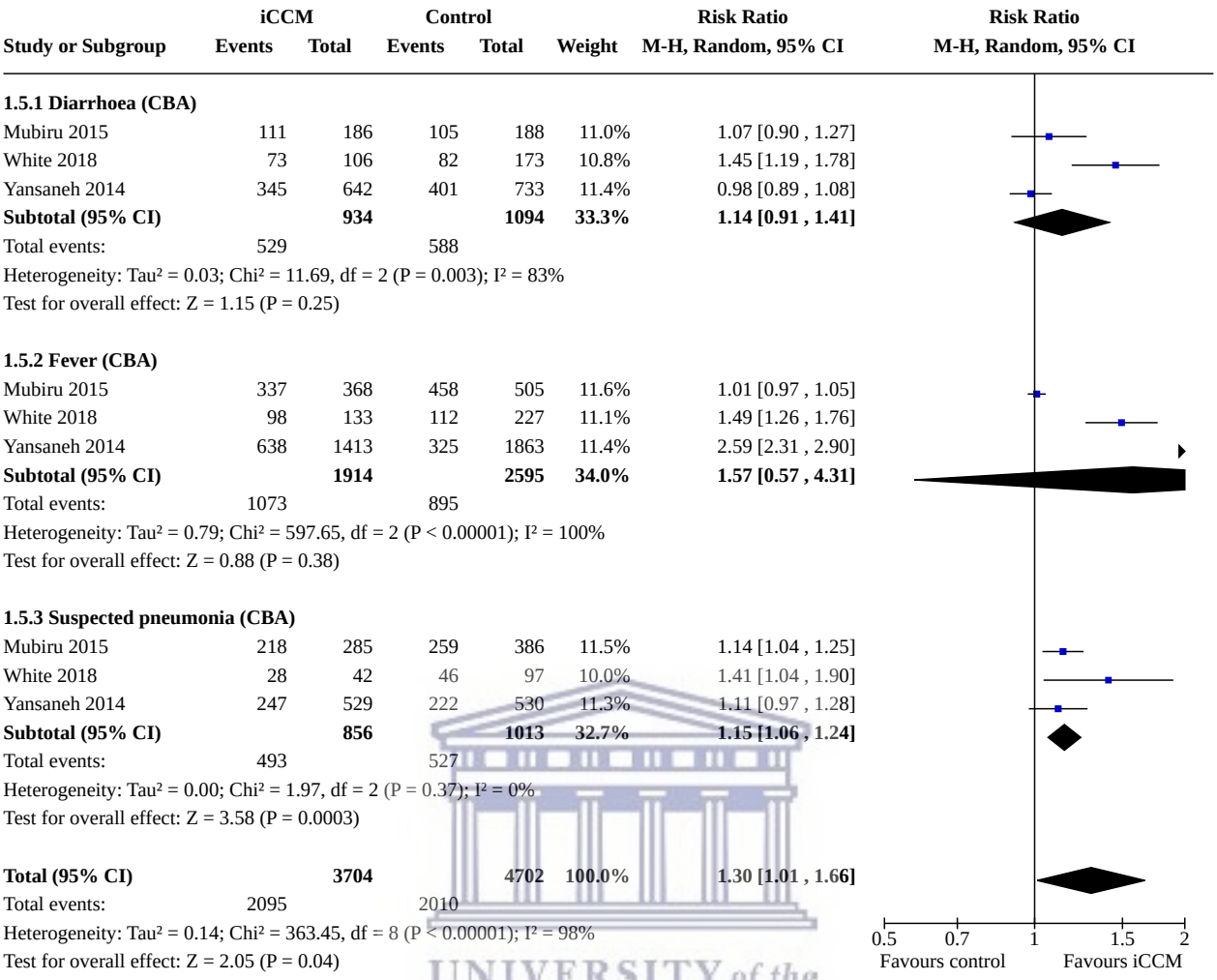


Footnotes

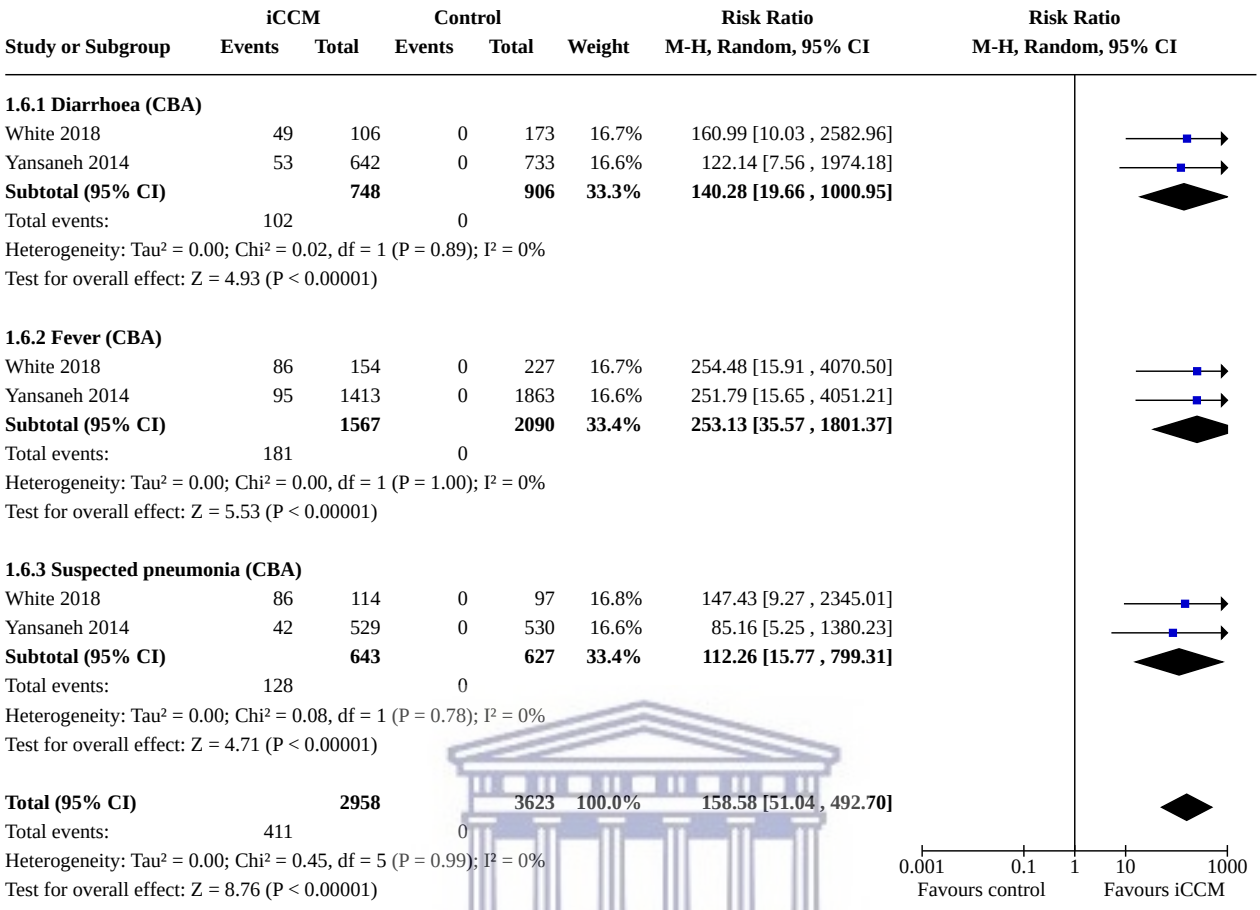
(1) Among children 6 months of age

(2) Among children 12 months of age

Analysis 1.5. Comparison 1: iCCM versus usual facility services, Outcome 5: Comparison 1 iCCM vs usual facility services: coverage of careseeking to an appropriate provider of treatment services (CBA)



Analysis 1.6. Comparison 1: iCCM versus usual facility services, Outcome 6: Comparison 1 iCCM vs usual facility services: coverage of careseeking to an iCCM provider (CBA)



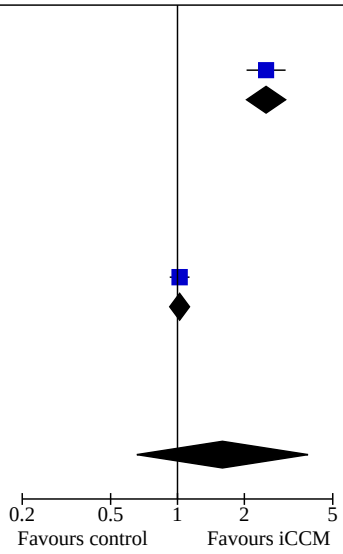
Comparison 2. iCCM versus usual facility services plus CCM for malaria

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.1 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of appropriate treatment by an appropriate provider (CBA)	1	7876	Risk Ratio (M-H, Random, 95% CI)	1.59 [0.66, 3.87]
2.1.1 Diarrhoea (CBA)	1	2641	Risk Ratio (M-H, Random, 95% CI)	2.51 [2.05, 3.07]
2.1.2 Malaria (CBA)	1	5235	Risk Ratio (M-H, Random, 95% CI)	1.02 [0.92, 1.13]
2.2 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.2.1 Any iCCM illness (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected
2.3 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (CBA)	1	8626	Risk Ratio (M-H, Random, 95% CI)	1.24 [1.01, 1.53]
2.3.1 Diarrhoea (CBA)	1	2641	Risk Ratio (M-H, Random, 95% CI)	1.56 [1.40, 1.73]
2.3.2 Fever (CBA)	1	5235	Risk Ratio (M-H, Random, 95% CI)	1.15 [1.09, 1.22]
2.3.3 Suspected pneumonia (CBA)	1	750	Risk Ratio (M-H, Random, 95% CI)	1.06 [0.93, 1.22]
2.4 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an iCCM provider (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected
2.4.1 Any iCCM illness (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected
2.4.2 Fever (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected
2.4.3 Suspected pneumonia (cRCT)	1		Risk Ratio (IV, Random, 95% CI)	Totals not selected
2.5 Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an iCCM provider (CBA)	1	8626	Risk Ratio (M-H, Random, 95% CI)	3.80 [1.91, 7.58]
2.5.1 Diarrhoea (CBA)	1	2641	Risk Ratio (M-H, Random, 95% CI)	8.48 [3.43, 20.95]
2.5.2 Fever (CBA)	1	5235	Risk Ratio (M-H, Random, 95% CI)	2.80 [2.10, 3.73]
2.5.3 Suspected pneumonia (CBA)	1	750	Risk Ratio (M-H, Random, 95% CI)	2.80 [0.99, 7.91]

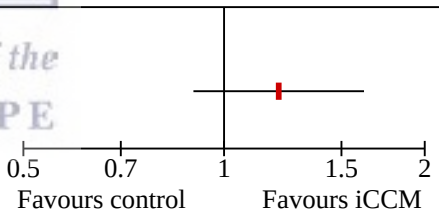
Analysis 2.1. Comparison 2: iCCM versus usual facility services plus CCM for malaria, Outcome 1: Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of appropriate treatment by an appropriate provider (CBA)

Study or Subgroup	iCCM Events	iCCM Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
2.1.1 Diarrhoea (CBA)						
Munos 2016	410	1627	102	1014	49.5%	2.51 [2.05 , 3.07]
Subtotal (95% CI)		**1627**		**1014**	**49.5%**	**2.51 [2.05 , 3.07]**
Total events:	410		102			
Heterogeneity: Not applicable						
Test for overall effect: Z = 8.90 (P < 0.00001)						
2.1.2 Malaria (CBA)						
Munos 2016	693	3057	483	2178	50.5%	1.02 [0.92 , 1.13]
Subtotal (95% CI)		**3057**		**2178**	**50.5%**	**1.02 [0.92 , 1.13]**
Total events:	693		483			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.42 (P = 0.67)						
Total (95% CI)		**4684**		**3192**	**100.0%**	**1.59 [0.66 , 3.87]**
Total events:	1103		585			
Heterogeneity: Tau² = 0.40; Chi² = 61.33, df = 1 (P < 0.00001); I² = 98%						
Test for overall effect: Z = 1.03 (P = 0.30)						
Test for subgroup differences: Chi² = 60.10, df = 1 (P < 0.00001), I² = 98.3%						



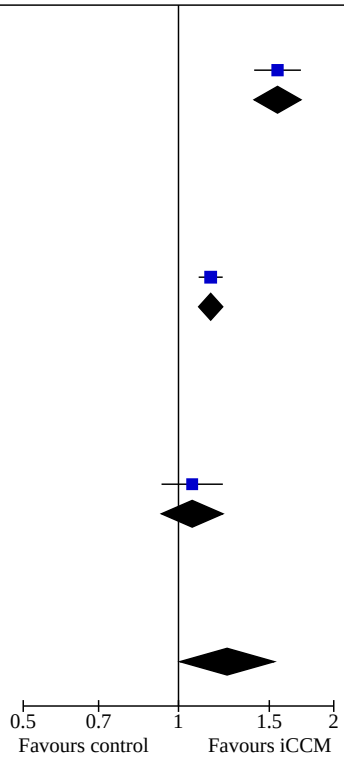
Analysis 2.2. Comparison 2: iCCM versus usual facility services plus CCM for malaria, Outcome 2: Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (cRCT)

Study or Subgroup	log[RR]	SE	Risk Ratio IV, Random, 95% CI
2.2.1 Any iCCM illness (cRCT)			
Kalyango 2012a	0.1888	0.1503	1.21 [0.90 , 1.62]



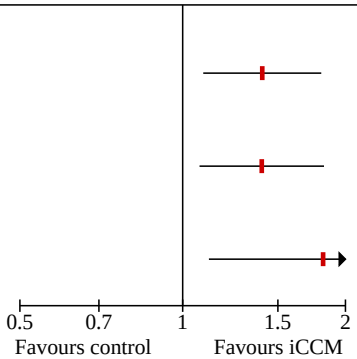
Analysis 2.3. Comparison 2: iCCM versus usual facility services plus CCM for malaria, Outcome 3: Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an appropriate provider of treatment services (CBA)

Study or Subgroup	iCCM Events	iCCM Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
2.3.1 Diarrhoea (CBA)						
Munos 2016	789	1627	316	1014	33.2%	1.56 [1.40 , 1.73]
Subtotal (95% CI)		**1627**		**1014**	**33.2%**	**1.56 [1.40 , 1.73]**
Total events:	789		316			
Heterogeneity: Not applicable						
Test for overall effect: Z = 8.31 (P < 0.00001)						
2.3.2 Fever (CBA)						
Munos 2016	1708	3057	1054	2178	35.4%	1.15 [1.09 , 1.22]
Subtotal (95% CI)		**3057**		**2178**	**35.4%**	**1.15 [1.09 , 1.22]**
Total events:	1708		1054			
Heterogeneity: Not applicable						
Test for overall effect: Z = 5.25 (P < 0.00001)						
2.3.3 Suspected pneumonia (CBA)						
Munos 2016	315	530	123	220	31.4%	1.06 [0.93 , 1.22]
Subtotal (95% CI)		**530**		**220**	**31.4%**	**1.06 [0.93 , 1.22]**
Total events:	315		123			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.88 (P = 0.38)						
Total (95% CI)		**5214**		**3412**	**100.0%**	**1.24 [1.01 , 1.53]**
Total events:	2812		1493			
Heterogeneity: Tau² = 0.03; Chi² = 29.42, df = 2 (P < 0.00001); I² = 93%						
Test for overall effect: Z = 2.02 (P = 0.04)						
Test for subgroup differences: Chi² = 28.74, df = 2 (P < 0.00001), I² = 93.0%						



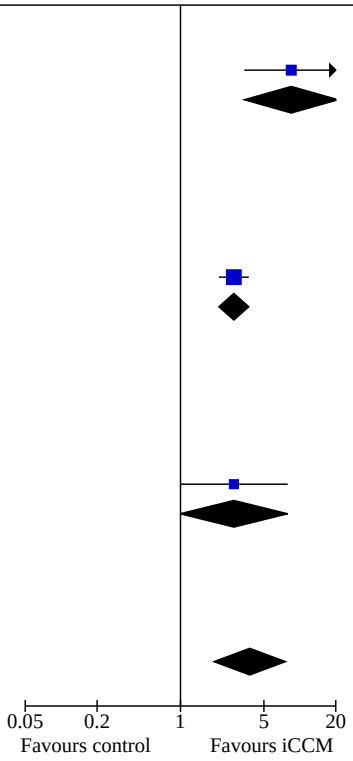
Analysis 2.4. Comparison 2: iCCM versus usual facility services plus CCM for malaria, Outcome 4: Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an iCCM provider (cRCT)

Study or Subgroup	log[RR]	SE	Experimental Total	Control Total	Risk Ratio IV, Random, 95% CI
2.4.1 Any iCCM illness (cRCT)					
Kalyango 2012a	0.3389	0.1282	419	392	1.40 [1.09 , 1.80]
2.4.2 Fever (cRCT)					
Kalyango 2012a	0.3368	0.1352	381	373	1.40 [1.07 , 1.83]
2.4.3 Suspected pneumonia (cRCT)					
Kalyango 2012a	0.598	0.2481	134	102	1.82 [1.12 , 2.96]



Analysis 2.5. Comparison 2: iCCM versus usual facility services plus CCM for malaria, Outcome 5: Comparison 2 iCCM vs usual facility services + CCM for malaria: coverage of careseeking to an iCCM provider (CBA)

Study or Subgroup	iCCM Events	iCCM Total	Control Events	Control Total	Weight	Risk Ratio M-H, Random, 95% CI
2.5.1 Diarrhoea (CBA)						
Munos 2016	68	1627	5	1014	27.6%	8.48 [3.43 , 20.95]
Subtotal (95% CI)		**1627**		**1014**	**27.6%**	**8.48 [3.43 , 20.95]**
Total events:	68		5			
Heterogeneity: Not applicable						
Test for overall effect: Z = 4.63 (P < 0.00001)						
2.5.2 Fever (CBA)						
Munos 2016	220	3057	56	2178	48.3%	2.80 [2.10 , 3.73]
Subtotal (95% CI)		**3057**		**2178**	**48.3%**	**2.80 [2.10 , 3.73]**
Total events:	220		56			
Heterogeneity: Not applicable						
Test for overall effect: Z = 7.00 (P < 0.00001)						
2.5.3 Suspected pneumonia (CBA)						
Munos 2016	27	530	4	220	24.0%	2.80 [0.99 , 7.91]
Subtotal (95% CI)		**530**		**220**	**24.0%**	**2.80 [0.99 , 7.91]**
Total events:	27		4			
Heterogeneity: Not applicable						
Test for overall effect: Z = 1.94 (P = 0.05)						
Total (95% CI)		**5214**		**3412**	**100.0%**	**3.80 [1.91 , 7.58]**
Total events:	315		65			
Heterogeneity: Tau² = 0.23; Chi² = 5.43, df = 2 (P = 0.07); I² = 63%						
Test for overall effect: Z = 3.80 (P = 0.0001)						
Test for subgroup differences: Chi² = 5.26, df = 2 (P = 0.07), I² = 62.0%						



ADDITIONAL TABLES

Table 1. iCCM components based on EPOC taxonomy (EPOC 2015)

EPOC category and subcategory	iCCM component	Input	Target	Bhandari 2012a	Boone 2016	Kalyango 2012a	Mubiru 2015	Munos 2016	White 2018	Yansaneh 2014
Who provides care and how the healthcare workforce is managed *– Role expansion or task shifting* *– Recruitment and retention strategies for underserved areas*	Training and deployment	Intervention to recruit, train and retain lay health workers to provide iCCM	Lay health workers	Y (d, m, p, nut, newb) children 0–59 months	Y (d, m, p) children 0–59 months	Y (m, p) children 4–59 months	Y (d, m, p) children 0–59 months	Y (d, m, p, nut) children 2–59 months	Y (d, m, p, nut) children "under-five"	Y (d, m, p) children "under-five"
		Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children < 5 years of age (iCCM/IMCI/IMNCI)	Doctors	Y (IMNCI)	None reported	Y (iCCM)	None reported	Y (IMCI)	None reported	None reported
			Nurses/midwives	Y (IMNCI)	None reported	Y (iCCM)	None reported	Y (IMCI)	None reported	None reported
Interventions targeted at health workers *– Clinical practice guidelines*		Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers	iCCM providers	Y (d, m, p, nut, newb) children 0–59 months	Y (d, m, p) children 0–59 months	Y (m, p) children 4–59 months	Y (d, m, p) children 0–59 months	Y (d, m, p, nut) children 2–59 months	Y (d, m, p, nut) children "under-five"	Y (d, m, p) children 0–59 months
Mechanisms for the payment of health services *– Payment methods for health workers*		Interventions for the payment of iCCM providers such as salary, fees for service, capitation	iCCM providers	Y	None reported	None reported	N*	Y	Y	N*
Co-ordination of care and management of care processes *– Referral systems*	Systems component	Interventions to improve systems for referral of patients between community and facility level	Health system	N	Y	Y (intervention and control arms)	Y	Y	Y	Y

Table 1. iCCM components based on EPOC taxonomy (EPOC 2015) *(Continued)*

– Procurement and distribution of supplies		Interventions to improve the supply of iCCM drugs and equipment	Health system	Y	Y	Y	Y	Y	Y	Y
Information and communication technology *– Health information systems*		Interventions to improve health information systems and use of information communication technology for iCCM	Health system	None reported	None reported	None reported	None reported	None reported	Y	None reported
– The use of information and communication technology		Interventions to improve health information systems and use of information communication technology for iCCM	Health system	None reported	None reported	None reported	None reported	None reported	Y	None reported
Interventions targeted at health workers *– Monitoring the performance of the delivery of health care*		Interventions to improve monitoring, evaluation and research for iCCM	iCCM providers, supervisors, managers, policy makers	None reported	None reported	None reported	Y	None reported	Y	Y
– Managerial supervision		Interventions to improve managerial supervision of iCCM	Supervisors, managers	Y	Y	Y (intervention and control arms)	Y	Y	Y	Y
Authority and accountability for health policies *– Community mobilisation*	Communication and community mobilisation	Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill	Communities and caregivers	Y	Y	None reported	Y	Y	Y	Y

iCCM components based on EPOC taxonomy EPOC 2015

Y = information reported sufficient to indicate yes.

Table 1. iCCM components based on EPOC taxonomy (EPOC 2015) *(Continued)*

N = information reported sufficient to indicate no.

N*= information reported sufficient to indicate no, however other types of incentives provided (see Additional Table 2b for details).

None reported = Information reported not sufficient to indicate yes or no.

d = diarrhoea; m = malaria; p = pneumonia; nut = malnutrition; newb = newborn infection.

EPOC: Effective Practice and Organisation of Care; iCCM: integrated community case management; IMCI: integrated management of childhood illness; IMNCI: Integrated Management of Neonatal and Childhood Illness.

Table 2. Approach for summary assessments of the risk of bias for each outcome (across domains) within and across studies

Risk of bias	Interpretation	Within a study	Across studies
Low risk of bias	Plausible bias unlikely to seriously alter the results.	Low risk of bias for all key domains.	Most information is from studies at low risk of bias.
Unclear risk of bias	Plausible bias that raises some doubt about the results.	Unclear risk of bias for ≥ 1 key domains.	Most information is from studies at low or unclear risk of bias.
High risk of bias	Plausible bias that seriously weakens confidence in the results.	High risk of bias for ≥ 1 key domains.	The proportion of information from studies at high risk of bias is sufficient to affect the interpretation of results.

From Higgins 2011.

Table 3. Details of inputs described narratively

Study	Input
Bhandari 2012a	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • All lay health workers (601 Anganwadi workers, 488 accredited social health activists) were provided an 8-day training on IMNCI (including iCCM) following the MOHFW 2003 IMNCI training modules, included training on iCCM for diarrhoea, malaria (in high-risk areas), pneumonia (ARI) and malnutrition – for children 0–59 months; treatment for newborn local infections; and referral of children 0–59 months with danger signs or severe illness to health facilities. Diarrhoea was diagnosed symptomatically and treated with ORT (ORS and zinc not specified); malaria was diagnosed presumptively based on fever and treated with antimalarials in high-risk areas and for children with no other obvious cause of fever; pneumonia was diagnosed as the presence of fast breathing or chest-indrawing (or both); it was unclear whether an RRT or watch with a second hand was used for the assessment of fast breathing; children diagnosed with pneumonia were treated with an antibiotic (type not specified); malnutrition (wasting and underweight) assessed per the 2003 MOHFW guidance referenced in the study; newborn local infection was assessed symptomatically and treated with antibiotics per the 2003 MOHFW guidance referenced in the study. • Anganwadi and ASHAs served a population of 1.1 million, resulting in the following ratios of iCCM trained lay health worker per population: 1:1010 Anganwadi + ASHA per population; 1:1830 Anganwadi workers per population; 1:2254 ASHA per population; for a population of 1.1 million). **Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children under-5 years of age (iCCM/IMCI/IMNCI)** • All 128 auxiliary midwives in intervention areas were provided an 8-day IMNCI training, resulting in a 1:8593 ratio of IMNCI trained auxiliary nurse midwives per population. • All 14 public sector physicians in intervention areas were provided 11-day IMNCI training course for all 14 public sector physicians, resulting in a 1:74,571 ratio of IMNCI trained public sector physicians per population. • 13 medically qualified private providers in intervention areas were provided a 6-hour orientation on IMNCI. • 614/973 (63%) non-medically qualified providers in intervention areas were provided 6-hour orientation (3 hours on 2 consecutive days) on IMNCI. • Orientation (4 hours) for traditional birth attendants on newborn care, covering clean delivery, cord care and newborn care. • 21 vacant supervisor positions were filled through temporary contractual hiring. Supervisors were trained on IMNCI and supervision skills.

Table 3. Details of inputs described narratively *(Continued)*

Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers

- Implementation of IMNCI (including iCCM) based on the training above.

Interventions for the payment of iCCM providers such as salary, fees for service, capitation

- Incentives for CHWs for home visits, women's group meetings, sick child contacts: quote: "task based incentives were expanded to include IMNCI activities. CHWs routinely get incentives for promoting institutional births (100 rupees; £1.27; €1.52; $2.00) and immunisation (100 rupees). In the intervention clusters, they received additional incentives for doing postnatal home visits (75 rupees), treating sick newborns and children (35 rupees), and running women's group meetings (35 rupees)." P. 2.

iCCM component: systems strengthening

Interventions to improve systems for referral of patients between community and facility levels

- None. Quote: "...the IMNCI programme does not include an emphasis on improved referral care for sick newborns and children and does not have specific interventions to link communities with referral facilities. The effect of IMNCI might be even greater than seen in this study if the proportion of early home visits, essential new born care in health facilities, and access to quality referral care can be increased." P. 5.

Interventions to improve the supply of iCCM drugs and equipment

- Providing iCCM providers with drugs and equipment at deployment and through the establishment of drug depots in villages.
- Training iCCM providers on the provision of prereferral medicines as part of the IMNCI training above.

Interventions to improve health information systems and use of information communication technology for iCCM

- None reported.

Interventions to improve monitoring, evaluation, and research for iCCM

- None reported.

Interventions to improve managerial supervision of iCCM providers

- Temporary contractual hiring to fill vacant supervisor positions (also under recruitment training and deployment above).
- Training supervisors of lay health workers (Anganwadi and accredited social health activist) on effective supervision.
- Implementing supervision of lay health workers (frequency, content and approach of supervision not reported).

iCCM component: communication and community mobilization

Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill

- 8-day IMNCI training for lay health workers (Anganwadi workers) to conduct home visits for counselling pregnant women and mothers on optimal newborn care practices, identify and treat illnesses among newborns, and refer sick newborns with danger signs or severe illness. The timing and frequency of the home visits was not stated but the authors provided references to the MOHFW training material. This training material indicated home visits were to be conducted on the day of birth (day 1), followed by visits on day 3 and day 7.
- Training lay health workers (accredited social health activists) in content and method of conducting women's group meetings.

Table 3. Details of inputs described narratively *(Continued)*

	• Conducting postnatal home visits by lay health workers (Anganwadi workers) and convening women's groups by lay health workers (accredited social health activists) based on the training above. Participation in the women's groups was reported as 45% in Bhandari 2012a/Mazumder.
Boone 2016	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • Training CHWs on iCCM – diarrhoea, malaria and pneumonia (moderate ARI) – for children 2–59 months and referral of children 2–59 months with severe illness to health facilities. Diarrhoea diagnosed symptomatically and treated with ORS and zinc; malaria diagnosed based on the presence of fever (i.e. no RDT) and treated with chloroquine for the first 12 months of the trial and then ACT thereafter. For pneumonia, no further definition was provided beyond "moderate acute respiratory infection;" it is unclear whether an RRT or watch with a second hand was used to diagnose; cotrimoxazole was used to treat. Training standards were developed in line with existing country protocols and WHO standards, and all training was delivered by qualified community IMCI trainers. 165 CHWs were trained with ≥ 1 CHW per village at a ratio of 1 CHW per 20–50 households. **Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children under-5 years of age (iCCM/IMCI/IMNCI)** • 10 trained community health nurses were hired to train and supervise CHWs and traditional birth attendants. • The 10 trained community health nurses visited villages twice per month to offer mobile clinic services, which included vaccinations, supplementation, deparasitization and growth monitoring for children, as well as basic antenatal and postnatal consultations for pregnant women. Over 3 years, 22 mobile events were conducted in 121 locations, resulting in 7015 antenatal consultations, 1583 postnatal consultations, 3281 tetanus vaccinations, 19,668 children vaccinated, 36,553 child health checks and 3942 malnutrition cases managed. **Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers** • Implementation of iCCM per training above. The 165 CHWs provided at total of 40,796 child-treatments over 3 years (or 82 child-treatments per CHW per year). • All services and treatments at the community level were provided free of charge at the point of delivery. **Interventions for the payment of iCCM providers such as salary, fees for service, capitation** • None reported. **iCCM component: systems strengthening** **Interventions to improve systems for referral of patients between community and facility levels** • 165 CHWs were trained on the identification and referral of young infants aged < 2 months and children with severe disease to health facilities as noted above under training and deployment. • No other interventions reported (e.g. prereferral medicines). **Interventions to improve the supply of iCCM drugs and equipment** • CHWs were supplied with iCCM drugs and equipment. The authors reported challenges with ensuring CHWs had a supply of iCCM drugs and equipment: quote: "We suggest that the distribution of medicines by community health workers might have been problematic because of inadequate protocols in communities, inadequate storage and care of drugs, or delays in referrals by community health workers in interventions villages, or a combination of these factors." • No other interventions reported (e.g. prereferral medicines). **Interventions to improve health information systems and use of information communication technology for iCCM** • None reported.

Table 3. Details of inputs described narratively *(Continued)*

	Interventions to improve monitoring, evaluation, and research for iCCM • None reported. **Interventions to improve managerial supervision of iCCM providers** • 10 trained community health nurses were hired to train and supervise CHWs and traditional birth attendants. They visited villages twice per month to offer mobile clinic services, which included vaccinations, supplementation, deparasitization, and growth monitoring for children, as well as basic antenatal and postnatal consultations for pregnant women. Content and approach to supervision not reported. **iCCM component: communication and community mobilization** **Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill** • 128 community health clubs were organized and facilitated by 22 trained health promoters. They met approximately 3 times a month for the first 6 months and once a month, outside the rainy season, for the remainder of the trial (22 health club session in 128 locations in year 1 and 18 health club session in 111 locations in years 2 and 3). They used participatory methods to address a range of topics on maternal and child health, e.g. antenatal care, safe delivery, malaria and diarrhoea. Health club participation was 36% in year 1 and 38% in years 2 and 3. • 128 traditional birth attendants (each village selected ≥ 1 female traditional birth attendant per 20–50 households) were trained to conduct home visits for counselling pregnant women and mothers on optimal care for newborn babies (this did not include treatment for sick newborns, only referral), and to promote healthy pregnancy and care for young infants, facility-based delivery and the use of clean delivery kits for the first 10 days after birth. The traditional birth attendants registered and monitored pregnant women, facilitated access to antenatal care, attended home deliveries with clean delivery kits, promoted newborn hygiene and thermal practices in home births, and did postnatal visits for the first 10 days after birth. **Additional notes:** • Quote: "The intervention did not include improvements to the standard health facilities, and these services were shared by people in both intervention and control clusters. Health facilities in the area were mostly so-called type C (ie, basic rural) facilities with 1–4 members of staff, a consultation room, and a basic delivery suite. Only one regional hospital was available in the two districts. All rural facilities had very basic supplies, medicines, and vaccines, and only the hospital was suitably equipped to provide management of severe cases and emergency obstetric care. Facilities were not easily accessible for many villages." P. e330. • Quote: "Pregnant women in the intervention group who were considered at high risk were encouraged to attend hospitals and were assisted with accommodation, transport, and modest food allowance." P. e330. • Quote: "All services and treatments at the community level were provided free of charge at the point of delivery." P. e330. • Quote: "Villages in the control group received few or no community-based services apart from annual vaccination campaigns. In some control villages, traditional birth attendants and community health workers had previously been trained, often many years before the trial, but they received no systematic training during the trial period, and did not have medicines or birthing kits to distribute. These villages did not receive any regular mobile clinic services, but pregnant women and children could travel to health clinics and hospitals with full access to available services." P. e331.
Kalyango 2012a	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • Before randomization, all CHWs (609 in intervention arm and 667 control arm) received 3 days of training on single-disease CCM for malaria for children 4–59 months following WHO guidance in 2009 (the trial was in 2009 and the WHO did not recommend using RDTs for diagnosis of malaria until 2010). CHWs were randomized to 3 strata in rural areas: clusters with populations of 190–320, 321–390 and ≥ 391. CHWs in urban areas were randomized to 2 strata: clusters with popula-

Table 3. Details of inputs described narratively *(Continued)*

tions of 280–430 and ≥ 431. After randomization, CHWs in the intervention arm received an additional 3 days of training on iCCM – malaria and pneumonia (ARI) for children 4–59 months and referral of children 4–59 months with severe illness to health facilities. Pneumonia was diagnosed by the presence of cough or difficult breathing and fast breathing (≥ 50 breaths per minute for children aged 4 to 12 months and ≥ 40 breaths per minute for children 12–59 months), with fast breathing assessed using a watch with a second hand; treatment was amoxicillin. Fever was treated presumptively as malaria with artemether-lumefantrine. Training of CHWs in control arm on CCM (malaria). Monthly refresher training (CCM for malaria in the control arm and iCCM for malaria in the intervention arm).

- CHWs in control arm were trained to assess children for febrile illness and to presumptively treat children with fever or with a history of fever in the last 24 hours with antimalarials and to refer children with danger signs or pneumonia symptoms, regardless of severity, to a nearby health facility (P. 3). CHWs in the control arm did not assess or classify pneumonia symptoms.
- Thermometers and RDTs were not used in either arm.
- Children with diarrhoea were not treated by the CHW in either arm (i.e. no CCM for diarrhoea).

Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children under-5 years of age (iCCM/IMCI/IMNCI)

- District health teams were trained first on CCM for malaria and then on iCCM for malaria and pneumonia by Ministry of Health officials together with the study investigators.
- In both arms, health facility workers at public, non-governmental organization and private health facilities received a 2-day training in iCCM for malaria and pneumonia; they were oriented on the algorithms that were to be used by the CHWs, and were trained on investigating and documenting adverse events, and supervision and training of CHWs.

Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers

- Implementation of iCCM per training above.

Interventions for the payment of iCCM providers such as salary, fees for service, capitation

- None reported.

iCCM component: systems strengthening

Interventions to improve systems for referral of patients between community and facility levels

- Children in both arms were classified as having severe illness and referred to the nearest health facility if any of the following danger signs were present: convulsions, repeated vomiting, lethargy/unconsciousness or failure to feed, chest indrawing, noisy breathing, dehydration or pallor. CHWs in both arms were required to follow up children they treated and refer those whose condition did not improve the nearest health facility.
- No other interventions reported (e.g. prereferral medicines).

Interventions to improve the supply of iCCM drugs and equipment

- CHWs in the intervention arm were provided prepackaged dispersible artemether-lumefantrine and amoxicillin tablets in age-specific doses and wrist watches with second hands.
- CHWs in the control arm were provided with artemether-lumefantrine only.
- Thermometers and RDTs were not provided to CHWs in either arm.
- The drugs were procured from manufacturers through local pharmaceutical distributors and distributed through the district system.

Interventions to improve health information systems and use of information communication technology for iCCM

- None reported.

Interventions to improve monitoring, evaluation, and research for iCCM

Table 3. Details of inputs described narratively *(Continued)*

	• None reported. **Interventions to improve managerial supervision of iCCM providers** • CHW supervisors (health workers at health facilities) were oriented on the algorithms CHWs were to use (iCCM for intervention and CCM for control) and they were trained on CHW supervision. • CHWs in both arms received monthly supportive supervision from health workers based at the nearest health facility; content and approach to supervision not reported. **iCCM component: communication and community mobilization** **Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill** • None reported. **Additional notes** • None.
Mubiru 2015	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • In intervention districts, 5585 VHT members (2 per village) received a 5-day training on iCCM – diarrhoea, malaria and pneumonia (ARI) – for children 0–59 months and referral of children 0–59 months with severe illness to health facilities. Diarrhoea was diagnosed symptomatically and treated with ORS and zinc; malaria was diagnosed with an RDT and treated with ACT; pneumonia was diagnosed as the presence of cough and fast breathing (assessed with RRT) and treated with amoxicillin. Training sessions demonstrating difficult topics such as fast breathing were held in clinical settings. The 5585 VHT members were selected for iCCM training because they ranked the highest per village on an assessment following their 6-day training on the basic VHT package of prevention and promotion interventions (see below under communication and social mobilization). • VHT members in comparison districts were not trained on iCCM. VHT members in some comparison districts had already received the 6-day training on the basic VHT package. **Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children under-5 years of age (iCCM/IMCI/IMNCI)** • None reported. **Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers** • Implementation of iCCM per training above. VHT members trained on iCCM provided 519,785 iCCM treatments in 2011 (baseline) and 1,387,961 iCCM treatments in 2012 (endline). The number of iCCM treatments per VHT member per year in 2012 was 248 (or 22 per month). **Interventions for the payment of iCCM providers such as salary, fees for service, capitation** • VHT members were volunteers but provided with a transport refund and a meal during quarterly meetings. **iCCM component: systems strengthening** **Interventions to improve systems for referral of patients between community and facility levels** • VHT members were trained on the identification of and referral for children U5 with danger signs during the 5-day training on iCCM. • No other interventions reported (e.g. prereferral medicines). **Interventions to improve the supply of iCCM drugs and equipment**

Table 3. Details of inputs described narratively *(Continued)*

	• VHT members in intervention districts were provided with drugs, respiratory rate timers, job aids (algorithms for diagnosis and treatment) and registers for recording data. • Supplies were purchased by UNICEF and distributed to each district by Malaria Consortium staff. CHWs were resupplied at health facilities during quarterly meetings. • Broader interventions to improve the supply of iCCM drugs and equipment to VHT members were not reported. **Interventions to improve health information systems and use of information communication technology for iCCM** • None reported. **Interventions to improve monitoring, evaluation, and research for iCCM** • Among the data sources for the study were routine and contextual data. It was unclear to what extent the collection and use of data through the study served as an 'intervention.' VHT members reported on availability of commodities and treatments given on a monthly basis using standardized registers. Peer-supervisors summarized VHT member data and sent it to the respective health facility affiliated with the parish. The reports were then sent to the district health management information systems focal person and Malaria Consortium. Facility treatment data were also collected from the health management information system in both the intervention and comparison districts. Data on health programmes taking place in the intervention and comparison districts during the study period were obtained from district officials in a standardized form. Relevant contextual factors, such as national stockouts of medicines, or disease outbreaks, were documented. **Interventions to improve managerial supervision of iCCM providers** • Health facility workers were trained to supervise VHT members, summarize and report compiled data, and to inform patients of the availability of VHT members. VHT members were supervised by health facility and Malaria Consortium staff, as well as their peer supervisors in each designated parish. Supervision consisted of home visits conducted by health workers and quarterly meetings. • Frequency of supervision provided through the intervention was not reported; however, the study monitored the percent of VHT members who received quarterly supervision. Content and approach to supervision not reported. **iCCM component: communication and community mobilization** **Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill** • Radio spots announcing the importance of seeking care for the 3 conditions and availability of VHT members. • Community leaders were trained to sensitize communities about the work of VHTs. • 11,170 VHT members (including the 5585 VHT members trained on iCCM) in the intervention districts received a basic 6-day VHT training package on promotion and prevention interventions, including hygiene, immunization, handwashing, optimal complementary feeding, insecticide-treated nets and intermittent preventive treatment of malaria during pregnancy. **Additional notes** • None.
Munos 2016	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • Training of lay health workers (ASBC) on iCCM for diarrhoea, malaria, pneumonia (ARI) and malnutrition among children 2–59 months. Diarrhoea was diagnosed symptomatically and treated with ORS and zinc. Pneumonia was diagnosed as the presence of cough/difficulty breathing as assessed by an RRT and treated with antibiotics. Malaria was diagnosed with an RDT and treated with ACT. Acute malnutrition using a MUAC strip with referral as appropriate.

Table 3. Details of inputs described narratively *(Continued)*

- Other community-based activities included detection and referral of cases of acute malnutrition and promotion of healthy practices by ASBCs.

Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children under-5 years of age (iCCM/IMCI/IMNCI)

- Training facility-based health workers on IMCI; emergency obstetric and newborn care; emergency triage and treatment.

Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers

- Implementation of iCCM for diarrhoea and malaria in 7 programme districts, and the implementation of iCCM for pneumonia, diarrhoea and malaria in 2 programme districts.

Interventions for the payment of iCCM providers such as salary, fees for service, capitation

- ASBCs providing iCCM services were responsible for visiting the local health facility to restock their drug kits; they then could sell these drugs to community members at a markup to provide a small financial "motivation" for their work.

iCCM component: systems strengthening

Interventions to improve systems for referral of patients between community and facility levels

- Identification and referral for danger signs per training on iCCM above. Other community-based activities included detection and referral of cases of acute malnutrition.
- No other interventions reported (e.g. prereferral medicines).

Interventions to improve the supply of iCCM drugs and equipment

- ASBCs providing iCCM services were responsible for visiting the local health facility to restock their drug kits; they then could sell these drugs to community members at a markup to provide a small financial "motivation" for their work.
- Broader interventions to improve the supply of iCCM drugs and equipment to ASBCs were not reported.

Interventions to improve health information systems and use of information communication technology for iCCM

- None reported.

Interventions to improve monitoring, evaluation and research for iCCM

- None reported (the evaluation was independent of the "intervention" and thus does not qualify as part of the "intervention" for this purpose).

Interventions to improve managerial supervision of iCCM providers

- iCCM-trained nurses at the local health centres were responsible for supervising ASBCs in their catchment area; Nurses were to supervise ASBCs bimonthly (it is unclear whether the authors meant twice every month or once every 2 months) in the areas implementing iCCM for malaria and diarrhoea and monthly in the areas implementing iCCM for malaria, diarrhoea and pneumonia. Content and approach to supervision not reported.

iCCM component: communication and community mobilization

Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill

- Other community-based activities included detection and referral of cases of acute malnutrition and promotion of healthy practices by ASBCs.

Additional notes

Table 3. Details of inputs described narratively *(Continued)*

	• The ASBCs were part of an existing cadre of volunteer lay health workers in Burkina Faso. They were selected by the community in which they worked (2 per village, 1 male and 1 female), were often illiterate and received little to no preservice training upon being selected as ASBCs. The number of ASBCs in a health facility catchment area in the programme districts ranged from 2 to 48. • A parallel national effort to implement malaria CCM, funded by the Global Fund and managed by Plan Burkina, was not integrated with the intervention districts.
White 2018	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • Training of lay health workers – CHW on iCCM – diarrhoea, malaria, pneumonia (ARI) and malnutrition – and referral of children with severe illness to health facilities. The age of children targeted for iCCM was not stated in the study. Diarrhoea was assessed symptomatically and treated with ORS and zinc. Pneumonia was diagnosed by the presence of cough + fast or difficult breathing; it was unclear whether diagnosis was based on use of an RRT or watch with a second hand; amoxicillin was used for treatment. Fever treated presumptively (i.e. no RDT) as malaria with ACT in alignment with the WHO "no touch" protocol during the Ebola epidemic (RDTs were reinstated in the last month of the study and CHWs resumed using RDTs). Screening for malnutrition did not use a MUAC strip during implementation of the WHO "no touch" policy but was reinstated in the last month of the study; children classified as having acute malnutrition were referred to a health facility (during implementation of the "no touch" policy it was not clear what triggered referrals). Referral for illnesses and age groups outside of their scope of practice was also included. CHW trained to do active case-finding in order to identify cases of illness in their community – as part of the active case-finding approach, they were trained to conduct routine household visits, with the expectation that they would visit every household in their catchment area at least once per month. At endline, there were 229 CHW. Each CHW served approximately 161 people. **Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children U5 (iCCM/IMCI/IMNCI)** • None stated. **Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers** • Implementation of iCCM per training above. CHW visited households monthly and performed active case-finding in order to identify cases of illness in their community. In addition, community members could self-refer to a CHW. **Interventions for the payment of iCCM providers such as salary, fees for service, capitation** • Providing CHW a monthly cash incentive of USD 70 by Last Mile Health for approximately 20 hours of work per week. CHW payment included additional compensation for training time with a daily spending allowance to cover meals and transportation to and from the training site. **iCCM component: systems strengthening** **Interventions to improve systems for referral of patients between community and facility levels** • Training on the identification and referral of children aged < 5 years with danger signs and age groups outside their scope of work. Danger signs necessitating referral were also reviewed and emphasized for each of these illnesses along with the principles of referral for illnesses and age groups outside of their scope of practice. • No other interventions reported (e.g. prereferral medicines). **Interventions to improve the supply of iCCM drugs and equipment** • Providing CHW with iCCM drugs and equipment. CHW were provided with age-appropriate ACT, amoxicillin, paracetamol, zinc, oral rehydration salts, RDTs for malaria, MUAC straps, and thermometers. CHW were given paper household registration forms, forms to track routine household visits and materials needed to hand-draw community maps. CHW were provided with sick child

Table 3. Details of inputs described narratively *(Continued)*

forms with diagnostic skip logic, referral forms and patient ledgers for tracking encounters. CHWL were responsible for ensuring CHW were restocked with iCCM drugs and equipment.

Interventions to improve health information systems and use of information communication technology for iCCM

- CHW, CHWL and CHSS used a combination of paper and mobile health tools to assist in workflow, help guide clinical decision-making, and collect programmatic data. Data were routed into a cloud-hosed database application, from which a number of reports could be generated allowing for monthly monitoring of outputs and outcomes. For the mobile health component, all CHW, CHWL and CHSS were equipped with an Android mobile phone + a waterproof case, a USB battery pack and a solar panel. The primary application used was a version of Open Data Kit adapted for use in completely disconnected settings. Electronic forms allowed for more granular data to be captured and analyzed on iCCM treatment, routine household visits, supervision visits and supply restocking.

Interventions to improve monitoring, evaluation, and research for iCCM

- During this time, CHW were also provided with visual job aids that enabled correct assessment, diagnosis and treatment of children aged < 5 years correctly. These job aids were designed in tandem with the iCCM sick child data collection forms and were highly visual and guided the CHW through a patient visit. CHW were also provided with a dose card job aid which allowed them to ensure correct medication and treatment was provided once they arrived at the correct diagnosis.

Interventions to improve managerial supervision of iCCM providers

- Recruitment and training of 2 cadres of CHW supervisors, called CHWLs and CCS. CHWLs were recruited jointly with the county health team to provide weekly supervision of the CHW in their home community. Nurses, physician assistants, and midwives were recruited to serve as CCSs. The monthly cash incentive for the CHWLs was USD 220 and for the CCS was USD 313 for full-time positions. The CCSs supervised the CHWLs and were responsible for overseeing the CHWs' clinical activities through monthly supervision in their home community. In addition, CCSs were attached to a primary health clinic to facilitate a stronger connection between community and the larger health system. While not formally a part of the supervision cascade within the programme, there was also a team made up of a mix of health professionals and non-health professionals responsible for training support and quality assurance. At endline, there were 21 CHWLs and 11 CCSs working.

iCCM component: communication and community mobilization

Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill

- Training of CHW on community engagement, household registration, community mapping and how to conduct household visits, focusing on child health – with the expectation that they would visit every household in their catchment area at least once per month.

Additional notes

- CHW were recruited from the communities in which they were assigned to serve. Only remote communities (those > 5 km from the nearest health facility) were targeted. Some CHW were assigned additional communities that were within a 30-minute walk.
- Communities were involved in recruitment, recommending specific candidates for screening. Candidates were also able to self-nominate.
- Candidates took a written literacy evaluation followed by a 1-on-1 interview for further assessment of internal motivation, communication skills and fit for the position.
- CHW training included community health and surveillance, child health, maternal and neonatal health, and adult health. CHW were trained on community engagement, household registration and community mapping. In the context of the ongoing Ebola epidemic, CHW were trained on appropriate Ebola infection prevention and control and surveillance. CHW were trained to conduct routine household visits, with the expectation that they would visit every household in their catchment area at least once per month.

Table 3. Details of inputs described narratively *(Continued)*

	• The authors noted that the Ebola epidemic had an effect on implementation of iCCM as well as other services. Regarding iCCM, the authors noted that CHW had to move to the WHO "no touch" policy. "The epidemic also precluded use of malaria rapid diagnostic tests because of Ebola contraction risks, limiting accurate report of malaria." (P. 1257). Other effects of the Ebola epidemic were described: " Standardized vaccination services were disrupted by stoppages during the Ebola virus disease epidemic and by mass campaigns after it, limiting estimation of the effect of CHW activities on vaccine uptake during the observation period." P. 1257.
Yansaneh 2014	**iCCM component: training and deployment** **Interventions to recruit, train and retain lay health workers to provide iCCM** • Training of lay health workers – CHVs – on iCCM for diarrhoea, malaria and pneumonia among children aged < 5 years and referral of children aged < 5 years with severe illness to health facilities. Diarrhoea was diagnosed symptomatically and treated with ORS and zinc. Malaria was diagnosed symptomatically (i.e. no RDT) and treated with artesunate-amodiaquine combined therapy (ACT). Pneumonia was diagnosed by the presence of fast or difficult breathing in the chest as assessed using RRTs and treated with cotrimoxazole. Training on iCCM was for 1 week and based on simplified algorithms adapted from WHO/UNICEF guidance. 2129 iCCM providers (CHVs) were recruited and trained with a mean ratio of 2 iCCM providers per 100 children aged < 5 years (or per 100 households). **Interventions to recruit, train and retain other types of health workers to provide integrated case management services for children U5 (iCCM/IMCI/IMNCI)** • None stated. **Implementation of simplified IMCI-adapted clinical guidelines for iCCM providers** • CHVs provided iCCM for diarrhoea, malaria and pneumonia as per training above; and identified and referred children with severe symptoms or danger signs (or both) to health facilities based on simplified algorithms adapted from WHO/UNICEF guidance. **Interventions for the payment of iCCM providers such as salary, fees for service, capitation** • CHVs were unpaid volunteers. Quote: "In lieu of payment, volunteers received recognition from the community with extra help with household tasks such as farming and exemption from community labour such as building or repair of roads and bridges." P. 1467. **iCCM component: systems strengthening** **Interventions to improve systems for referral of patients between community and facility levels** • CHVs were trained on recognition of severe symptoms or danger signs (or both) and referral of these cases to health facilities. • No other interventions reported (e.g. prereferral medicines). **Interventions to improve the supply of iCCM drugs and equipment** • UNICEF and civil society organizations provided CHVs with drug kits with simplified algorithms for ICCM and forms for recording number of visits, treatments and deaths. • Broader interventions to improve the supply of iCCM drugs and equipment to CHVs were not reported. **Interventions to improve health information systems and use of information communication technology for iCCM** • None stated. **Interventions to improve monitoring, evaluation, and research for iCCM** • CHVs used simplified algorithms and forms developed and previously tested in Sierra Leone for illiterate CHVs.

Table 3. Details of inputs described narratively *(Continued)*

- Quote: "[The implementing civil society organizations] kept monthly reports on drug supply, CHV supervision and reports on treatment and referral of children U5." P. 1467.

Interventions to improve managerial supervision of iCCM providers

- Supervision of volunteers took place on a monthly basis and included review of CHV reports and direct observation of CHVs during visits.

iCCM component: communication and community mobilization

Interventions to promote good practices for health and nutrition and generate demand for use of iCCM providers when children are ill

- CHVs promoted good practices for health, nutrition and careseeking behaviour.
- CHV services and locations were announced in religious centres and during community functions.

Additional notes

- CHVs were non-paid volunteers, with limited or no literacy, and selected by their respective communities.
- Quote: "[The] intervention was implemented a few months after the launch of the Free Health Care Initiative in late 2010 to early 2011 in two districts of Sierra Leone … Before implementation, CHV services and locations were announced in religious centres and during community functions. Community members received free treatment from CHV homes or from local health posts where volunteers sometimes provided care." P. 1467.

ACT: artemisinin-based combination therapy; ARI: acute respiratory infection; ASBC: Agents de Santé à Base Communautaire; ASHA: Accredited Social Health Activists; CCM: community case management; CCS: community clinical supervisor; CHW: community health worker; CHWL: community health worker leader; iCCM: integrated community case management; IMCI: integrated management of childhood illness; IMNCI: Integrated Management of Neonatal and Childhood Illness; MOHFW: Ministry of Health and Family Welfare; MUAC: mid-upper arm circumference; ORT; oral rehydration therapy; ORS: oral rehydration salts; RDT: rapid diagnostic test; RRT: respiratory rate timer; U5: aged under-five years; UNICEF: United Nations Children's Fund; VHT: village health team; WHO: World Health Organization.

Table 4. Sensitivity analysis: careseeking to an appropriate provider for any iCCM illness (iCCM for two diseases)

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Cluster-adjusted relative effect (95% CI)	Coverage indicators analysis summary
			iCCM	Control	iCCM	Control		
Coverage of careseeking to an appropriate provider for any iCCM illness compared to usual facility services with or without CCM for malaria	Kalyango 2012a	cRCT of 2 disease iCCM (malaria and pneumonia) compared to usual health facility services + CCM for malaria	Not given	Not given	69.6% (292/419)	65.5% (257/392)	**RR 1.06** (0.97 to 1.17)	Adjusted for stratified sampling
	Boone 2016	cRCT of iCCM with 3 diseases (diarrhoea, malaria and pneumonia) compared to usual facility services	Not given	Not given	42.5% (362/851)	29.6% (318/1078)	**RR 1.38** (1.13 to 1.69)	Adjusted for stratified sampling
	Bhandari 2012a	cRCT of iCCM with 4 diseases (diarrhoea, malaria, pneumonia and newborn infection) compared to usual facility services	Not given	Not given	45.2% 1560/3454	23.2% 1039/4470	**RR 1.86** (1.20 to 2.88)	Adjusted for stratified sampling

CCM: community case management; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management.

Table 5. Additional summary of findings: iCCM versus usual facility services

iCCM compared to usual facility services

Patient or population: children U5

Settings: middle- and low-income countries

Intervention: integrated community case management

Comparison: usual facility services

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Certainty of the evidence (GRADE)	Narrative results
	Assumed risk	Corresponding risk				
	Control (baseline risk in comparison)	iCCM (endline in intervention)				
Coverage of appropriate treatment						
From an appropriate provider						
ORS and zinc for diarrhoea	**43 children U5 with diarrhoea who received appropriate treatment from an appropriate provider per 100 children U5 with diarrhoea**	**44 children U5 with diarrhoea who received appropriate treatment from an appropriate provider per 100 children U5 with diarrhoea** (41 to 48)	**RR 2.92** (0.27 to 31.6)	1749 children (2 CBAs)[a,b]	⊕⊖⊖⊖ **Very low** [c]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for diarrhoea (ORS and zinc).
ACT for malaria	**45 children U5 with malaria who received appropriate treatment from an appropriate provider per 100 children U5 with malaria**	**36 children U5 with malaria who received appropriate treatment from an appropriate provider per 100 children U5 with malaria** (34 to 39)	**RR 0.85** (0.68 to 1.06)	4149 children (2 CBAs)[a,b]	⊕⊖⊖⊖ **Very low** [d]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for malaria (ACTs).
RUTF for severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate provider for severe acute malnutrition (RUTF).
Antibiotics for newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate provider for newborn sepsis (antibiotics).

Table 5. Additional summary of findings: iCCM versus usual facility services *(Continued)*

Antibiotics for newborn local infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate provider for newborn local infection (antibiotics).
From an iCCM provider						
Any iCCM illness	**0 children U5 with any iCCM illness who received appropriate treatment from an iCCM provider per 100 children U5 with any iCCM illness**	**5 children U5 with any iCCM illness who received appropriate treatment from an iCCM provider per 100 children U5 with any iCCM illness** (4 to 6)	**RR 124.40** (17.37 to 890.83)	4651 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [e]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an iCCM provider for any iCCM illness.
ORS and zinc for diarrhoea	**0 children U5 with diarrhoea who received appropriate treatment from an iCCM provider per 100 children U5 with diarrhoea**	**9 children U5 with diarrhoea who received appropriate treatment from an iCCM provider per 100 children U5 with diarrhoea** (7 to 11)	**RR 128.99** (7.99 to 2083.46)	1375 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [f]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an iCCM provider for diarrhoea (ORS and zinc).
ACT for malaria	**0 children U5 with malaria who received appropriate treatment from an iCCM provider per 100 children U5 with malaria**	**3 children U5 with malaria who received appropriate treatment from an iCCM provider per 100 children U5 with malaria** (2 to 4)	**RR 119.96** (7.40, 1945.55)	3276 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [g]	We are uncertain of the effect of iCCM on appropriate treatment from an iCCM provider for malaria (ACTs).
RUTF for severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment by from iCCM provider for severe acute malnutrition (RUTF).
Antibiotics for newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment by from iCCM provider for newborn sepsis (antibiotics).
Antibiotics for newborn infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment by from iCCM provider for newborn infection (antibiotics).
Coverage of careseeking						

Table 5. Additional summary of findings: iCCM versus usual facility services *(Continued)*

To an appropriate provider of treatment services

Diarrhoea	**29 children U5 with diarrhoea for whom care was sought from an appropriate provider per 100 children U5 with diarrhoea**	**39 children U5 with diarrhoea for whom care was sought from an appropriate provider per 100 children U5 with diarrhoea** (37 to 42)	**RR 1.44** (1.12 to 1.85)	3049 children (2 cRCTs)[h,i]	⊕⊕⊕⊖ **Moderate** [j]	iCCM probably improves careseeking to an appropriate provider of treatment services for diarrhoea.
Fever	**27 children U5 with fever for whom care was sought from an appropriate provider per 100 children U5 with fever**	**44 children U5 with fever for whom care was sought from an appropriate provider per 100 children U5 with fever** (37 to 52)	**RR 1.61** (1.37 to 1.90)	1101 children (1 cRCT)[h]	⊕⊕⊖⊖ **Low** [k]	iCCM may improve careseeking to an appropriate provider of treatment services for fever.
Suspected pneumonia	**20 children U5 with suspected pneumonia for whom care was sought from an appropriate provider per 100 children U5 with suspected pneumonia**	**29 children U5 with suspected pneumonia for whom care was sought from an appropriate provider per 100 children U5 with suspected pneumonia** (21 to 38)	**RR 1.39** (1.03 to 1.88)	1328 children (2 cRCTs)[h,i]	⊕⊕⊕⊖ **Moderate** [l]	iCCM probably improves careseeking to an appropriate provider of treatment services for suspected pneumonia.
Severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for severe acute malnutrition.
Newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services newborn sepsis.
Newborn local infection	**13 newborns with local infection for whom care was sought from an appropriate provider per 100 newborns with local infection**	**58 newborns with local infection for whom care was sought from an appropriate provider per 100 newborns with local infection** (49 to 68)	**RR 4.62** (3.92 to 5.44)	2096 children (1 cRCT)[i]	⊕⊕⊖⊖ **Low** [m]	iCCM may improve careseeking to an appropriate provider of treatment services for newborn local infection.
Newborn danger signs	**29 newborns with danger signs for whom care**	**47 newborns with danger signs for whom care**	**RR 1.59** (1.43 to 1.77)	2279 children (1 cRCT)[i]	⊕⊕⊖⊖ **Low** [n]	iCCM may improve careseeking to an appropriate provider of treatment ser-

Table 5. Additional summary of findings: iCCM versus usual facility services *(Continued)*

	was sought from an appropriate provider per 100 newborns with danger signs	**was sought from an appropriate provider per 100 newborns with danger signs** (42 to 52)				vices for newborn danger signs.
To an iCCM provider						
Any iCCM illness	**0 children U5 with any iCCM illness for whom care was sought from an iCCM provider per 100 children U5 with any iCCM illness**	**16 children U5 with any iCCM illness for whom care was sought from an iCCM provider per 100 children U5 with any iCCM illness** (15 to 18)	**RR 158.58** (51.04 to 492.70)	6581 children (2 CBAs)[a,o]	⊕⊖⊖⊖ **Very low** [p]	We are uncertain of the effect of iCCM on coverage of care-seeking to an iCCM provider for any iCCM illness.
Diarrhoea	**0 children U5 with diarrhoea for whom care was sought from an iCCM provider per 100 children U5 with diarrhoea**	**14 children U5 with diarrhoea for whom care was sought from an iCCM provider per 100 children U5 with diarrhoea** (11 to 16)	**RR 140.28** (19.66 to 1000.95	1654 children (2 CBAs)[a,o]	⊕⊖⊖⊖ **Very low** [p]	We are uncertain of the effect of iCCM on coverage of care-seeking to an iCCM provider for diarrhoea.
Fever	**0 children U5 with fever for whom care was sought from an iCCM provider per 100 children U5 with fever**	**12 children U5 with fever for whom care was sought from an iCCM provider per 100 children U5 with fever** (10 to 13)	**RR 253.13** (35.57 to 1801.37)	3657 children (2 CBAs)[a,o]	⊕⊖⊖⊖ **Very low** [q]	We are uncertain of the effect of iCCM on coverage of care-seeking to an iCCM provider for fever.
Suspected pneumonia	**0 children U5 with suspected pneumonia for whom care was sought from an iCCM provider per 100 children U5 with suspected pneumonia**	**20 children U5 with suspected pneumonia for whom care was sought from an iCCM provider per 100 children U5 with suspected pneumonia** (17 to 23)	**RR 112.26** (15.77 to 799.31)	1270 children (2 CBAs)[a,o]	⊕⊖⊖⊖ **Very low** [r]	We are uncertain of the effect of iCCM on coverage of care-seeking to an iCCM provider for suspected pneumonia.
Severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of care-seeking to an iCCM provider for severe acute malnutrition.
Newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on careseeking to an iCCM provider for newborn sepsis.

Table 5. Additional summary of findings: iCCM versus usual facility services *(Continued)*

Newborn local infection	No studies reported this outcome.	We do not know the effect of iCCM on careseeking to an iCCM provider for newborn local infection.
Newborn danger signs	No studies reported this outcome.	We do not know the effect of iCCM on careseeking to an iCCM provider for newborn danger signs.

*The basis for the **assumed risk** is the control group risk across studies (number of events in control group across studies / total in control group across studies). The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

ACT: artemisinin-based combination therapy; **CBA:** controlled before-after study; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **HR:** hazard ratio; **iCCM:** integrated community case management; **ORS:** oral rehydration salts; **RR:** risk ratio; **RUTF:** ready-to-use therapeutic food; **U5:** aged < 5 years.

GRADE Working Group grades of evidence
High certainty: further research is very unlikely to change our confidence in the estimate of effect.
Moderate certainty: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low certainty: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low certainty: we are very uncertain about the estimate.

[a] Yansaneh 2014.
[b] Mubiru 2015.
[c]Downgraded three levels (two for serious risk of bias due to the studies being CBAs, one for serious inconsistency and serious imprecision).
[d]Downgraded three levels (two for serious risk of bias due to the studies being CBAs, one for serious imprecision).
[e]Downgraded three levels (two for serious risk of bias due to the study being a CBA, one for indirectness and serious imprecision).
[f]Downgraded three levels (two for serious risk of bias due to the study being a CBA, one for indirectness and serious imprecision).
[g]Downgraded three levels (two for serious risk of bias due to the study being a CBA, one for indirectness and serious imprecision).
[h] Boone 2016.
[i] Bhandari 2012a/Mazumder 2014.
[j]Downgraded one level. Heterogeneity was high (I^2 = 81%, P = 0.004), but the effect was consistent (moderate-to-large effects in favour of the intervention) across studies and confidence intervals overlapped; therefore, we did not downgrade for serious inconsistency. Both trials included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India, which may contextually different than the typical rural environment where iCCM is implemented, so we downgraded one level for indirectness.
[k]Downgraded two levels. The trial included significant newborn components which have not been implemented widely in other contexts, so we downgraded one level for indirectness. We downgraded one level for indirectness due to the effect being based on a single cluster-randomized controlled trial.
[l]Downgraded one level. Both trials included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India, which may contextually different than the typical rural environment where iCCM is implemented, so we downgraded one level for indirectness.
[m]Downgraded two levels. We downgraded one level for indirectness due to the effect being based on a single cluster-randomized controlled trial. We downgraded an additional one level for indirectness because the trial included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India, which may contextually different than the typical rural environment where iCCM is implemented.
[n]Downgraded two levels. We downgraded one level for indirectness due to the effect being based on a single cluster-randomized controlled trial. We downgraded one level for indirectness because the trial included significant newborn components that have not been implemented widely in other contexts and Bhandari 2012a was conducted in a mixed rural/urban area of northern India, which may contextually different than the typical rural environment where iCCM is implemented.
[o] White 2018.
[p]Downgraded three level (two for serious risk of bias due to the studies being CBAs, one for serious imprecision).
[q]Downgraded three levels (two for serious risk of bias due to the studies being CBAs, one for serious imprecision).

[r]Downgraded three levels (two for serious risk of bias due to the studies being CBAs, one for serious imprecision).

Table 6. Additional summary of findings: iCCM versus usual facility services plus CCM for malaria

iCCM compared to usual facility services + CCM for malaria						
Patient or population: children U5 **Settings:** middle- and low-income countries **Intervention:** iCCM **Comparison:** usual facility care + CCM for malaria						
Outcomes	**Illustrative comparative risks* (95% CI)**		**Relative effect (95% CI)**	**No of participants (studies)**	**Certainty of the evidence (GRADE)**	**Narrative results**
	Assumed risk	**Corresponding risk**				
	Control (baseline risk in comparison)	**iCCM (endline in intervention)**				
Coverage of appropriate treatment						
From an appropriate provider						
ORS and zinc for diarrhoea	**10 children U5 with diarrhoea who received appropriate treatment from an appropriate provider per 100 children U5 with diarrhoea**	**25 children U5 with diarrhoea who received appropriate treatment from an appropriate provider per 100 children U5 with diarrhoea** (23 to 27)	**RR 2.51** (2.05 to 3.07)	2641 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for diarrhoea (ORS and zinc).
ACT for malaria	**22 children U5 with malaria who received appropriate treatment from an appropriate provider per 100 children U5 with malaria**	**23 children U5 with malaria who received appropriate treatment from an appropriate provider per 100 children U5 with malaria** (21 to 24)	**RR 1.02** (0.92 to 1.13)	5235 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for malaria (ACTs).
RUTF for severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate provider for severe acute malnutrition (RUTF).
Antibiotics for newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate

Table 6. Additional summary of findings: iCCM versus usual facility services plus CCM for malaria *(Continued)*

						provider for newborn sepsis (antibiotics).
Antibiotics for newborn local infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an appropriate provider for newborn local infection (antibiotics).
From an iCCM provider						
Any iCCM illness	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an iCCM provider for any iCCM illness.
ORS and zinc for diarrhoea	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an iCCM provider for diarrhoea (ORS and zinc).
ACT for malaria	No studies reported this outcome.					We do not know the effect of coverage of iCCM on appropriate treatment from an iCCM provider for malaria (ACTs).
RUTF for severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an iCCM provider for severe acute malnutrition (RUTF).
Antibiotics for newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an iCCM provider for newborn sepsis (antibiotics).
Antibiotics for newborn local infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of appropriate treatment from an iCCM provider for newborn local infection (antibiotics).
Coverage of careseeking						
To an appropriate provider of treatment services						
Diarrhoea	**31 children U5 with diarrhoea for whom care was sought from an appropriate provider per 100 children U5 with diarrhoea**	**49 children U5 with diarrhoea for whom care was sought from an appropriate provider per 100 children U5 with diarrhoea** (46 to 51)	**RR 1.56** (1.40 to 1.73)	2641 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for diarrhoea.

Table 6. Additional summary of findings: iCCM versus usual facility services plus CCM for malaria *(Continued)*

Fever	**48 children U5 with fever for whom care was sought from an appropriate provider per 100 children U5 with fever**	**56 children U5 with fever for whom care was sought from an appropriate provider per 100 children U5 with fever** (54 to 58)	**RR 1.15** (1.09 to 1.22)	5235 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for fever.
Suspected pneumonia	**56 children U5 with suspected pneumonia for whom care was sought from an appropriate provider per 100 children U5 with suspected pneumonia**	**59 children U5 with suspected pneumonia for whom care was sought from an appropriate provider per 100 children U5 with suspected pneumonia** (55 to 64)	**RR 1.06** (0.93 to 1.22)	750 children (1 CBA)[a]	⊕⊖⊖⊖ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia.
Severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for severe acute malnutrition.
Newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for newborn sepsis.
Newborn local infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for newborn local infection.
Newborn danger signs	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an appropriate provider for newborn danger signs.
To an iCCM provider						
Any iCCM illness	**22 children U5 with any iCCM illness for whom care was sought from an iCCM provider per 100 children U5 with any iCCM illness**	**31 children U5 with any iCCM illness for whom care was sought from an iCCM provider per children U5 with any iCCM illness 100** (26 to 35)	**RR 1.40** (1.09 to 1.80)	811 children (1 cRCT)[c]	⊕⊕⊖⊖ **Low** [d]	iCCM may improve coverage of careseeking to an iCCM provider for any iCCM illness

Table 6. Additional summary of findings: iCCM versus usual facility services plus CCM for malaria *(Continued)*

Diarrhoea	**1 child U5 with diarrhoea for whom care was sought from an iCCM provider per 100 children U5 with diarrhoea**	**4 children U5 with diarrhoea for whom care was sought from an iCCM provider per 100 children U5 with diarrhoea** (3 to 5)	**RR 8.48** (3.43 to 20.95)	2641 children (1 CBA)[a]	⊕⊝⊝⊝ **Very low** [b]	We are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea.
Fever	**19 children U5 with fever for whom care was sought from an iCCM provider per 100 children U5 with fever**	**27 children U5 with fever for whom care was sought from an iCCM provider per 100 children U5 with fever** (23 to 32)	**RR 1.40** (1.07 to 1.83)	754 children (1 cRCT)[c]	⊕⊕⊝⊝ **Low** [d]	iCCM may improve coverage of careseeking to an iCCM provider for fever.
Suspected pneumonia	**18 children U5 with suspected pneumonia for whom care was sought from an iCCM provider per 100 children U5 with suspected pneumonia**	**32 children U5 with suspected pneumonia for whom care was sought from an iCCM provider per 100 children U5 with suspected pneumonia** (24 to 41)	**RR 1.82** (1.12 to 2.96)	236 children (1 cRCT)[b]	⊕⊕⊝⊝ **Low** [d]	iCCM may improve coverage of careseeking to an iCCM provider for suspected pneumonia.
Severe acute malnutrition	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an iCCM provider for severe acute malnutrition.
Newborn sepsis	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an iCCM provider for newborn sepsis.
Newborn local infection	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an iCCM provider for newborn local infection.
Newborn danger signs	No studies reported this outcome.					We do not know the effect of iCCM on coverage of careseeking to an iCCM provider for newborn danger signs.

*The basis for the **assumed risk** is the control group risk across studies (number of events in control group across studies / total in control group across studies). The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

ACT: artemisinin-based combination therapy;**CBA:** controlled before-after study; **CCM:** community case management; **CI:** confidence interval; **cRCT:** cluster-randomized trial; **iCCM:** integrated community case management; **ORS:** oral rehydration salts; **RR:** risk ratio; **RUTF:** ready-to-use therapeutic food; **U5:** aged under-five years.

Table 6. Additional summary of findings: iCCM versus usual facility services plus CCM for malaria *(Continued)*

GRADE Working Group grades of evidence
High certainty: further research is very unlikely to change our confidence in the estimate of effect.
Moderate certainty: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low certainty: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low certainty: we are very uncertain about the estimate.

[a] Munos 2016.
[b]Downgraded three levels (two for serious risk of bias due to the study being a CBA, one for indirectness because the estimate of effect was based on one CBA).
[c] Kalyango 2012a.
[d]Downgraded two levels. We downgraded one level for risk of bias because the primary outcome measure for Kalyango 2012a, under-five mortality, has never been published – indicating risk of reporting bias for this study. We downgraded one level for indirectness due to the effect being based on a single cRCT.

Table 7. Comparison 1 results: coverage of appropriate treatment by an appropriate provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Risk ratio (95% CI)
			iCCM	Control	iCCM	Control	
Coverage of appropriate treatment from an appropriate provider for any iCCM illness	Mubiru 2015 (diarrhoea)	CBA	2.2% 3/136	5.8% 11/191	16.1% 30/186	1.6% 3/188	**10.11** (3.14 to 32.55)[a]
	Mubiru 2015 (malaria)	CBA	32.4% 77/238	49.2% 184/374	64.1% 236/368	67.7% 342/505	**0.95** (0.86 to 1.04)[a]
	Yansaneh 2014 (diarrhoea)	CBA	31.6% 237/751	35.67% 237/664	52.2% 335/642	53.8% 394/733	**0.97** (0.88 to 1.07)[a]
	Yansaneh 2014 (malaria)	CBA	29.8% 581/1948	30.9% 562/1819	29.2% 412/1413	38.2% 712/1863	**0.76** (0.69 to 0.84)[a]
Coverage of appropriate treatment from an appropriate provider for diarrhoea	Mubiru 2015	CBA	2.2% 3/136	5.8% 11/191	16.1% 30/186	1.6% 3/188	**10.11** (3.14 to 32.55)[a]
	Yansaneh 2014	CBA	31.6% 237/751	35.67% 237/664	52.2% 335/642	53.8% 394/733	**0.97** (0.88 to 1.07)[a]
Coverage of appropriate treatment by an appropriate provider for malaria	Mubiru 2015	CBA	32.4% 77/238	49.2% 184/374	64.1% 236/368	67.7% 342/505	**0.95** (0.86 to 1.04)[a]
	Yansaneh 2014	CBA	29.8% 581/1948	30.9% 562/1819	29.2% 412/1413	38.2% 712/1863	**0.76** (0.69 to 0.84)[a]

CBA: controlled before-after study; **CI:** confidence intervals; **iCCM:** integrated community case management.
[a]We recalculated results for Mubiru 2015 and Yansaneh 2014 based on unadjusted counts (see Data extraction and management).

Table 8. Comparison 1 results: coverage of appropriate treatment by an iCCM provider

Outcome	Trial ID	Study design	Preintervention coverage	Postintervention coverage	Risk ratio (95% CI)	Coverage indicators analysis summary

Table 8. Comparison 1 results: coverage of appropriate treatment by an iCCM provider *(Continued)*

			iCCM	Control	iCCM	Control		
Coverage of appropriate treatment for diarrhoea from an iCCM provider	Yansaneh 2014	CBA	0% (0/751)	0% (0/644)	8.7% (56/642)	0% (0/733)	**128.99** (7.99 to 2083.46)	Recalculated, unadjusted results[a]
Coverage of appropriate treatment for malaria from an iCCM provider	Yansaneh 2014	CBA	0% (1/1948)	0.4% (8/1819)	3.1% (45/1413)	0% (0/1863)	**119.96** (7.40 to 1945.55)	Recalculated, unadjusted results[a]

CBA: controlled before-after study; **CI:** confidence intervals; **iCCM:** integrated community case management.
[a]We recalculated results for Yansaneh 2014 based un unadjusted counts (see Data extraction and management).

Table 9. Comparison 1 results: mortality

Outcome	Trial ID	Study design	Preintervention mortality rate		Postintervention mortality rate		Hazard ratio (95% CI)	Coverage indicators analysis summary
			iCCM	Control	iCCM	Control		
Neonatal mortality rate	Bhandari 2012a	cRCT	32.6/1000 live births (n NA)	32.4/1000 live births (n NA)	41.9/1000 live births (1244/29667)	43.0/1000 live births (1326/30813)	**0.91** [a,b] (0.80 to 1.03)	Adjusted for cluster design and potential confounders
	Boone 2016	cRCT	Not given	Not given	42.1/1000 live births (117/2326)	50.4/1000 live births (101/2403)	**1.21** [c] (0.89 to 1.63)	Adjusted for cluster design and stratifying variables
Infant mortality rate	Bhandari 2012a	cRCT	44.9/1000 live births (n NA)	43.9/1000 live births (n NA)	65/1000 live births (1925/29667)	69/1000 live births (2136/30813)	**0.85** [a,d] (0.77 to 0.94)	Adjusted for cluster design and potential confounders
	Boone 2016	cRCT	Not given	Not given	83/1000 live births (195/2326)	71.6/1000 live births (173/2403)	**1.17** [c] (0.93 to 1.47)	Adjusted for cluster design and stratifying variables
Under-5 mortality rate	Boone 2016	cRCT	Not given	Not given	128.2/1000 live births	110.4/1000 live births	**1.16** (0.99 to 1.37)	Adjusted for cluster design and stratifying variables

Table 9. Comparison 1 results: mortality *(Continued)*

						(311/6729)	(273/6894)	

CI: confidence interval; **cRCT:** cluster-randomized controlled trial;**iCCM:** integrated community case management; **n:** number of participants; **NA:** not available.

[a]Adjusted for cluster design (shared frailty option, random-effects model) and potential confounders (toilet inside house, illiterate mother, schedule caste or tribe, possession of mobile phone, family with below poverty line card, distance from primary health centre to nearest point on highway, percentage of home births in cluster).

[b]The confidence interval included no effect but subgroup analysisfound an important effect in favour of the intervention among home births (adjusted hazard ratio 0.80, 95% CI 0.68 to 0.93) versus facility births (hazard ratio 1.06, 95% CI 0.91 to 1.23) (P = 0.001).

[c]Adjusted for cluster design and stratifying variables, including ethnic origin (Balanta, non-Balanta and mixed) and distance from a regional health centre or hospital (within/further than 3.5 hours' walking).

[d]The confidence interval included no effect but subgroup analysisfound an important effect in favour of the intervention among home births (adjusted hazard ratio 0.77, 95% CI 0.69 to 0.87) versus facility births (hazard ratio 0.98, 95% CI 0.87 to 1.10) (P = 0.001).

Table 10. Comparison 1 results: subgroup analysis on mortality by wealth quintile and gender

Outcome	Subgroup	Trial ID	Study design	Preintervention mortality rate		Postintervention mortality rate		Difference in equity gradient (95% CI)	Analysis summary
				iCCM	Control	iCCM	Control		
Change in neonatal mortality rate subgroup (inequity gradient)	Wealth quintile	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	−3.6 (−6.0 to −1.2)	−4.1 (−5.9 to −2.3)	**0.5** [a] (−2.0 to 2.9) P = 0.681	Multiple linear regressions adjusted for cluster design and potential confounders
Neonatal mortality rate	Wealth quintile (poorest)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	52.1/1000 live births (293/5620)	54.2/1000 live births (348/6421)	—	
	Wealth quintile (very poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	46.1/1000 live births (248/5380)	50.2/1000 live births (334/6660)		
	Wealth quintile (Poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	43.3/1000 live births (252/5818)	36.0/1000 live births (224/6222)		
	Wealth quintile (Less poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	39.9/1000 live births (241/6039)	36.3/1000 live births (218/6001)		

Table 10. Comparison 1 results: subgroup analysis on mortality by wealth quintile and gender *(Continued)*

	Wealth quintile (Least poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	30.9/1000 live births (208/6732)	33.4/1000 live births (177/5300)		
Change in neonatal mortality rate subgroup (inequity gradient)	Gender	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	1.9 (–4.9 to 8.7)	2.0 (–3.1 to 7.2)	**–0.1** [a] (–8.7 to 8.4) P = 0.974	Multiple linear regressions adjusted for cluster design and potential confounders
Neonatal mortality rate	Gender (female)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	41.1/1000 live births (557/14,044)	42.2/1000 live births (614/14,561)	—	
	Gender (male)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	42.7/1000 live births (667/15,623)	43.8/1000 live births (712/16,252)		
Change in infant mortality rate subgroup (inequity gradient)	Wealth quintile	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	–2.8 (–4.2 to –1.3)	–4.9 (–7.0 to –2.8)	**2.2** [a] (0 to 4.4) P = 0.053	Multiple linear regressions adjusted for cluster design and potential confounders
Infant mortality rate	Wealth quintile (poorest)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	38.1/1000 live births (214/5620)	41.7/1000 live births (268/6421)	—	
	Wealth quintile (very poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	24.9/1000 live births (134/5380)	32.9/1000 live births (219/6660)		
	Wealth quintile (Poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	20.5/1000 live births (119/5818)	24.6/1000 live births (153/6222)		
	Wealth quintile (Less poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	18.4/1000 live births (111/6039)	15.2/1000 live births (91/6001)		

Table 10. Comparison 1 results: subgroup analysis on mortality by wealth quintile and gender *(Continued)*

	Wealth quintile (Least poor)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	14.9/1000 live births (100/6732)	14.0/1000 live births (74/5300)		
Change in infant mortality rate subgroup (inequity gradient)	Gender	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	−9.1 (−12.2 to −6.0)	−10.8 (−14.7 to −6.9))	**1.7** [a] (−3.2 to 6.6) P = 0.479	Multiple linear regressions adjusted for cluster design and potential confounders
Infant mortality rate	Gender (female)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	27.9/1000 live births (392/14,044)	32.3/1000 live births (471/14,561)	—	
	Gender (male)	Bhandari 2012a/ Taneja 2015	cRCT	NA	NA	18.5/1000 live births (289/15,623)	20.8/1000 live births (338/16,252)		

CI: confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management; **NA:** not applicable.
[a]Multiple linear regressions adjusted for cluster design and potential confounders (distance of nearest point from primary health centre to highway, percent of home births, and years of schooling of mother, gender, religion and caste and wealth quintile).

Table 11. Comparison 1 results: coverage of careseeking to an appropriate provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Risk ratio (95% CI)
			iCCM	Control	iCCM	Control	
Coverage of careseeking to an appropriate provider of treatment services for any iCCM illness	White 2018 (any)	CBA	43.9% 79/180	64.4% 103/160	71.6% 136/190	52.3% 158/302	**1.43** (1.23 to 1.66)[a]
	Yansaneh 2014 (any)	CBA	35.3% 699/1980	36.9% 724/1962	57.1% 946/1657	48.9% 1027/2102	**1.17** (1.10 to 1.24)[a]
	Bhandari 2012a/Mazumder 2014 (diarrhoea, 6 months)	cRCT	Not given	Not given	146/642	106/866	**1.86** (1.48 to 2.33)[c]
	Bhandari 2012a/Mazumder 2014 (diarrhoea, 12 months)	cRCT	Not given	Not given	271/425	337/661	**1.25** (1.13 to 1.39)[c]

Table 11. Comparison 1 results: coverage of careseeking to an appropriate provider *(Continued)*

Boone 2016 (diarrhoea)	cRCT	Not given	Not given	41.3% (86/208)	31.1% (77/247)	**1.33** (1.04 to 1.70)[b]
Mubiru 2015 (diarrhoea)	CBA	43.4% 59/136	70.0% 140/200	59.7% 111/186	55.9% 105/188	**1.07** (0.90 to 1.27)[a]
White 2018 (diarrhoea)	CBA	44/103	54/81	73/106	82/173	**1.45** (1.19 to 1.78)[a]
Yansaneh 2014 (diarrhoea)	CBA	31.9% (240/751)	42.3% (281/664)	53.7% (345/642)	54.7% (401/733)	**0.98** (0.89 to 1.08)[a]
Boone 2016 (fever)	cRCT	Not given	Not given	43.7% (214/489)	18.9% (116/612)	**1.61** (1.37 to 1.90)[b]
Mubiru 2015 (fever)	CBA	76.1% 181/238	87.2% 326/374	91.6% 337/368	90.7% 458/505	**1.01** (0.97 to 1.05)[a]
White 2018 (fever)	CBA	40.0% 56/140	60.0% 69/115	73.7% 98/133	49.3% 112/227	**1.49** (1.26 to 1.76)[a]
Yansaneh 2014 (fever)	CBA	29.2% (569/1948)	30.6% (557/1819)	45.2% (638/1413)	17.4% (325/1863)	**2.59** (2.31 to 2.90)[a]
Bhandari 2012a/Mazumder 2014 (suspected pneumonia, 6 months)	cRCT	Not given	Not given	26.8% 72/269	14.9% 56/375	**1.79** (1.31 to 2.45)[c]
Bhandari 2012a/Mazumder 2014 (suspected pneumonia, 12 months)	cRCT	Not given	Not given	17.8% 20/112	14.1% 28/199	**1.27** (0.75 to 2.15)[c]
Boone 2016 (suspected pneumonia)	cRCT	Not given	Not given	(62/154)	(76/219)	**1.16** (0.89 to 1.51)[b]
Mubiru 2015 (suspected pneumonia)	CBA	55.5% 101/182	80.1% 237/296	76.5% 218/285	67.1% 259/386	**1.15** (1.05 to 1.27)[a]
White 2018 (suspected pneumonia)	CBA	39.6%	69.4%	66.7%	47.4%	**1.41** (1.05 to 1.90)[a]

Table 11. Comparison 1 results: coverage of careseeking to an appropriate provider *(Continued)*

			19/48	25/36	28/42	46/97	
	Yansaneh 2014 (suspected pneumonia)	CBA	25.0% (129/515)	35.0% (208/595)	46.7% (247/529)	41.9% (222/530)	**1.12** (0.97 to 1.28)[a]
	Bhandari 2012a/Mazumder 2014 (newborn local infections)	cRCT	Not given	Not given	57.9% 577/996	12.5% 138/1100	**4.62** (3.92 to 5.45)[c]
	Bhandari 2012a/Mazumder 2014 (newborn danger signs)	cRCT	Not given	Not given	46.9% 474/1010	29.4% 374/1269	**1.58** (1.43 to 1.77)[c]
Coverage of careseeking to an appropriate provider of treatment services for diarrhoea	Bhandari 2012a/Mazumder 2014 (diarrhoea, 6 months)	cRCT	Not given	Not given	146/642	106/866	**1.86** (1.48 to 2.33)[c]
	Bhandari 2012a/Mazumder 2014 (diarrhoea, 12 months)	cRCT	Not given	Not given	271/425	337/661	**1.25** (1.13 to 1.39)[c]
	Boone 2016 (diarrhoea)	cRCT	Not given	Not given	41.3% (86/208)	31.1% (77/247)	**1.33** (1.04 to 1.70)[b]
	Mubiru 2015 (diarrhoea)	CBA	43.4% 59/136	70.0% 140/200	59.7% 111/186	55.9% 105/188	**1.07** (0.90 to 1.27)[a]
	White 2018 (diarrhoea)	CBA	44/103	54/81	73/106	82/173	**1.45** (1.19 to 1.78)[a]
	Yansaneh 2014 (diarrhoea)	CBA	31.9% (240/751)	42.3% (281/664)	53.7% (345/642)	54.7% (401/733)	**0.98** (0.89 to 1.08)[a]
Coverage of careseeking to an appropriate provider of treatment services for fever	Boone 2016 (fever)	cRCT	Not given	Not given	43.7% (214/489)	18.9% (116/612)	**1.61** (1.37 to 1.90)[b]
	Mubiru 2015 (fever)	CBA	76.1% 181/238	87.2% 326/374	91.6% 337/368	90.7% 458/505	**1.01** (0.97 to 1.05)[a]
	White 2018 (fever)	CBA	40.2% 56/139	60.0% 69/115	73.7% 98/133	49.3% 112/227	**1.49** (1.26 to 1.76)[a]

Table 11. Comparison 1 results: coverage of careseeking to an appropriate provider *(Continued)*

	Yansaneh 2014 (fever)	CBA	29.2% (569/1948)	30.6% (557/1819)	45.2% (638/1413)	17.4% (325/1863)	**2.59** (2.31 to 2.90)[a]
Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia	Bhandari 2012a/Mazumder 2014 (suspected pneumonia, 6 months)	cRCT	Not given	Not given	26.8% 72/269	14.9% 56/375	**1.79** (1.31 to 2.45)[c]
	Bhandari 2012a/Mazumder 2014 (suspected pneumonia, 12 months)	cRCT	Not given	Not given	17.8% 20/112	14.1% 28/199	**1.27** (0.75 to 2.15)[c]
	Boone 2016 (suspected pneumonia)	cRCT	Not given	Not given	(62/154)	(76/219)	**1.16** (0.89 to 1.51)[b]
	Mubiru 2015 (suspected pneumonia)	CBA	55.5% 101/182	80.1% 237/296	76.5% 218/285	67.1% 259/386	**1.15** (1.05 to 1.27)[a]
	White 2018 (suspected pneumonia)	CBA	39.6% 19/48	69.4% 25/36	66.7% 28/42	47.4% 46/97	**1.41** (1.04 to 1.90)[a]
	Yansaneh 2014 (suspected pneumonia)	CBA	25.0% (129/515)	35.0% (208/595)	46.7% (247/529)	41.9% (222/530)	**1.12** (0.97 to 1.28)[a]
Coverage of careseeking to an appropriate provider of treatment services for newborn local infections	Bhandari 2012a/Mazumder 2014 (newborn local infections)	cRCT	Not given	Not given	57.9% 577/996	12.5% 138/1100	**4.62** (3.92 to 5.45)[c]
Coverage of careseeking to an appropriate provider of treatment services for newborn danger signs	Bhandari 2012a/Mazumder 2014 (newborn danger signs)	cRCT	Not given	Not given	46.9% 474/1010	29.4% 374/1269	**1.58** (1.43 to 1.77)[c]

CBA: controlled before-after study; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management; **RR:** risk ratio.

[a]We recalculated results for Mubiru 2015, White 2018, and Yansaneh 2014 based on unadjusted counts (see Data extraction and management).

[b]Adjusted for cluster design and stratification variables: ethnic origin (Balanta, non-Balanta and mixed) and by distance from a regional health centre or hospital (within/further 3.5 hours' walking).

[c]Adjusted for cluster design (shared frailty option, random-effects model) and potential confounders (toilet inside house, illiterate mother, schedule caste or tribe, possession of mobile phone, family with below poverty line card, distance from primary health centre to nearest point on highway, percentage of home births in cluster).

Table 12. Comparison 1 results: subgroup analysis on coverage of careseeking to an appropriate provider by wealth quintile and gender

Outcome	Subgroup	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Difference in equity gradient (95% CI)	Analysis summary
				iCCM	Control	iCCM	Control		
Change in coverage of careseeking to an appropriate provider for danger signs during the neonatal period (equity gradient)	Wealth quintile	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	4.6 (2.8 to 6.4)	4.0 (2.5 to 5.5)	**0.6** [a] (–1.6 to 2.8) P = 0.554	Multiple linear regressions adjusted for cluster design and potential confounders
Coverage of careseeking to an appropriate provider for danger signs during the neonatal period	Wealth quintile (poorest)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	32.4% (60/185)	17.1% (44/257)	—	
	Wealth quintile (very poor)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	35.4% (58/164)	18.2% (47/258)		
	Wealth quintile (Poor)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	47.6% (89/187)	33.6% (86/256)		
	Wealth quintile (Less poor)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	48.1% (100/208)	36.4% (91/250)		
	Wealth quintile (Least poor)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	62.5% (165/264)	42.7% (105/246)		

Table 12. Comparison 1 results: subgroup analysis on coverage of careseeking to an appropriate provider by wealth quintile and gender *(Continued)*

Change in coverage of careseeking to an appropriate provider of treatment services for newborn danger signs (equity gradient)	Gender	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	8.3 (1.6 to 15.1)	17.6 (11.4 to 23.8)	**–9.3** [a] (–18.2 to –0.4) P = 0.042	Multiple linear regressions adjusted for cluster design and potential confounders
Coverage of careseeking to an appropriate provider of treatment services for newborn danger signs	Gender (female)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	41.3% (165/400)	19.3% (99/514)	—	
	Gender (male)	Bhandari 2012a (Taneja 2015)	cRCT	Not given	Not given	50.7% 309/610	36.4% 275/755		

CI: confidence interval; **cRCT:** cluster-randomized controlled trial;**iCCM:** integrated community case management.
[a]Multiple linear regressions adjusted for cluster design and potential confounders (distance of nearest point from primary health centre to highway, percent of home births, and years of schooling of mother, gender, religion and caste and wealth quintile).

Table 13. Comparison 1 results: coverage of careseeking to an iCCM provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Cluster-adjusted relative effect (95% CI)	Coverage indicators analysis summary
			iCCM	Control	iCCM	Control		
Coverage of careseeking to an iCCM provider for diarrhoea	White 2018	CBA	0% 0/103	0% 0/81	49/106 46.2%	0% 0/173	**RR 160.99** (10.03 to 2582.96)	Recalculated, unadjusted results[a]
	Yansaneh 2014	CBA	0.2% 1/644	0.2% 1/644	8.3% 53/642	0.0% 0/733	**RR 122.14** (7.56 to 1974.18)	Recalculated, unadjusted results[a]
Coverage of careseeking to an iCCM provider for fever	White 2018	CBA	0% 0/140	0% 0/115	55.8% 86/154	0% 0/227	**RR 251.79** (15.65 to 4051.21)	Recalculated, unadjusted results[a]
	Yansaneh 2014	CBA	0.1% 2/1948	0.4% 8/1819	6.7% 95/1413	0.0% 0/1863	**RR 251.79** (15.65 to 4041.21)	Recalculated, unadjusted results[a]

Table 13. Comparison 1 results: coverage of careseeking to an iCCM provider *(Continued)*

Coverage of careseeking to an iCCM provider for suspected pneumonia	White 2018	CBA	0% 0/48	0% 0/36	75.4% 86/114	0% 0/97	**RR 254.48** (15.91 to 4070.50)	Recalculated, unadjusted results[a]
	Yansaneh 2014	CBA	0.0% 0/515	0.2% 1/595	7.9% 42/529	0.0% 0/530	**RR 85.16** (5.25 to 1380.23)	Recalculated, unadjusted results[a]

CBA: controlled before-after study; **CI:** confidence interval; **iCCM:** integrated community case management; **RR:** risk ratio.
[a]We recalculated results for Mubiru 2015, White 2018 and Yansaneh 2014 based on unadjusted counts (see Data extraction and management).

Table 14. Comparison 2 results: coverage of appropriate treatment by an appropriate provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Risk ratio (95% CI)
			iCCM	Control	iCCM	Control	
Coverage of appropriate treatment from an appropriate provider for any iCCM illness	Munos 2016 (diarrhoea)	CBA	26.5% 379/1431	17.5% 125/715	25.2% 410/1627	10.1% 102/1014	**2.51** (2.05 to 3.07)
	Munos 2016 (malaria)	CBA	27.1% 986/3639	25.2% 589/2338	22.7% 693/3057	22.2% 483/2178	**1.02** (0.92 to 1.13)
Coverage of appropriate treatment from an appropriate provider for diarrhoea	Munos 2016	CBA	26.5% 379/1431	17.5% 125/715	25.2% 410/1627	10.1% 102/1014	**2.51** (2.05 to 3.07)
Coverage of appropriate treatment by an appropriate provider for malaria	Munos 2016	CBA	27.1% 986/3639	25.2% 589/2338	22.7% 693/3057	22.2% 483/2178	**1.02** (0.92 to 1.13)

CBA: controlled before-after study; **CI:** confidence interval; **iCCM:** integrated community case management.

Table 15. Comparison 2 results: coverage of careseeking to an appropriate provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Risk ratio (95% CI)
			iCCM	Control	iCCM	Control	

Table 15. Comparison 2 results: coverage of careseeking to an appropriate provider *(Continued)*

Coverage of careseeking to an appropriate provider of treatment services for any iCCM illness	Kalyango 2012a (any)	cRCT	—	—	69.6% (292/419)	65.5% (257/392)	**1.06** (0.97 to 1.17)[a]
	Munos 2016 (diarrhoea)	CBA	666/1431	241/715	789/1627	316/1014	**1.56** (1.40 to 1.73)[a]
	Munos 2016 (fever)	CBA	62.9% (2288/3639)	55.6% 1299/2338	55.9% 1708/3057	48.4% 1054/2178	**1.15** (1.09 to 1.22)[a]
	Munos 2016 (suspected pneumonia)	CBA	67.7% 208/307	62.2% 102/164	59.4% 315/530	55.9% 123/220	**1.06** (0.93 to 1.22)[a]
Coverage of careseeking to an appropriate provider of treatment services for diarrhoea	Munos 2016 (diarrhoea)	CBA	666/1431	241/715	789/1627	316/1014	**1.56** (1.40 to 1.73)[a]
Coverage of careseeking to an appropriate provider of treatment services for fever	Munos 2016 (fever)	CBA	62.9% (2288/3639)	55.6% 1299/2338	55.9% 1708/3057	48.4% 1054/2178	**1.16** (1.09 to 1.22)[a]
Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia	Munos 2016 (suspected pneumonia)	CBA	67.7% 208/307	62.2% 102/164	59.4% 315/530	55.9% 123/220	**1.06** (0.93 to 1.22)[a]

CBA: controlled before-after study; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management.
[a]Adjusted for cluster design.

Table 16. Comparison 2 results: coverage of careseeking to an iCCM provider

Outcome	Trial ID	Study design	Preintervention coverage		Postintervention coverage		Cluster-adjusted relative effect (95% CI)	Coverage indicators analysis summary
			iCCM	Control	iCCM	Control		
Coverage of careseeking to an iCCM provider for any iCCM illness	Kalyango 2012a	cRCT	—	—	27.9% 117/419	19.9% 78/392	**RR 1.40** (1.09 to 1.80)	Adjusted for stratified sampling

Table 16. Comparison 2 results: coverage of careseeking to an iCCM provider *(Continued)*

Coverage of careseeking to an iCCM provider for diarrhoea	Munos 2016	CBA	3.5% 50/1431	0.5% 4/715	4.2% 68/1627	4.9% 5/1014	**RR 8.47** (3.43 to 20.95)	Adjusted for cluster design and non-response
Coverage of careseeking to an iCCM provider for fever	Kalyango 2012a	cRCT	—	—	27.0% 103/381	19.3% 72/373	**RR 1.40** (1.07 to 1.83)	Adjusted for stratified sampling
	Munos 2016	CBA	4.5% 163/3639	2.1% 49/2338	7.2% 220/3057	2.5% 56/2178	**RR 2.80** (2.10 to 3.73)	Adjusted for cluster design and non-response
Coverage of careseeking to an iCCM provider for suspected pneumonia	Kalyango 2012a	cRCT	—	—	32.1% 43/134	17.6% 18/102	**RR 1.82** (1.12 to 2.96)	Adjusted for stratified sampling
	Munos 2016	CBA	4.9% 15/307	0.6% 1/164	5.1% 27/530	1.8% 4/220	**RR 2.80** (0.99 to 7.91)	Adjusted for cluster design and non-response

CBA: controlled before-after study; **CI:** confidence interval; **cRCT:** cluster-randomized controlled trial; **iCCM:** integrated community case management; **RR:** risk ratio.

APPENDICES

Appendix 1. Search strategies

CENTRAL, the Cochrane Library (searched 7 November 2019)

ID	Search	Hits
#1	("integrated community case management of childhood illness" or "integrated community case management of childhood illnesses" or iccm):ti,ab	35
#2	("integrated management of neonatal and childhood illness" or "integrated management of neonatal and childhood illnesses"):ti,ab	12
#3	("integrated management of childhood illness or "integrated management of childhood illnesses):ti,ab	36
#4	#1 or #2 or #3	71
#5	MeSH descriptor: [Community Health Workers] this term only	437
#6	MeSH descriptor: [Allied Health Personnel] this term only	252
#7	MeSH descriptor: [Volunteers] this term only	276
#8	MeSH descriptor: [Peer Group] explode all trees	1314
#9	MeSH descriptor: [Home Nursing] this term only	275
#10	MeSH descriptor: [Midwifery] this term only	312
#11	MeSH descriptor: [Delivery of Health Care, Integrated] this term only	350
#12	("integrated management" or "integrated community management" or "integrated community case management" or "community case management"):ti,ab,kw	243
#13	(community next worker* or community next health* next worker* or community next health next care next worker*):ti,ab,kw	1372
#14	(community next level next worker* or community next level next health* next worker* or community next level next health next care next worker*):ti,ab,kw	2
#15	(community next health* next provider* or community next health next care next provider* or community next health* next aide* or community next health next care next aide* or community next health* next agent* or community next health next care next agent* or community next health* next assistant* or community next health next care next assistant* or community next health* next promoter* or community next health next care next promoter* or community next health* next distributor* or community next health next care next distributor* or community next health* next surveyor* or community next health next care next surveyor*):ti,ab,kw	63
#16	(community next based next health* next provider* or community next based next health next care next provider* or community next based next health* next aide* or community next based next health next care next aide* or community next based next health* next agent* or community next based next	4

(Continued)

	health next care next agent* or community next based next health* next assistant* or community next based next health next care next assistant* or community next based next health* next promoter* or community next based next health next care next promoter* or community next based next health* next distributor* or community next based next health next care next distributor* or community next based next health* next surveyor* or community next based next health next care next surveyor*):ti,ab,kw	
#17	(community next volunteer* or community next health* next volunteer* or community next health next care next volunteer*):ti,ab,kw	210
#18	(community next health* next educator* or community next health next care next educator*):ti,ab,kw	21
#19	(health next promoter*):ti,ab,kw	56
#20	(allied next health next personnel or allied next health* next worker* or allied next health next care next worker*):ti,ab,kw	262
#21	(health next assistant* or welfare next assistant*):ti,ab,kw	31
#22	(voluntary next worker* or voluntary next health* next worker* or voluntary next health next care next worker* or volunteer next worker* or volunteer next health* next worker* or volunteer next health next care next worker*):ti,ab,kw	38
#23	(voluntary next team* or voluntary next health* next team* or voluntary next health next care next team* or volunteer next team* or volunteer next health* next team* or volunteer next health next care next team* or volunteer next collaborator*):ti,ab,kw	4
#24	(health* next auxiliary or health* next auxilliary or health next care next auxiliary or health next care next auxilliary or health* next auxiliaries or health* next auxilliaries or health next care next auxiliaries or health next care next auxiliaries or auxiliary next nurse* or auxilliary next nurse*):ti,ab,kw	510
#25	(village next health* next worker* or village next health next care next worker* or village next health* next volunteer* or village next health next care next volunteer*):ti,ab,kw	79
#26	(lay next worker* or lay next health* next worker* or lay next health next care next worker*):ti,ab,kw	185
#27	(lay next personnel or lay next health* next personnel or lay next health next care next personnel):ti,ab,kw	14
#28	(lay next advisor* or lay next health* next advisor* or lay next health next care next advisor* or lay next counselor* or lay next health* next counselor* or lay next health next care next counselor* or lay next counsellor* or lay next health* next counsellor* or lay next health next care next counsellor* or adherence next counselor* or adherence next counsellor*):ti,ab,kw	150
#29	(lay next volunteer* or lay next health* next volunteer* or lay next health next care next volunteer*):ti,ab,kw	43
#30	(peer next educator* or peer next counselor* or peer next counsellor*):ti,ab,kw	317
#31	(lady next health*):ti,ab,kw	53

(Continued)

#32	(child next health* next worker* or child next health next care next worker* or maternal next health* next worker* or maternal next health next care next worker*):ti,ab,kw	3
#33	(traditional next midwife or traditional next midwives or traditional next birth next attendant* or doula or doulas or skilled next birth next attendant*):ti,ab,kw	229
#34	(health* next extension next worker* or health next care next extension next worker*):ti,ab,kw	39
#35	(paramedics or paramedic* next personnel):ti,ab,kw	669
#36	(drug next seller* or drug next distributor* or drug next vendor*):ti,ab,kw	24
#37	(medicin* next seller* or medicin* next distributor* or medicin* next vendor* or medication next seller* or medication next distributor* or medication next vendor*):ti,ab,kw	15
#38	(licensed next chemical next seller*):ti,ab,kw	2
#39	(pharmaceutical next seller* or pharmaceutical next distributor* or pharmaceutical next vendor*):ti,ab,kw	1
#40	("community management" or "community based management" or "community case management" or "community based case management"):ti,ab,kw	196
#41	("home based management" or "home nursing" or "home based nursing" or home next based next carer*):ti,ab,kw	532
#42	(barefoot next doctor* or traditional next healer* or link next worker* or front next line next worker* or front next line next health* next worker* or front next line next health next care next worker* or frontline next worker* or frontline next health* next worker* or frontline next health next care next worker* or family next planning next personnel or family next planning next worker*):ti,ab,kw	155
#43	(health next surveillance next assistant* or relais or accredited next social next health next activist* or anganwadi next worker* or agentes next polivalentes next elementares or shasthya next shebika or promotoras or keshatan or gizi or health next development next army or therapy next supporter or behvarz or brigadista*):ti,ab,kw	141
#44	#5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39 or #40 or #41 or #42 or #43	5915
#45	MeSH descriptor: [Disease Management] this term only	872
#46	MeSH descriptor: [Case Management] this term only	687
#47	MeSH descriptor: [Malaria] explode all trees	2812
#48	MeSH descriptor: [Diarrhea] explode all trees	3256
#49	MeSH descriptor: [Malnutrition] explode all trees	3720

(Continued)

#50	MeSH descriptor: [Infant, Newborn, Diseases] explode all trees	6381
#51	MeSH descriptor: [Sepsis] explode all trees	4146
#52	MeSH descriptor: [Respiratory Tract Infections] explode all trees	13,171
#53	MeSH descriptor: [Dehydration] this term only	518
#54	MeSH descriptor: [Fever] explode all trees	2000
#55	("disease management" or "case management"):ti,ab	3524
#56	(malaria or paludism or diarrhea or diarrhoea or diarrheal next disease* or diarrhoeal next disease* or pneumonia or malnutrition or mal next nutrition or malnurished or mal next nurished or respiratory next infection* or respiratory next tract next infection* or sepsis or severe next infection* or fever or dehydration or dehydrated or danger next sign*):ti,ab,kw	79,350
#57	((newborn* or new next born* or neonat* or neo next nat* or perinatal or peri next natal or childhood) near/3 (disease* or illness*)):ti,ab,kw	3431
#58	#45 or #46 or #47 or #48 or #49 or #50 or #51 or #52 or #53 or #54 or #55 or #56 or #57	102,020
#59	(Africa or Asia or Caribbean or "West Indies" or "South America" or "Latin America" or "Central America"):ti,ab,kw	11,520
#60	(Afghanistan or Albania or Algeria or Angola or Antigua or Barbuda or Argentina or Armenia or Armenian or Aruba or Azerbaijan or Bahrain or Bangladesh or Barbados or Benin or Byelarus or Byelorussian or Belarus or Belorussian or Belorussia or Belize or Bhutan or Bolivia or Bosnia or Herzegovina or Hercegovina or Botswana or Brasil or Brazil or Bulgaria or "Burkina Faso" or "Burkina Faso" or "Upper Volta" or Burundi or Urundi or Cambodia or "Khmer Republic" or Kampuchea or Cameroon or Cameroons or Cameron or Camerons or "Cape Verde" or "Central African Republic" or Chad or Chile or China or Colombia or Comoros or "Comoro Islands" or Comores or Mayotte or Congo or Zaire or "Costa Rica" or "Cote d'Ivoire" or "Ivory Coast" or Croatia or Cuba or Cyprus or Czechoslovakia or "Czech Republic" or Slovakia or "Slovak Republic"):ti,ab,kw	24,165
#61	(Djibouti or "French Somaliland" or Dominica or "Dominican Republic" or "East Timor" or "East Timur" or "Timor Leste" or Ecuador or Egypt or "United Arab Republic" or "El Salvador" or Eritrea or Estonia or Ethiopia or Fiji or Gabon or "Gabonese Republic" or Gambia or Gaza or Georgia or Georgian or Ghana or "Gold Coast" or Greece or Grenada or Guatemala or Guinea or Guam or Guiana or Guyana or Haiti or Honduras or Hungary or India or Maldives or Indonesia or Iran or Iraq or "Isle of Man" or Jamaica or Jordan or Kazakhstan or Kazakh or Kenya or Kiribati or Korea or Kosovo or Kyrgyzstan or Kirghizia or "Kyrgyz Republic" or Kirghiz or Kirgizstan or "Lao PDR" or Laos or Latvia or Lebanon or Lesotho or Basutoland or Liberia or Libya or Lithuania):ti,ab,kw	31,774
#62	(Macedonia or Madagascar or "Malagasy Republic" or Malaysia or Malaya or Malay or Sabah or Sarawak or Malawi or Nyasaland or Mali or Malta or "Marshall Islands" or Mauritania or Mauritius or "Agalega Islands" or Mexico or Micronesia or "Middle East" or Moldova or Moldovia or Moldovian or Mongolia or Montenegro or Morocco or Ifni or Mozambique or Myanmar or Myanma or Burma or Namibia or Nepal or "Netherlands Antilles" or "New Caledonia" or Nicaragua or Niger or Nigeria or "Northern Mariana Islands" or Oman or Muscat or Pakistan or Palau or Palestine or Panama or Paraguay or Peru or Philip-	13,284

(Continued)

	pines or Philipines or Phillipines or Phillippines or Poland or Portugal or "Puerto Rico"):ti,ab,kw	
#63	(Romania or Rumania or Roumania or Russia or Russian or Rwanda or Ruanda or "Saint Kitts" or "St Kitts" or Nevis or "Saint Lucia" or "St Lucia" or "Saint Vincent" or "St Vincent" or Grenadines or Samoa or "Samoan Islands" or "Navigator Island" or "Navigator Islands" or "Sao Tome" or "Saudi Arabia" or Senegal or Serbia or Montenegro or Seychelles or "Sierra Leone" or Slovenia or "Sri Lanka" or Ceylon or "Solomon Islands" or Somalia or Sudan or Suriname or Surinam or Swaziland or Syria or Tajikistan or Tadzhikistan or Tadjikistan or Tadzhik or Tanzania or Thailand or Togo or "Togolese Republic" or Tonga or Trinidad or Tobago or Tunisia or Turkey or Turkmenistan or Turkmen or Uganda or Ukraine or Uruguay or USSR or "Soviet Union" or "Union of Soviet Socialist Republics" or Uzbekistan or Uzbek or Vanuatu or "New Hebrides" or Venezuela or Vietnam or "Viet Nam" or "West Bank" or Yemen or Yugoslavia or Zambia or Zimbabwe or Rhodesia):ti,ab,kw	14,851
#64	(developing or less* next developed or "under developed" or underdeveloped or "middle income" or low* next income or underserved or "under served" or deprived or poor*) next (countr* or nation* or population* or world):ti,ab,kw	6453
#65	(developing or less* next developed or "under developed" or underdeveloped or "middle income" or low* next income) next (economy or economies):ti,ab,kw	15
#66	low* next (gdp or gnp or "gross domestic" or "gross national"):ti,ab,kw	48
#67	(low near/3 middle near/3 countr*):ti,ab,kw	1205
#68	(lmic or lmics or "third world" or "lami country" or "lami countries"):ti,ab,kw	375
#69	("transitional country" or "transitional countries"):ti,ab,kw	6
#70	#59 or #60 or #61 or #62 or #63 or #64 or #65 or #66 or #67 or #68 or #69	87,385
#71	#4 or (#44 and #58 and #70) in Trials	533

MEDLINE and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily 1946 to November 05, 2019 (searched 7 November 2019)

#	Searches	Results
1	(integrated community case management of childhood illness* or iccm).ti,ab,kf.	204
2	"integrated management of neonatal and childhood illness*".ti.	15
3	"integrated management of childhood illness*".ti.	152
4	or/1-3	371
5	Community Health Workers/	5006
6	Allied Health Personnel/	11,520

(Continued)

7	Volunteers/	9412
8	exp Peer Group/	20,012
9	Home Nursing/	8492
10	Midwifery/	18,766
11	Delivery of health Care, Integrated/	12,123
12	(integrated management or integrated community management or integrated community case management or community case management).ti,ab,kf.	1943
13	(community worker? or community health* worker? or community health care worker?).ti,ab,kf.	4742
14	(community level worker? or community level health* worker? or community level health care worker?).ti,ab,kf.	39
15	(community health* provider? or community health care provider? or community health* aide? or community health care aide? or community health* agent? or community health care agent? or community health* assistant? or community health care assistant? or community health* promoter? or community health care promoter? or community health* distributor? or community health care distributor? or community health* surveyor? or community health care surveyor?).ti,ab,kf.	549
16	(community based health* provider? or community based health care provider? or community based health* aide? or community based health care aide? or community based health* agent? or community based health care agent? or community based health* assistant? or community based health care assistant? or community based health* promoter? or community based health care promoter? or community based health* distributor? or community based health care distributor? or community based health* surveyor? or community based health care surveyor?).ti,ab,kf.	53
17	(community volunteer? or community health* volunteer? or community health care volunteer?).ti,ab,kf.	978
18	(community health* educator? or community health care educator?).ti,ab,kf.	62
19	health promoter?.ti,ab,kf.	540
20	(allied health personnel or allied health* worker? or allied health care worker?).ti,ab,kf.	398
21	(health assistant? or welfare assistant?).ti,ab,kf.	243
22	(voluntary worker? or voluntary health* worker? or voluntary health care worker? or volunteer worker? or volunteer health* worker? or volunteer health care worker?).ti,ab,kf.	407
23	(voluntary team? or voluntary health* team? or voluntary health care team? or volunteer team? or volunteer health* team? or volunteer health care team? or volunteer collaborator?).ti,ab,kf.	40

(Continued)

24	(health* auxiliary or health* auxilliary or health care auxiliary or health care auxilliary or health* auxiliaries or health* auxilliaries or health care auxiliaries or health care auxilliaries or auxiliary nurse? or auxilliary nurse?).ti,ab,kf.	404
25	(village health* worker? or village health care worker? or village health* volunteer? or village health care volunteer?).ti,ab,kf.	449
26	(lay worker? or lay health* worker? or lay health care worker?).ti,ab,kf.	472
27	(lay personnel or lay health* personnel or lay health care personnel).ti,ab,kf.	54
28	(lay advisor? or lay health* advisor? or lay health care advisor? or lay counselor? or lay health* counselor? or lay health care counselor? or lay counsellor? or lay health* counsellor? or lay health care counsellor? or adherence counselor? or adherence counsellor?).ti,ab,kf.	391
29	(lay volunteer? or lay health* volunteer? or lay health care volunteer?).ti,ab,kf.	125
30	(peer educator? or peer counselor? or peer counsellor?).ti,ab,kf.	965
31	lady health*.ti,ab,kf.	149
32	(child health* worker? or child health care worker? or maternal health* worker? or maternal health care worker?).ti,ab,kf.	65
33	(traditional midwife or traditional midwives or traditional birth attendant? or doula? or skilled birth attendant?).ti,ab,kf.	2275
34	(health* extension worker? or health care extension worker?).ti,ab,kf.	267
35	(paramedics or paramedic* personnel).ti,ab,kf.	4593
36	(drug seller? or drug distributor? or drug vendor?).ti,ab,kf.	290
37	((medicin* or medication) adj (seller? or distributor? or vendor?)).ti,ab,kf.	115
38	licensed chemical seller?.ti,ab,kf.	9
39	(pharmaceutical seller? or pharmaceutical distributor? or pharmaceutical vendor?).ti,ab,kf.	17
40	(community management or community based management or community case management or community based case management).ti,ab,kf.	864
41	(home based management or home nursing or home based nursing or home based carer?).ti,ab,kf.	1637
42	(barefoot doctor? or traditional healer? or link worker? or front line worker? or frontline worker? or front line health* worker? or frontline health* worker? or front line health care worker? or frontline health care worker? or family planning personnel or family planning worker?).ti,ab,kf.	3880
43	(health surveillance assistant? or relais or accredited social health activist? or anganwadi worker? or agentes polivalentes elementares or shasthya shebika or promotoras or keshatan or gizi or health development army or therapy supporter or behvarz or brigadista?).ti,ab,kf.	602

(Continued)

44	or/5-43 [Community Health Workers]	101,840
45	Disease Management/	34,180
46	Case Management/	9929
47	exp Malaria/	64,551
48	exp Diarrhea/	51,703
49	exp Malnutrition/	119,205
50	exp Infant, Newborn, Diseases/	170,551
51	exp Sepsis/	119,212
52	exp Respiratory Tract Infections/	348,755
53	Dehydration/	13,002
54	exp Fever/	42,184
55	((disease or case) adj management).ti,ab,kf.	25,465
56	(malaria or paludism or diarrhea or diarrhoea or diarrheal disease? or diarrhoeal disease? or pneumonia or malnutrition or mal nutrition or malnurished or mal nurished or respiratory infection? or respiratory tract infection? or sepsis or severe infection? or fever or dehydration or dehydrated or danger sign?).ti,ab,kf.	620,613
57	((newborn? or new born? or neonat* or neo nat* or perinatal or peri natal or childhood) adj3 (disease? or illness*)).ti,ab,kf.	30,990
58	or/45-57 [Conditions to be managed]	1,324,207
59	Developing Countries.sh,kf.	84,414
60	(Africa or Asia or Caribbean or West Indies or South America or Latin America or Central America).hw,kf,ti,ab,cp.	266,024
61	(Afghanistan or Albania or Algeria or Angola or Antigua or Barbuda or Argentina or Armenia or Armenian or Aruba or Azerbaijan or Bahrain or Bangladesh or Barbados or Benin or Byelarus or Byelorussian or Belarus or Belorussian or Belorussia or Belize or Bhutan or Bolivia or Bosnia or Herzegovina or Hercegovina or Botswana or Brasil or Brazil or Bulgaria or Burkina Faso or Burkina Fasso or Upper Volta or Burundi or Urundi or Cambodia or Khmer Republic or Kampuchea or Cameroon or Cameroons or Cameron or Camerons or Cape Verde or Central African Republic or Chad or Chile or China or Colombia or Comoros or Comoro Islands or Comores or Mayotte or Congo or Zaire or Costa Rica or Cote d'Ivoire or Ivory Coast or Croatia or Cuba or Cyprus or Czechoslovakia or Czech Republic or Slovakia or Slovak Republic or Djibouti or French Somaliland or Dominica or Dominican Republic or East Timor or East Timur or Timor Leste or Ecuador or Egypt or United Arab Republic or El Salvador or Eritrea or Estonia or Ethiopia or Fiji or Gabon or Gabonese Republic or Gambia or Gaza or Georgia Republic or Georgian Republic or Ghana or Gold Coast or Greece or Grenada or Guatemala or Guinea or Guam or Guiana or Guyana or Haiti or Honduras or Hungary or India or Maldives or Indonesia or Iran or Iraq or Isle of Man or Jamaica or Jordan or Kazakhstan or Kazakh or Kenya or Kiri-	3,582,010

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	bati or Korea or Kosovo or Kyrgyzstan or Kirghizia or Kyrgyz Republic or Kirghiz or Kirgizstan or Lao PDR or Laos or Latvia or Lebanon or Lesotho or Basutoland or Liberia or Libya or Lithuania or Macedonia or Madagascar or Malagasy Republic or Malaysia or Malaya or Malay or Sabah or Sarawak or Malawi or Nyasaland or Mali or Malta or Marshall Islands or Mauritania or Mauritius or Agalega Islands or Mexico or Micronesia or Middle East or Moldova or Moldovia or Moldovian or Mongolia or Montenegro or Morocco or Ifni or Mozambique or Myanmar or Myanma or Burma or Namibia or Nepal or Netherlands Antilles or New Caledonia or Nicaragua or Niger or Nigeria or Northern Mariana Islands or Oman or Muscat or Pakistan or Palau or Palestine or Panama or Paraguay or Peru or Philippines or Philipines or Phillipines or Phillippines or Poland or Portugal or Puerto Rico or Romania or Rumania or Roumania or Russia or Russian or Rwanda or Ruanda or Saint Kitts or St Kitts or Nevis or Saint Lucia or St Lucia or Saint Vincent or St Vincent or Grenadines or Samoa or Samoan Islands or Navigator Island or Navigator Islands or Sao Tome or Saudi Arabia or Senegal or Serbia or Montenegro or Seychelles or Sierra Leone or Slovenia or Sri Lanka or Ceylon or Solomon Islands or Somalia or South Africa or Sudan or Suriname or Surinam or Swaziland or Syria or Tajikistan or Tadzhikistan or Tadjikistan or Tadzhik or Tanzania or Thailand or Togo or Togolese Republic or Tonga or Trinidad or Tobago or Tunisia or Turkey or Turkmenistan or Turkmen or Uganda or Ukraine or Uruguay or USSR or Soviet Union or Union of Soviet Socialist Republics or Uzbekistan or Uzbek or Vanuatu or New Hebrides or Venezuela or Vietnam or Viet Nam or West Bank or Yemen or Yugoslavia or Zambia or Zimbabwe or Rhodesia).hw,kf,ti,ab,cp.	
62	((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or under served or deprived or poor*) adj (countr* or nation? or population? or world)).ti,ab,kf.	123,944
63	((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)).ti,ab,kf.	512
64	(low* adj (gdp or gnp or gross domestic or gross national)).ti,ab,kf.	236
65	(low adj3 middle adj3 countr*).ti,ab,kf.	14,973
66	(lmic or lmics or third world or lami countr*).ti,ab,kf.	7132
67	transitional countr*.ti,ab,kf.	156
68	or/59-67	3,732,522
69	randomized controlled trial.pt.	493,884
70	controlled clinical trial.pt.	93,410
71	multicenter study.pt.	260,566
72	pragmatic clinical trial.pt.	1213
73	non-randomized controlled trials as topic/	582
74	interrupted time series analysis/	703
75	controlled before-after studies/	448
76	(randomis* or randomiz* or randomly).ti,ab.	858,944

(Continued)

77	groups.ab.	1,972,948
78	(trial or multicenter or multi center or multicentre or multi centre).ti.	246,210
79	(intervention? or effect? or impact? or controlled or control group? or (before adj5 after) or (pre adj5 post) or ((pretest or pre test) and (posttest or post test)) or quasiexperiment* or quasi experiment* or pseudo experiment* or pseudoexperiment* or evaluat* or time series or time point? or repeated measur*).ti,ab.	9,246,420
80	or/69-79	10,307,387
81	exp Animals/	22,739,409
82	Humans/	18,098,731
83	81 not (81 and 82)	4,640,678
84	review.pt.	2,576,922
85	meta analysis.pt.	107,532
86	news.pt.	198,022
87	comment.pt.	812,757
88	editorial.pt.	507,578
89	cochrane database of systematic reviews.jn.	15,272
90	comment on.cm.	812,702
91	(systematic review or literature review).ti.	143,313
92	or/83-91	8,424,872
93	80 not 92 [Methods filter]	7,260,748
94	4 or (44 and 58 and 68 and 93)	2361

Embase 1974 to 2019 November 06, Ovid (searched 7 November 2019)

#	Searches	Results
1	("integrated community case management of childhood illness" or "integrated community case management of childhood illnesses" or iccm).ti,ab,kw.	257
2	limit 1 to embase	107

CINAHL 1981 to present, EBSCOhost (searched 7 November 2019)

#	Query	Results
S1	TI ("integrated community case management of childhood illness" or "integrated community case management of childhood illnesses" or iccm) OR AB ("integrated community case management of childhood illness" or "integrated community case management of childhood illnesses" or iccm) Exclude MEDLINE records	10

Virtual Health Library (VHL Regional Portal): bvsalud.org/en/ (searched 8 November 2019)

(tw:(integrated)) AND (tw:("case management")) AND (tw:(child*))

International Clinical Trials Registry Platform (ICTRP): www.who.int/ictrp/en (searched 8 November 2019)

Searched using Advanced search – in Title OR intervention – Limited to Clinical trials in Children – Recruitment status All

iccm OR integrated management OR community management OR community based management OR community case management OR community based case management

ClinicalTrials.gov: www.clinicaltrials.gov (searched 8 November 2019)

Searched using: Advanced Search – Other terms – Study type: Interventional studies – Age group: Child (birth-17):

iccm OR "integrated management" OR "community management" OR "community based management" OR "community case management" OR "community based case management"

Web of Science Core Collection 1987–2019, Clarivate Analytics – Citation search for 9 included studies (12 papers) (searched 27 September 2019)

Bhandari 2012; Boone 2016; Kalyango 2012; Kalyango 2012; Kalyango 2013; Kalyango 2013; Mazumder 2014; Mubiru 2015; Munos 2016, Taneja 2015; White 2018; Yansaneh 2014

POPLINE, K4health (searched 5 December 2018)

All Fields: "integrated community case management of childhood illness" OR "integrated community case management of childhood illnesses" OR iccm

OpenGrey: www.opengrey.eu/ (searched 22 March 2019)

1. "community case management"
2. management AND ("childhood illness" OR "childhood illnesses")

Grey Literature Report: www.greylit.org/ (searched 22 March 2019)

1. Iccm
2. "integrated management"
3. "community management"
4. "community based management"
5. "community case management"
6. "community based case management"
7. "childhood illness" Limited to management
8. "childhood illnesses" Limited to management

Eldis: www.eldis.org/ (searched 22 March 2019)

1. Topic: Health systems with search term: iccm
2. Topic: Health systems with search term: case management
3. Topic: Health systems with search term: integrated management
4. Topic: Health systems with search term: child illnesses

5. Topic: Children and young people with search term: iccm
6. Topic: Health with search term: iccm

Appendix 2. Additional analysis for mortality

The following is an appendix providing additional analysis complementary to "Analysis 1.3 Comparison 1 iCCM vs usual facility services: mortality", including heterogeneity of effects and information pertinent to the interpretation of the results.

Heterogeneity of neonatal mortality effects and possible explanatory factors

I^2 of the pooled estimate for neonatal mortality was 64%. The reasons for the heterogeneity were unclear but may have been due to differences in adjustments made by the study authors during analysis, differences in intervention components and inputs (see Table 1; Table 3), and differences in contextual setting between Bhandari 2012a and Boone 2016. Regarding differences in adjustments during analysis, see Table 9 for a summary of adjustments made by the study authors.

Regarding differences in components and inputs, iCCM providers in Bhandari 2012a were trained to treat newborn local infection and identify and refer newborns with danger signs, whereas iCCM providers in Boone 2016 were not trained to manage ill children below two months of age. Although both studies included perinatal home visits (day one, day three and day seven in Bhandari 2012a and during the first 10 days after birth in Boone 2016) by lay health workers and convening of health groups (women's health groups in Bhandari 2012a and health clubs for caregivers in Boone 2016) by lay health workers, the lay health workers in Bhandari 2012a were trained on iCCM for newborns (as noted above) whereas lay health workers that conducted home visits and convened health clubs for caregivers in Boone 2016 were not trained on iCCM for newborns. Lay health workers in Bhandari 2012a were paid incentives for perinatal home visits, treatment of sick newborns and convening of women's groups, whereas Boone 2016 did not report that lay health workers were paid (it may be fair to assume they were not paid). In addition, Bhandari 2012a included training of facility-based providers on IMNCI to improve facility-based case management. Boone 2016 included training of registered nurses to provide mobile health services, including vaccinations, supplementation, deparasitization and growth monitoring for children, as well as basic antenatal and postnatal consultations for pregnant women, but training on case management was not reported and the intervention did not include important enhancements for facility-based IMNCI/IMCI. The authors of Bhandari 2012a attributed the effect to substantial improvements in careseeking to an appropriate provider for newborn illness (and timeliness thereof), improvements in other newborn care practices (early breastfeeding, exclusive breastfeeding, delayed bathing, appropriate cord care) and reductions in hospital admissions and reporting of morbidities such as neonatal illness associated with danger signs and diarrhoea and pneumonia during infancy. Boone 2016 indicated the following factors may have dampened the effect: the short timeframe of the study; possible issues with therapeutic effectiveness of malaria treatment (chloroquine per national protocol) early in the trial and possible earlier population access to ACTs in control clusters, once the national protocol changed to ACTs from chloroquine; and lack of broader health system strengthening, including lack of interventions at health facility level to improve availability and quality of care for severe illness and lack of interventions to improve successful referral from community to health facilities for children with serious illness. Differences in context may have also contributed to the heterogeneity. Bhandari 2012a was conducted in a mixed rural/urban area of northern India whereas Boone 2016 was conducted in rural Guinea-Bissau. However the lack of important differences in effect for careseeking to an appropriate provider between the two studies suggests that the differences in inputs related to newborn health may explain more of the heterogeneity than do the differences in contextual setting.

Heterogeneity of infant mortality effects and possible explanatory factors

I^2 of the pooled estimate for infant mortality was 84%. Bhandari 2012a estimated infant mortality may be 15% lower in the iCCM group (HR 0.85, 95% CI 0.77 to 0.94). Boone 2016 estimated infant mortality may be 17% higher in the iCCM group (HR 1.17, 95% CI 0.93 to 1.47) with CIs that included no effect. The reasons for the heterogeneity may have included the factors noted above for newborn mortality. Bhandari 2012a noted that the persistent effect into infancy was likely the result of mother's retention of disease prevention messages communicated through the women's group meetings, with a reported 45% participation, rather than the postnatal visits by lay health workers, since the latter were restricted to days one, three and seven following birth. Boone 2016 noted a similar level of participation (36% to 38%) for the caregiver's health clubs but did not achieve an effect on infant mortality similar to Bhandari 2012a. Differences in intervention inputs included incentives for lay health workers and breadth of the iCCM package – and possibly quality of the care and messages delivered – as well as training of facility-based providers on IMNCI and, as noted above for neonatal mortality, these differences may have played a role in the differences in the effect of iCCM on infant mortality. Also as noted above for neonatal mortality, differences in contextual setting may have contributed to differences in the effect of iCCM on infant mortality but the lack of important differences in the effect of iCCM on careseeking to an appropriate provider between the two studies suggests that the differences in inputs related to newborn and infant health better may explain more of the the heterogeneity than do differences in contextual setting.

Possible explanatory factors for the under-five mortality effects

Boone 2016 indicated several factors may have dampened the effect of iCCM on under-five mortality: the short timeframe of the study; lack of broader health system strengthening, including lack of interventions at health facility level to improve availability and quality of care for severe illness, inadequate interventions to improve successful referral from community to health facilities for children with serious illness; the possibility that iCCM providers may have inadvertently delayed careseeking to health facilities in the case of severe illness (parents may have waited to observe the effects of treatment provided by iCCM providers); possible issues with therapeutic effectiveness of malaria

treatment (iCCM providers initially used chloroquine for treatment of malaria instead of ACTs and the introduction of ACTs for treatment of malaria may have been earlier at health facilities in control clusters than among iCCM providers in intervention clusters; the authors also reported that there was inadequate storage of iCCM drugs).

WHAT'S NEW

Date	Event	Description
11 February 2021	Amended	Correction made to author affiliation and declarations of interest updated

HISTORY

Protocol first published: Issue 11, 2017
Review first published: Issue 2, 2021

Date	Event	Description
28 November 2017	Amended	Protocol republished with a new citation to correct an error in spelling of author's name

CONTRIBUTIONS OF AUTHORS

Co-ordinating the review: NPO, TD.

Conceived and developed the protocol: NPO, KD, DB, EWJ, SM, TD, WAO, MK, KL.

Conducting the search strategies: WAO.

Abstract and full-text screening: NPO, KD, DB, EWJ, TD, WAO, MK.

Data extraction: NPO, KD, DB, EWJ, TD, WAO, MK.

Data entry into Review Manager 5: NPO, SM.

Data analysis: SM, NPO, TD.

Drafted the review: NPO, TD.

Reviewed the draft review and provided feedback for the final review: NPO, KD, DB, EWJ, SM, TD, WAO, MK.

All review authors agreed to the final version of the review.

DECLARATIONS OF INTEREST

NPO has worked as a Health Specialist for UNICEF at its headquarters in New York, USA. UNICEF was involved in the development of iCCM with WHO; UNICEF has advocated for countries to adopt iCCM; and UNICEF has provided funding and technical support in numerous countries for iCCM implementation, monitoring, evaluation and research. NPO was involved in providing technical support in numerous countries for iCCM monitoring, evaluation, and implementation research. NPO works as a Health Specialist – Public Health and M&E – for the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) in Geneva, Switzerland. GFATM has funded the implementation of iCCM and CCM in numerous countries. NPO has also served as an expert advisor to the WHO on IMCI, including iCCM.

SM, KD, DB, MK and TD were members of the research team for a UNICEF commissioned evaluation of the Integrated Health Systems Strengthening (IHSS) programme, which included iCCM, in six Sub-Saharan Africa countries.

WAO: none.

EWJ: none.

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Internal sources

- No sources of support supplied

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- Bill and Melinda Gates Foundation, USA

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

In the "Types of outcomes measures" subsection of the "Methods" section of our protocol, we stated that "Reporting of the outcomes listed here will not be an inclusion criterion for the review and we will include studies regardless of the assessed outcomes." In our review, we excluded studies that did not report on one or more of the outcome measures indicated in our protocol.

Our planned subgroup analyses were not possible (except for household wealth and gender for mortality and careseeking to an appropriate provider) due to insufficient data. We included the following additional six outcomes not explicitly mentioned in our protocol but that were implicit in our understanding of iCCM as a flexible package, adapted to different contexts:

- coverage of appropriate treatment from an appropriate provider for newborn local infection;
- coverage of appropriate treatment from an iCCM provider for newborn local infection;
- coverage of careseeking to an appropriate provider for newborn local infection;
- coverage of careseeking to an iCCM provider for newborn local infection;
- coverage of careseeking to an appropriate provider for newborn danger signs; and
- coverage of careseeking to an iCCM provider for newborn danger signs.

In the "Types of outcome measures" subsection of the "Methods" section of our protocol, we stated that coverage of appropriate treatment could include antimalarial drug prescription for fever. We considered appropriate treatment for malaria to be antimalarial drug prescription for rapid diagnostic testing (RDT)- or microscopy-confirmed malaria or fever, the latter where the treatment protocol was presumptive treatment without confirmation by RDT or microscopy.

We performed the following additional sensitivity analyses not prespecified in our protocol: to explore whether effects on our outcomes differed by illness, we conducted sensitivity analyses that stratified results by illness. See Table 5; Table 6; Table 7; Table 8; Table 9; Table 10; Table 11; Table 12; Table 13; Table 14; Table 15; Table 15; Table 16.

INDEX TERMS

Medical Subject Headings (MeSH)

Africa South of the Sahara; Asia; Bias; Case Management [*organization & administration]; Child Health Services [*organization & administration]; *Community Health Workers [economics] [education] [organization & administration]; Controlled Before-After Studies; *Developing Countries; Diarrhea [therapy]; Fever [therapy]; Infant Mortality; Infant Nutrition Disorders [therapy]; Malaria [therapy]; Neonatal Sepsis [therapy]; Pneumonia [therapy]; Randomized Controlled Trials as Topic; Salaries and Fringe Benefits; United Nations

MeSH check words

Child, Preschool; Humans; Infant; Infant, Newborn

CHAPTER FOUR: DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

This chapter begins with a reminder of the aim of the research. This is followed by a summary and discussion of the overarching findings and conclusions of the research and the contributions of the research to the field. A summary of the limitations of the research is then presented. The chapter closes with recommendations for policy, practice, and future research.

Aim

The aim of this research was to contribute to improved understanding of the contribution of CHWs to geographical accessibility of integrated PHC services at community level, including iCCM, explore geospatial approaches for optimizing the scale and deployment of CHWs to maximize geographical accessibility of integrated PHC services, including iCCM, at community level, and assess the effectiveness of iCCM in LMICs with the aim of informing health policy and planning.

Overarching findings and conclusions

The contribution of CHWs to geographical accessibility of integrated PHC services

Studies 1 and 2 address the first aim of this research and make an important contribution to the field by estimating the contribution of CHWs to geographical accessibility of integrated PHC services at national scale in Niger and Sierra Leone. In both countries, CHWs made important contributions to geographic accessibility to these services. Previous research has focused on the use of geospatial analysis to assess the geographical accessibility of health facilities (for example, Weiss *et al*., 2020, Blanford *et al*., 2012, and van Duinen *et al*., 2021), and the contribution of CHW networks to geographical accessibility of health services at subnational scale (Inhantamalala *et al*., 2020 in Madagascar, and Brunie *et al*., 2020 in Madagascar). No studies prior to this research have assessed the contribution of CHWs to geographical accessibility of integrated PHC services at national scale. Using robust geospatial analysis, the research found that the scale-up and deployment of CHWs in Niger and Sierra Leone contributed to important increases in the geographical accessibility of integrated PHC services at community level, including iCCM. The studies also identified policy relevant variation in the contribution of CHWs to geographical accessibility to integrated PHC services at community level across subnational areas (pointing to geographic areas of greatest need), gender of the CHW (pointing to inequalities in CHW employment), and training of CHWs on specific interventions (pointing to piecemeal CHW

support). The research in Niger and Sierra Leone complements earlier research on geographical accessibility of health facility-based services in Niger (Blanford *et al*., 2012 and Weiss *et al*., 2020) and Sierra Leone (Duinen *et al*., 2020 and Weiss *et al*., 2020) in the following ways: 1) the research used more complete and more accurate health facility datasets 2) the research included data on the CHW networks, including data on the scale-up and deployment of CHWs across space and time, as well as information on the gender and training of the CHWs, which were not included in the previous studies 3) the research involved experts from the Ministry of Health and partners as authors in the research, contributing to a more equitable approach to the research despite its own shortcomings (a reflexivity statement published with study 2 is included in Appendix 6) and more realistic assumptions e.g., on travel speeds. For example, Weiss *et al*. (2020) used generic, global travel speeds to inform its model on geographical accessibility to health facilities in Niger and Sierra Leone. In this way the research in Niger and Sierra Leone provides more accurate estimates of geographical accessibility to health facilities than previously existed and provides new insight on the contribution of CHWs to geographical accessibility of integrated PHC services.

Approaches for optimizing the scale and deployment of CHWs

Studies 1-3 address the second aim of this research and make an important contribution to the field by exploring geospatial approaches for optimizing the scale and deployment of CHWs to maximize geographical accessibility of integrated PHC services, including iCCM, at national scale in Niger, Sierra Leone, and Mali and reflect on implications of CHW optimization for health systems, CHWs, their families and communities they serve. Previous research has focused on the use of geospatial analysis to assess the efficiency of CHW deployment for subnational areas (Pratt *et al*., 2014; Cherkesly *et al*., 2019; Ihantamalala *et al*., 2020; Brunie *et al*., 2020). Champagne *et al*., 2022 (published after Study 1 and at the same time as publication of Study 2 and submission of Study 3) explored optimization of CHW scale-up and deployment at national scale in Haiti. The research in studies 1-3 complement the previous literature by exploring approaches for optimizing the scale and deployment of CHWs at national scale to maximize their contribution to integrated PHC services. Using robust geospatial analysis, the research estimated the number of CHWs needed (or additional CHWs needed in the case of Niger and Mali) – and, importantly, where they should be deployed at fine spatial scale i.e., 1km x 1km resolution and the optimal sequence for their deployment i.e., the first group of 500 CHWs, the second

group of 500 CHWs and so on – to maximize geographical accessibility of integrated PHC services at community level. Hypothetical optimized CHW networks were more efficiently deployed than existing CHW networks by 32.3%–47.1% in Niger and by 22.4%-71.9% in Sierra Leone, depending on targeting metric (prioritizing the estimated population, under-five deaths, or *Pf* malaria cases), pointing to important opportunities for improving the efficiency of CHW deployment and realizing cost-savings that could be re-invested in strengthening the health policy and systems needed for CHWs to work effectively and enjoy the benefits of decent working conditions in alignment with WHO guidelines.

In Niger, the research estimated important efficiencies (indicated above) that could be realized through retargeting of the existing community health post network but noted in the study that such a retargeting may be disruptive and politically contentious. The study proposed two alternative approaches that may be less disruptive and more politically feasible, using the geospatial optimization approach described in the paper: 1) to optimize further scale-up of the community health post network staffed by paid, full-time CHWs and/or 2) to scale-up the volunteer CHW (*relais communautaire* or RC) network. For the latter, the study estimated that an optimized network of 7741 additional RCs could increase geographical coverage from 41.5% to 82.9%, providing geographical accessibility to at least some integrated PHC services at community level for an additional 7.4 million people not covered. The study discusses trade-offs between scaling different types of CHWs with different scopes of work and concludes that it may be more prudent from an equity perspective to optimize further scale-up of the network of full-time, paid CHWs providing a broader package of services from community health posts while progressively upgrading community health posts to referral facilities, where needed, to enable broadening of the package of services that are geographically accessible to the population rather than scale up the RC network. In country contexts where multiple types of CHWs exist, this kind of reflection on trade-offs for scale-up and deployment is relevant. The study also discusses the challenge of scaling to very remote, sparsely populated areas. The study notes that covering the last 15-20% of the population in Niger will be increasingly less efficient and more logistically challenging than covering the first 80% of the population – a complex problem facing many countries as they attempt to achieve equity and universal health coverage (Oliphant *et al*., 2021).

In Sierra Leone, early iterations (in 2016) of the analysis from study 2 revealed that 65% of CHWs were located within 3 kilometers of a health facility, not in alignment with MOHS

policy. The MOHS subsequently led a CHW policy dialogue that spanned multiple years, and included consultation with CHWs, communities, and all levels of the health system, as well as careful consideration of multiple sources of information (including the geospatial analysis in study 2, a CHW program evaluation, and a HLMA). The CHW policy dialogue led to the development of a new national community health strategy for 2022-2025 for Sierra Leone and support for a policy decision by the MOHS to "rightsize and retarget" the existing CHW workforce, reducing it by 40% and ensuring CHWs were recruited from and deployed to areas of greatest need in alignment with the new strategy. The example of "rightsizing and retargeting" the existing CHW workforce in Sierra Leone is unique in the literature. Other countries that have undertaken this kind of geospatial optimization (Niger and Mali) have so far opted to use the analysis to inform future scale-up, rather than "rightsize and retarget" their existing CHW network(s). This is discussed in the published paper for study 2 but additional reflection is useful here. Between 2000-2015 there was a large and rapid scale-up of CHWs in Sierra Leone – not all of which was carefully planned. The MOHS policy decision to "rightsize and retarget" the existing CHW workforce in 2021 was preceded by a MOHS-led CHW policy dialogue between 2018-2020 and significant investment between 2015-2018 in developing the robust datasets, analyses, and consultation process that would enable a data-informed and consultative CHW policy dialogue. Notably, the MOHS had the foresight to establish the first national georeferenced CHWML for Sierra Leone – which first identified the misalignment with national policy – and to update the national master health facility list (MFL) in 2015-2016. Developing the first CHWML and updating the MFL in 2015-2016 cost approximately US$300,000 (PhD candidate's estimate based on his work on those efforts). This was followed by a health labour market assessment and an evaluation of the national CHW programme. The MOHS also led a national consultation process (described in the reflexivity statement, Appendix 6, of the study 2) to engage CHW representatives, community leaders, primary health care workers, and district management teams in the CHW policy dialogue.

The implications of "rightsizing and retargeting" the existing CHW workforce in Sierra Leone are discussed in detail in the published paper for study 2 and are summarized here. The study indicates that employers (largely non-governmental organizations funded by donors) will need to end the employment of CHWs and CHW peer supervisors located within 3 km of a health facility, and that affected workers and their families should be compensated fairly for early termination of their employment. The study suggests that planners should anticipate the need to engage affected communities to regain their trust. The study also

indicates that new CHWs and CHW peer supervisors will need to be recruited from communities in areas prioritized by the new strategy (informed by the analysis in study 2) not already adequately covered. It further indicates that the new CHWs and CHW supervisors will need to be trained, paid, supervised, and supported and that this will require effective planning, coordination, logistics and resources. In addition, measures should be in place to ensure that children of CHWs recruited from and deployed to work in very remote communities have access to schools and other essential services. One important action not mentioned in the study would be to monitor for negative effects of the CHW "rightsizing and retargeting", particularly in communities where CHWs were no longer supported per policy. For example, this could entail monitoring whether the policy change results in an increased workload for health staff at particular health facilities or reduced accessibility to services among vulnerable populations (e.g., populations in urban or peri-urban slums). The study concludes that, on balance, the positives of the decision to rightsize and retarget the CHW workforce outweighed the negatives. The study estimated cost- savings (efficiencies) from the planned rightsizing and re-targeting of the CHW workforce to be approximately US$3.8 million annually and noted that cost-savings could be re-directed toward professionalizing the CHW workforce (i.e., shifting from part-time, "volunteer" CHWs paid small incentives toward CHWs that are trained and certified to work as CHWs, have a contract specifying their terms of work and benefits, and work full-time and are remunerated accordingly) and strengthening the health policy and systems needed to optimize CHW performance (e.g., supervision, supply chain, referral, data systems, monitoring and evaluation) and ensure they are provided with the conditions of decent work. Study 2 highlights that while the example of "rightsizing and retargeting" the existing CHW workforce in Sierra Leone is quite unique and reflective of a particular context, it may provide lessons from which other countries may learn – perhaps most notably the importance of investing in the requisite datasets (e.g. developing and maintaining the CHWML and MFL) and geospatial analyses, and incorporating insight into planning processes coupled with national consultation to enable data-informed and consultative CHW policy dialogue. Indeed, the subject of "rightsizing and retargeting" existing CHW workforces is complex, including challenging ethical, technical, and political dilemmas. This is an important area for additional research and discourse in Sierra Leone and beyond – and where policymakers and researchers in Sierra Leone can provide significant contributions and leadership.

In Mali, the research explored differences in geographic coverage between hypothetical optimized networks prioritizing CHW scale-up and deployment based on the estimated population, U5 deaths, or *Pf* malaria cases. No important differences in geographic coverage of the estimated population, under-five deaths, or *Pf* malaria cases were found between these hypothetical networks. The equivalence of geographic coverage across outcomes of interest and approaches for optimizing the scale and deployment of CHWs may provide policymakers and planners with confidence that trade-offs between the approaches are negligible and that any of the approaches will perform equally well across outcomes. This will be useful information to policymakers and planners in Mali who were interested in minimizing trade- offs between the outcomes of interest and maximizing value for money when optimizing the scale and deployment of CHWs in the context of the country's health sector reform. The research also found that a network of 15843 CHW, if optimally deployed, would ensure that 77.3% of the population beyond 5 km of the primary health facility and referral health facility networks would be within a 30-minute walk of a CHW. The same network would cover an estimated 59.5% of U5 deaths and 58.5% of *Pf* malaria cases. As an intermediary step, an optimized network of 4500 CHW, primarily filling deficits of CHWs (compared to the existing network of CHW) in the regions of Ségou, Koulikoro, Sikasso, and Kayes, would ensure geographic coverage for 31.3% of the estimated population. Faced with similar ethical and operational challenges regarding retargeting of the CHW workforce as described above (and in detail in study 2) for Sierra Leone, the Ministry of Health and Social Development (MSDS, acronym in French) of Mali decided to not retarget the existing CHW workforce but to optimize future scale-up of the CHWs based on the geospatial analysis presented in study 3. At the time of writing this thesis, the MSDS was using the outputs of study 3 to support microplanning of the deployment of new CHWs by district health management teams, health facility in-charges, CHW supervisors, and existing CHWs. This included the use of high-resolution maps for the area surrounding each health facility showing the number of existing CHWs and the number, location, and 30-minute catchment area (walking scenario) of the hypothetical optimized network of CHWs needed to achieve the MSDS' next milestone of 4500 CHWs according to the geospatial modelling (examples of these maps are included in the published paper for study 3).

Further discussion on the contributions of this research to the discourse on CHW catchment areas is warranted here. The concept of CHW catchment areas has not been well-developed in the literature or defined in policy or planning documents in Niger, Sierra Leone or Mali

prior to this research. The literature typically refers to ratios of CHWs per population or households but lacks precision on how to define the geographic boundaries of a CHW catchment area. WHO guidelines suggest using the following criteria when determining a target population size for CHWs in all contexts: expected workload based on epidemiology and anticipated demand for services; frequency of contact required; nature and time requirements of the services provided; expected weekly time commitment (factoring in time away from service provision for training, administrative duties, and other requirements); and local geography (including proximity of households, distance to clinic and population density) (World Health Organization, 2018). WHO guidelines suggest the following criteria might be of relevance in some settings (undefined): weather and climate; transport availability and cost; health worker safety; mobility of population; and available human and financial resources (World Health Organization, 2018). While the above criteria are important and should be considered when determining target population sizes, they lack precision in terms of definitions, measurement, and *how* to incorporate this information when defining the geographic boundaries of a CHW catchment area. For example, how should proximity of households, distance to clinic and population density be defined and measured? How should barriers to movement of CHWs and the population be accounted for? How can information on "local geography" be used (along with the other criteria) to precisely define the geographic boundaries of a CHW catchment area? Similarly in the policy and planning documents of Niger, Sierra Leone, and Mali, the concept of CHW catchment areas has not been defined apart from reference to ratios of CHWs per population or households (Ministère de la Santé Publique, 2013; Ministère de la Santé Publique et de la Lutte contre les Endémies, 2006; Ministry of Health and Sanitation, the Republic of Sierra Leone, 2017; Ministère de la Santé et de l'Hygiene Publique, 2015). In Mali, policy and planning documents add the stipulation that while CHWs are assigned to communities ("CHW sites") they are also to cover neighboring communities ("satellite communities) (Ministère de la Santé et de l'Hygiene Publique, 2015). In practice, this results in an administrative list of communities that are intended to be covered or served by a CHW. However, this list is typically only available at the health facility to which the CHW is attached for supervision and maps delineating the geographic boundaries of the area covered by the CHWs (e.g., as a Thiessen polygon connecting the communities under the purview of a CHW) – what could be denoted as the "administrative CHW catchment area" – are not typically available. This research expands the discourse on CHW catchment areas by introducing the concept of a catchment area based on modelled travel time. Catchment

areas based on modelled travel time are useful in that they provide a visualization of the geographic area that might realistically be expected to be covered by a CHW given the terrain, dispersion of the population, and maximum population that can be served by a CHW given national ratios for CHWs per population – as argued by Ray *et al*. (2008) for health facility catchment areas. CHW catchment areas based on travel time tend to be more realistic than CHW catchment areas based on straight-line distance (e.g., a buffer of 3 km or 5 km) because they account for constraints to movement (Ray *et al*., 2008). CHW catchment areas based on travel time complement administrative CHW catchment areas in that the latter defines the area that should be covered by the CHW while the former provides a more realistic notion of what a CHW might actually be able to cover, given operational constraints – a point Macharia and colleagues (2021) have argued for health facility catchment areas as well. Taken together, administrative catchment areas and travel time catchment areas provide policymakers and planners with useful information for planning scale and deployment of CHWs. They could also be useful for CHWs as job aids and for CHW supervisors to support performance management of CHWs (Whidden *et al*., 2018 and Yang *et al*., 2021).

Some discussion on the cut-offs used in studies 1-3 to define CHW catchments areas is warranted. In Niger, a 60-minute catchment area (walking scenario) was used in study 1 whereas in Sierra Leone and Mali a 30-minute catchment area was used in studies 2 and 3. These cut-offs were used based on discussions with Ministries of Health in the respective countries, considering terrain, CHW per population ratios, whether CHWs were full-time or part-time, workload of CHWs (given packages of services), and geographic dispersion of the population / households. Deciding upon reasonable cut-offs should involve consideration of these and other factors (e.g., means of transportation available to CHWs) and should involve discussion with CHWs, CHW supervisors and subnational administrators. Given the challenging terrain where CHWs typically work and the workload of CHWs, the PhD candidate is of the opinion that in many rural contexts a 60-minute catchment area will be too large an area for a CHW to cover and a smaller catchment area (e.g., 30-minute catchment area as used in Sierra Leone and Mali) will be more appropriate. How to define and delineate CHW catchment areas for the purposes of planning health services and supporting other functions such as CHW performance management and the daily work of CHWs is an important area for further research. At the time of writing this thesis, the PhD candidate was embarking on further research in this area and anticipates

being able to publish additional papers on this important subject.

While the results are not directly comparable across countries because the model assumptions were intentionally fine-tuned to fit specific country contexts (e.g., travel speeds across land cover classes varied slightly by country, maximum capacities of population per CHW differed per national policies), the tendencies are clear (as summarized above and detailed in the published papers). The modelling sought to provide policymakers and planners with useful information for planning based on available data and assumptions fine-tuned to country realities and the expressed needs of policymakers and planners – it did not seek to provide comparable but otherwise generic measurements unfit for use within the country context. Indeed, the specification or "contextualization" of the model within the country context is among the greatest strengths of the modelling approach.

The experiences from Niger, Sierra Leone, and Mali summarized above and described in detail in studies 1-3 were broadly similar in terms of approach. They provide useful examples and lessons on the use of geospatial analysis for optimizing CHW scale and deployment. They also point to the complementarity of geospatial analysis to existing PHC planning tools outlined in Chapter 1, including for planning physical infrastructure e.g., Accessmod (Accessmod, 2021) and the health and care workforce e.g., Health Labour Market Analysis or HLMA (WHO, 2022b), Workload Indicators of Staffing Need (WISN) (WHO, 2010), and the Community Health Planning and Costing Tool (UNICEF, 2020). A further step in Niger, Sierra Leone, and Mali is to build the capacity of national institutions to conduct the geospatial analysis, further develop and maintain the datasets underpinning the analysis (e.g., the national georeferenced CHWML, MFL), and to integrate the use of geospatial analysis within national planning processes together with existing tools and approaches. Guidance on developing and maintaining a functional national georeferenced CHWML hosted in a registry can support such efforts (Liu *et al*., 2021). Based on the experiences in Niger, Sierra Leone, and Mali, establishing the initial datasets, conducting the first analysis, and building basic country capacity on the use of geospatial analysis is roughly a 1-2 year process and may cost roughly $300 000 - $500 000, depending on size of the country, size of the CHW network(s), number of health facilities in the country, status of other underlying datasets, and existing country capacity (e.g., MOH staff with experience using and analysing geospatial data). Maintaining the underlying datasets through routine processes should be prioritized from the start to minimize future recurrent costs and ensure strong integration within national processes (e.g., Mali plans to maintain its national

georeferenced CHWML by leveraging the digital application used by CHW supervisors, enabling the CHWML to be maintained without additional costs beyond the costs of CHW supervision). Costs for routine maintenance of the underlying datasets, analyses, and capacity development should be built into health sector plans, including CHW and HRH strategic plans, where possible using domestic financing and where necessary leveraging donor funding.

Effects of iCCM

Study 4 addresses the third aim of this research and makes an important contribution to the field by providing a robust systematic review assessing the effects of iCCM as an integrated approach on coverage of appropriate treatment for childhood illness by an appropriate provider, quality of care, case load or severity of illness at health facilities, mortality, adverse events, and coverage of careseeking for children younger than five years of age in LMICs. In comparison with usual facility care, we concluded that we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness (very low-certainty evidence); iCCM may have little to no effect on neonatal mortality (low- certainty evidence); we are uncertain of the effect of iCCM on infant mortality (very low- certainty evidence) and under-five mortality (very low-certainty evidence); and iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness by 68% (moderate-certainty evidence). None of the studies reported quality of care, severity of illness or adverse events.

The low- to moderate-certainty of evidence was due to several factors, including indirectness (e.g., having only two RCTs meant that for some outcomes the effect was based on only one RCT from a particular context), serious heterogeneity of effects, serious inconsistency of effects, and serious imprecision of effects. Given the very low- to moderate-certainty evidence for all reported outcomes, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates.

Beyond geographical accessibility: other factors influencing effective coverage

Effective coverage is the "fraction of potential health gain that is actually delivered to the population through the health system, given its capacity" contingent on need, use, and quality (Ng *et al*., 2014). While the focus of the thesis was on the contribution of CHWs to geographical accessibility, approaches for optimizing scale and deployment of CHWs, and the

effectiveness of iCCM, studies 1-4 also highlight important weaknesses across health policy and system enablers as well as contextual factors needed for CHWs to deliver quality, integrated community based PHC services such as iCCM, and contribute to effective coverage. Studies 1-3, point to important weaknesses in terms of CHW selection (e.g., gender), training, and availability of supplies. Study 4 points to weaknesses in terms of CHW remuneration, supportive supervision, availability of supplies, and referral systems, as well as weaknesses at health facilities to which CHWs refer. Other reviews and analyses on CHWs have found similar weaknesses (Kok *et al*., 2015; Kok *et al*., 2017; Zulu *et al*., 2021; Olaniran *et al*., 2022; Stansert Katzen *et al*., 2022). WHO guidelines on CHWs include evidence-based recommendations for addressing these and other health policy and systems weaknesses that undermine CHW performance and thereby effective coverage, including for selection, duration of pre-service training, pre-service training competencies, modalities of pre-service training, competency-based certification, supportive supervision, remuneration, contracting agreements, career ladder, target population size, data collection and use, types of CHWs, community engagement, mobilization of community resources, and availability of supplies (World Health Organization, 2018). The WHO guidelines on CHWs are intended to be broadly relevant across country contexts but acknowledge the need for adaptation to health system configurations, as well as country / local values, preferences, and other contextual factors (World Health Organization, 2018).

Research following the publication of the WHO guidelines on CHWs, further strengthens the rationale for and evidence-base underpinning several recommendations. For example, a qualitative evidence synthesis by Stansert Katzen *et al.* (2022) found that the frequency and quality of CHW supervision was inadequate and that CHW supervisors may not have adequate time for CHW supervision (e.g., nurse in-charges at health facilities tasked with supervising CHWs have other responsibilities, including clinical duties, and may be overwhelmed) or may not have adequate support (e.g., training, resources such as fuel/transport) to ensure adequate frequency and quality of CHW supervision in the communities where CHWs serve. Stansert Katzen *et al*. (2022) recognize this as a broader HRH issue – with implications for HRH planning and financing – and suggest that employing supervisors with the sole responsibility of supervising CHWs may be an effective strategy.

Two RCTs (Whidden *et al*., 2018 and Yang *et al*., 2021) published prior to Katzen *et al*. (2022) have tested the effectiveness of such a "dedicated" supportive supervision model for

CHWs in Mali. The model included monthly supervision by a "dedicated supervisor" (i.e., a supervisor recruited, trained, equipped and remunerated for the sole purpose of CHW supervision) with direct observation of CHW service delivery in the community they serve, a 360-degree quality improvement approach involving feedback from community members and the CHW supervisor, group problem-solving with all CHWs in a given health facility catchment area, digital applications and dashboards for supervision, and CHW mobile applications designed with CHW feedback. The RCTs have shown promising results of the "dedicated" supportive supervision model for improving availability of supplies, CHW and CHW supervisor motivation, and improving the quantity, timeliness, and quality of iCCM services (Whidden *et al*., 2018 and Yang *et al*., 2021).

An earlier review by Rowe *et al*. (2018) on the effectiveness of strategies to improve health-care provider practices in LMICs showed important positive effects of group problem-solving and multi-faceted strategies (e.g., training plus supervision and group problem-solving) on enhanced health-care provider performance, lending further credibility to the results of the RCTs by Whidden *et al*. (2018) and Yang *et al*. (2021). Preliminary analysis of an RCT on the use of pro-active iCCM, an approach to iCCM whereby CHWs proactively visit households, has shown promising results (Muso, 2022).

A study by Ballard *et al*. (2022a) suggests that CHWs supported in alignment with the WHO guidelines were able to effectively maintain coverage of health services during the COVID-19 pandemic. This is promising given the documentation of widespread disruption to PHC services, including at CHW level (World Health Organization, 2022c). Studies 1-4 and broader literature, including the reviews and analyses noted above, reinforce the need for health policymakers and planners to adapt and apply WHO recommendations on CHWs to their country context. They also imply that careful design and planning of CHW scale-up and deployment, including the use of geospatial analyses in the context of broader HRH planning, coupled with investment across health policy and systems enablers in alignment with WHO guidelines in advance of further scale-up and deployment of CHWs (i.e., investments that enable "readiness for scale") may be a promising way forward.

There are many contextual factors beyond health policy and systems supports that may influence effective coverage and that are relevant to planning CHW scale and deployment as well as CHW performance management. Studies 1-4 include discussion of many of these factors. Trusting relationships between CHWs, communities, and CHW supervisors play an important role in mediating community use and satisfaction with CHW services, as well as

CHW motivation, competency, satisfaction, agency, attitude, and self-esteem (Kok *et al*., 2017). Trusting relationships develop out of and operate through mechanisms such as embeddedness leading to feelings of connectedness, culturally competent care, and a sense of serving common goals, the history of CHWs in the community, as well as the relationships and power dynamics between the community and actors in the health sector and how these have evolved over time (Kok *et al*., 2017). Such relationships have played notable roles in mediating the effectiveness of CHW responses during recent the COVID-19 pandemic (Anstey *et al*., 2021). Other contextual factors include social and economic barriers to care-seeking (e.g., social norms, intrahousehold power dynamics, cost of transportation, opportunity costs of travel time, out-of-pocket costs of services and/or commodities) which may influence access to and use of services, as well as satisfaction with and experiential (perceived) quality of services (Bedford and Sharkey, 2014).

Alternatives to CHWs

Robust health policy and systems planning involves weighing and considering competing options for meeting population needs. Private sector providers, mobile outreach from health facilities, telemedicine, road network expansion and improvement, and further expansion of public sector health facilities are examples of alternatives to CHWs for expanding geographical accessibility to integrated PHC services. While this was not a question of focus for the thesis, some reflection on this point is warranted given its importance to policymakers and planners. In the country contexts of studies 1-3 (rural areas of Niger, Sierra Leone, and Mali), careseeking to medical private sector service providers (i.e., excluding traditional healers) is generally low and the market for scale is circumscribed given that households in rural areas are generally of a low socioeconomic status and thereby have limited means to pay for services and commodities from the private sector (Besada *et* al., 2016; Bognini *et al*., 2022; INSTAT *et al*., 2019). In other contexts (e.g., countries of South-East Asia, Nigeria, Tanzania, and Uganda) the private sector plays a more important role (Noordham *et al*., 2015; Bradley *et al*., 2020) and the economic conditions for private sector scale exist.

Mobile outreach from health facilities exists in most LMICs (e.g., for childhood immunization), however this service delivery modality is typically periodic (i.e., not continuously available) and therefore not ideal for many community-based PHC services such as iCCM and may lack the cultural competency of CHW-provided services (Oyo-Ita *et al*., 2016). However, the discussion section of studies 1-3 point out that mobile outreach

may be needed to complement the scale-up and deployment of CHWs, depending on the package of community-based PHC services the CHWs provide (e.g., for antenatal care), and to service hard-to-reach communities where deployment of a CHW may be inefficient due to low population density and/or the costs of adequately supporting a CHW with supervision and supplies may be beyond the means of available resources. Telemedicine remains nascent in many LMIC contexts given health policy and infrastructure constraints (Singh, 2022).

Expanding and improving the road network is a non-health sector intervention that has shown promise for increasing geographical accessibility to health services (Aggarwal, 2021; Sharjarizadeh *et al*., 2022) and improving social determinants of health (Vilela *et al*., 2020; Berg *et al*., 2015). However algorithms used in the planning for expansion and enhancement of road networks should consider prioritizing road segments that would benefit geographical accessibility to health services (Kanuganti *et al*., 2017; Heyns *et al*., 2021), be coupled with efforts to improve quality of care and referral systems to improve health outcomes (Aggarwal, 2021; Sharjarizadeh *et* al., 2022) and complement efforts to efficiently scale health facilities and CHWs rather than obviate the need for additional health facilities or CHWs.

Lastly, the scale and deployment of CHWs typically occurs within contexts of expansion of the number and distribution of health facilities. While the expansion of health facilities does not necessarily obviate the need for CHWs since CHWs can play important roles in the provision of integrated PHC services even in urban / peri-urban environments where geographical accessibility of health facilities is fairly good (Besada *et al*., 2020; Altaras *et al*., 2017), it is important to consider future health facility expansion when planning CHW scale and deployment.

Need for further research

Studies 1-3 point to additional research needed on the contribution of CHWs to geographical accessibility and further exploration of approaches for optimizing the scale and deployment of CHWs in different contexts. Further research is also needed on approaches for building capacity of countries to integrate geospatial analyses within HRH and health sector planning processes.

Study 4 indicates additional research is needed to assess the effects of iCCM on all outcomes included in the review, as well as potential effect modifiers. For example, research on effect modifiers such as the modality of service delivery (e.g., CHWs

proactively conducting household visits / proactively looking for sick children passively waiting for care givers to bring sick children to the CHW) could lend useful new insight for polices, planning and implementation. One study (Ma *et al*., 2019) was published just prior to publication of the systematic review and will be considered in future updates of the systematic review. Ma *et al*. (2019) assessed the effect of home visits by lay health workers trained on iCCM on coverage of appropriate treatment by an appropriate provider for diarrhoea and malaria, as well as prevalence of diarrhoea and malaria. One systematic review (Whidden *et al*., 2019) assessed the effect of proactive case detection by lay health workers on infant mortality, under-five mortality, child morbidity, coverage of appropriate treatment by an appropriate provider and coverage of careseeking to an appropriate provider compared to usual health services, including "conventional community-based healthcare delivery" (i.e. without a proactive case detection approach by lay health workers) but it is unclear whether all studies included iCCM.

Another potential effect modifier is the modality of supervision as noted by Stansert Katzen *et al.* (2022). Indeed studies exploring the effectiveness of monthly "dedicated" supportive supervision with a 360-degree quality improvement approach, digital applications and dashboards for supervision, and CHW mobile applications designed with CHWs feedback have shown promise for improving CHW performance in Mali (Whidden *et al*., 2018; Yang *et al*., 2021; Stansert Katzen *et al*., 2022). Further research on this kind of "dedicated" supportive supervision are warranted. In terms of study designs, the rapid scale-up of iCCM may preclude the use of RCTs in the future to explore the effect and/or effect modifiers of iCCM compared to usual facility-based case management services. However study designs using interrupted time series analysis (ITSA) of aggregate and/or individual patient data from CHW and/or CHW supervisors (e.g., collected through mobile applications for CHWs and/or CHW supervisors) may hold promise in this respect as ITSA designs have increasingly been applied in situations similar to that of iCCM, where exposure to the intervention or contextual factor being assessed has become ubiquitous and where RCTs may be infeasible (Cochrane EPOC, 2021b; Hategeka *et al*. 2020, Ballard *et al*., 2022a*;* Namuganga *et al*., 2021; Roh *et al.,* 2022).

Conclusions

The evidence presented in this thesis highlights important inefficiencies in the scale and deployment of CHWs, gender inequalities in CHW employment, ethical questions, practical challenges, trade-offs and other important considerations that arise when optimizing the

CHW workforce, and weaknesses across health policies and systems needed for CHWs to effectively deliver integrated PHC services such as iCCM. The overarching conclusions of the research are that CHWs have made important contributions to geographical accessibility of integrated PHC services at community level, including iCCM, in Niger, Sierra Leone, and Mali however the scale and deployment of CHWs has not been optimized and gender inequalities in CHW employment persist in Niger and Sierra Leone. Additionally, when compared to usual facility services, iCCM probably improves coverage of careseeking to an appropriate provider of treatment services for any iCCM illness. However, we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness. iCCM may have little or no effect on neonatal mortality and we are uncertain of the effect on infant mortality or under- five mortality. Given the very low- to moderate-certainty evidence for all reported outcomes in the systematic review, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, more research is needed on the effect of iCCM on quality of care, case load or severity of illness at health facilities, and adverse events.

A key strength of the research is that it builds on existing conceptual frameworks and normative guidance (WHO, 2018; WHO and UNICEF, 2020; WHO, 2022). The WHO and UNICEF PHC framework and WHO Working for Health 2022-2030 Action Plan call for optimizing the distribution of the health and care workforce and geographical accessibility to integrated PHC services, but the tools and resources referenced in these documents (e.g., Accessmod) had not, until this research, been used to explore optimization of the scale and deployment of CHWs at national scale (WHO & UNICEF, 2020; WHO, 2022). The research underscores the value of integrating geospatial and gender analyses into planning for the scale-up and deployment of CHWs in the context of broader health and care workforce planning, along with assessments of the health policies and systems needed for optimizing support to CHWs and CHW performance everywhere. It also underscores the need for moving beyond piecemeal, short-term approaches to investment in PHC, focused mostly on training health and care workers on discrete interventions, toward more comprehensive health policy and systems strengthening efforts (detailed above and below in the recommendations), as well as ensuring the conditions of decent work for CHWs everywhere, in alignment with WHO and UNICEF normative guidance.

Positionality

The assumed roles of the PhD candidate at UNICEF (from 2010-2016) and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (from 2017-present) have shaped his views and thereby selection of frameworks rooted in global normative guidance from WHO and UNICEF. The PhD candidate supports the global normative guidance and is of the view that the guidance has been developed based on the state-of-the-art of evidence and rigorous consultative processes.

Limitations

The limitations of each study are captured in the corresponding paper. The overarching limitations of the research include:

- For the geospatial analysis
    - There is a lack of data on variation in travel speeds and principal modes of transportation at subnational level and across populations of interest. Information of this kind would be useful for better tailoring assumptions on travel scenarios to realities across subnational geographies and populations of interest.
    - There is a lack of data on the uncertainty of the population estimates used in the analysis of geographical accessibility (travel time analysis) and geographic coverage. Data on the uncertainty of the population estimates would be useful for informing uncertainty of estimates of the population within given thresholds of geographical accessibility (travel time) and for estimating geographic coverage.
    - Completeness and quality of spatial data on road networks, particularly when sourced from open-source sources as was the case in Niger and Sierra Leone, is uncertain and may affect travel time estimates, particularly for motorized vehicle scenarios.
    - The data for the Niger analysis is relatively old (collected in 2012) and may not be relevant for use currently. This is noted in the published paper (study 1) and it is noted that there are plans to update the analysis with more recent data.
    - The thesis lacks qualitative data (e.g., through key informant interviews with policymakers, planners, CHWs, and CHW supervisors) and qualitative analysis exploring current approaches and the political economy of CHW planning and deployment.

- For the systematic review assessing the effects of iCCM
    - Given the very low- to moderate-certainty evidence for all reported outcomes, further research is likely to have an important impact on our confidence in the estimates of effects and may change the estimates. Moreover, evidence was not reported for three primary outcomes: quality of care, case load or severity of illness at health facilities, and adverse events – research is needed on these outcomes.

Recommendations for health policy and practice

- Integrate geospatial and gender analyses into planning for the scale-up and deployment of CHWs in the context of broader planning of the health and care workforce and health sector as a means for achieving greater efficiency and improving likelihood of sustainability, leveraging resources from donors as necessary and building country-capacity to lead and conduct such analyses (e.g., leveraging donor resources to build the capacity of national research institutions and the MOH, building regional networks of capacitated institutions and enabling countries to share experiences).
- Systematically assess the status of health policies and systems against the WHO normative guidance on health policy and system support for optimizing CHW programmes (WHO, 2018) e.g., through country-led annual review processes.
- Reinvest cost-savings from optimization of CHW deployment toward the professionalization of CHWs (CHWs that are trained and certified to work as CHWs, have a contract specifying their terms of work and benefits, and work full-time and are remunerated accordingly) and strengthening the health policy and systems needed for CHWs to work effectively and to enjoy the conditions of decent work in alignment with WHO normative guidance and the WHO Working for Health 2020-2030 Action Plan (WHO, 2018; WHO, 2022).
- Move beyond piecemeal, short-term approaches to investment in PHC, focused mostly on training health and care workers (including CHWs) on discrete interventions, toward more comprehensive health policy and systems strengthening efforts in alignment with WHO normative guidance on health policy and systems supports for optimizing CHW programmes, WHO and UNICEF normative guidance on PHC, and the WHO Working for Health 2022-2030 Action Plan (WHO, 2018; WHO and UNICEF, 2020; WHO, 2022). For example, greater attention should be

given to solving the HRH challenge underpinning weak CHW supervision systems (for instance shifting to a "dedicated supervision" model to ensure CHW supervisors have adequate time for CHW supervision, ensuring CHW supervisors are well-trained including on quality improvement approaches, adequately equipped, and supervised themselves) which can serve the dual function of improving CHW performance in terms of quantity, timeliness and quality of services, as well as ensuring availability of supplies at CHW level, as described in the RCTs in Mali (Whidden *et al*., 2018 and Yang *et al*., 2021). Greater attention should be given to CHW development, using frequent supervision (as noted above) for coaching and mentoring and providing opportunities for career development (e.g., becoming a CHW supervisor). Greater attention should also be given to strengthening referral systems (e.g., providing CHWs with means of transportation or resources to enable CHWs to facilitate referral from community to health facility level) and strengthening quality of care at health facility level.

- Develop an annex to the WHO guidelines for CHWs, providing a maturity model and/or measure of "institutionalization" for each recommendation – outlining a step-wise progression countries can take toward alignment with each recommendation. This would enable countries across contexts to situate themselves vis a vis steps along the maturity model and plan for further progress adapted to their context. The Child Health Task Force (USAID) iCCM Working Group is currently developing a toolkit to measure "institutionalization" of iCCM (Child Health Taskforce, 2022). The step-wise maturity model could be integrated within the conceptualization of "institutionalization" as part of the toolkit.

Recommendations for further research

- Conduct geospatial analysis studies estimating the contribution of CHWs to geographical accessibility to integrated PHC services and explore approaches for optimizing the scale and deployment of CHWs, as well for delineating the CHW catchment areas, in additional countries, including in the context of CHW planning, support and performance management, as well as broader health and care workforce optimization and health sector planning.
- Compare the above geospatial analysis approaches for optimizing the scale and deployment of CHWs with other planning approaches.
- Explore current approaches to and political economy of CHW (and broader HRH and

health infrastructure) planning through qualitative methods.

- Conduct additional studies on the effects of iCCM and effect modifiers of iCCM (e.g., modalities of service delivery and supervision), using designs (e.g., ITSA, leveraging data from routine data systems, where possible) that meet the need for rigour in a context where iCCM has already rapidly scaled-up and RCTs may not be feasible. Paper 4 provides detailed recommendations on thematic areas for further research on iCCM.

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APPENDICES

Appendix 1: UWC Senate Research Committee Approval Letter

UNIVERSITY of the
WESTERN CAPE

DEPARTMENT OF RESEARCH DEVELOPMENT

18 January 2016

To Whom It May Concern

I hereby certify that the Senate Research Committee of the University of the Western Cape approved the methodology and ethics of the following research project by:
Mr N Oliphant (School of Public Health)

Research Project:	Putting community health workers on the map: Toward a geography of national community health worker programs in sub-Saharan Africa.
Registration no:	15/7/271

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

Private Bag X17, Bellville 7535, South Africa
T: +27 21 959 2988/2948 . F: +27 21 959 3170
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Appendix 2: Journal editor and peer reviewer comments for Study 1, Optimising geographical accessibility to primary health care: a geospatial analysis of community health posts and community health workers in Niger

Decision Letter (bmjgh-2021-005238)

From: info.bmjgh@bmj.com

To: npoliphant@gmail.com

CC:

Subject: BMJ Global Health - Decision on Manuscript ID bmjgh-2021-005238

Body: ----------

COVID-19: A message from BMJ: https://authors.bmj.com/policies/covid-19

27-Mar-2021

bmjgh-2021-005238 - "Toward a geography of community health workers in Niger: a geospatial analysis"

Dear Mr. Oliphant,

Following review of your article to BMJ Global Health, we invite you to submit a major revision.

The review comments can be found at the end of this email, together with any comments from the Editorial Office regarding formatting changes or additional information required to meet the journal's policies at this time.

Please note that your revision may be subject to further review and that this initial decision does not guarantee acceptance
at this time.
To submit your revised article please click this link: *** PLEASE NOTE: This is a two-step process. After clicking on the link, you will be directed to a webpage to confirm. ***

https://mc.manuscriptcentral.com/bmjgh?URL_MASK=49337282 1e414a719fbbbfb3c5b79827. Alternatively, you can log on to your Author Dashboard in ScholarOne and under "Action" click "create a revision".

Please read and respond to all of the peer review comments. You should provide a point-by-point response to explain any changes you have (or have not) made to the original article and be as specific as possible in your responses.

The original files will be available to you when you start your revision. Please delete any files that you intend to replace with updated versions and upload the following using the appropriate file designation:
- ''Main Document'' - This is a clean copy (without tracked or highlighted changes) of your revised article. Please delete your original submission file.
- "Main Document - marked copy" - This is the edited version of your original article, including edits to address the peer review comments. Any changes have been highlighted using a track change function or bold or coloured text.
Please replace any other files that have been updated e.g. Images, forms

Information relating to your article, including author names and affiliations, title, abstract and required statements (e.g. competing interests, contributorship, funding) will be taken directly from the information held in ScholarOne, and not from the article file. Please check that this information has been entered correctly and has been updated as appropriate. If your revised article is accepted, you will only be able to make minor changes (e.g. correction of typesetting errors and proof stage) prior to publication.

Please submit your revised article by 24-Apr-2021. If we have not received it by this date, the opportunity to submit a revision will expire and your article may be treated as a new submission. If you need to request an extension, please contact the Editorial Office as soon as possible.

Thank you for submitting your article to BMJ Global Health; we look forward to receiving your revision.

If you have any queries, please contact the Editorial Office at info.bmjgh@bmj.com.

Kind regards,

Editor in Chief, BMJ Global Health

Dr. Sanni Yaya
Associate Editor, BMJ Global Health

Formatting Amendments (where applicable):

Reviewer(s)' Comments to Author (if any):

Reviewer: 1

Comments to the Author
1. What do the new findings imply? In this section, mention the actual scale-up approach (point 1) instead of leaving it open, the same applies to the optimizing approach (point 2)

2. Are there any particular reasons why the study was done between 2000-2013 and not update? Justify in the manuscript. Even if scaling up was done between this epoch, a policy maker would be more interested with recent years (2019, 2020). I would recommend carrying out the optimization and scale up analysis using recent data. This would be more meaningful to decision makers in Niger.

3. Why the focus on the first level and not all the health facilities within the country?

4. The datasets are listed, but would be useful to qualify why each is needed very briefly in a preamble or when each data is first mentioned. At the moment one is left wondering why Pf data why U5M data etc.

5. The choice of doing analyses in dry season only is not substantiated. It would also have been useful to include an uncertainty range by increasing/decreasing the speeds by 20%, this might cater for wet seasons and fluctuations in travelling speeds

6. Mention the actual Niger coordinate system alluded to

7. Discus the limitation of resampling rasters at 5 by 5km to 1km due to lack of data at 1km*1km

8. Accessibility has been done to different combination of health networks. I would suggest minimizing the results in the main manuscript to those that are key and shifting some to the SI. At the moment the paper is bulky in terms of the results presented and the main results/messages might be diluted.

9. The authors seem to have concentrated more on the strengths and limitations of the paper and less about what the results imply. I would suggest adding more discussion points as this is a good paper and by contextualizing the results in Niger and SSA would make it a great paper

Reviewer: 2

Comments to the Author
Consider changing title From "Toward a geography of community health workers in Niger: a geospatial analysis" to "Optimising geographical accessibility of community health workers in Niger: a geospatial analysis" OR "Optimising geographical accessibility to primary health care in Niger: a geospatial analysis" (Clarification below).

Overall need to be clear if it the care site (PHC) or the provider (ASCs/CHWs) that are being optimised. The authors appear to use these two interchangeably all through the manuscript.

No need to include citations in the "What is already known section" (Citation 1-5). Rather these citations and text built around them need to move to the introduction of the manuscript, as part of the rationale for this paper.

The point above links to the next. The rationale for the paper needs to come out more strongly in the introduction section. This can be done by including a brief review of the existing literature and what is known at the moment, as well as the gaps that remain.

Please only include the most pertinent details on 'settings'. This paper has no relevance to the "predominantly herbaceous vegetation" in Niger!

Methods section is mostly well described. Kudos to the authors.

"The maximum population capacity was set at 10000 for CSI and 2500 for CS-ASC based on norms

of the MOPH of Niger". This statement could not be verified in the cited reference (citation 18). Did the MOPH set this standard? Or was it Countdown? Any sense on how this was done? It is a central underpinning assumption for the modelling. As such, it needs to be well justified.

Even though ethics was not required based on the use of secondary data for this analysis. This still needs to be stated and any relevant ethical considerations from the original survey acknowledged.

The discussion is probably the section where more work is required. It is only a rehash of the results, strengths and limitations. there has been no attempt to discuss the findings. For example:

What contributed to the improvement in geographical accessibility of PHC services between 2000-2013? Were there specific government interventions that led to the observed improvements? Recruitment drives, Redistribution etc.?

Second, where are the gaps? Urban, rural, poorer Communities? etc. The authors already talked about "large variation at subnational levels, given a 60-minute cutoff and walking scenario" in the results. This needs to be in the narrative

The authors talk about "rational scale up". This needs to be given more attention and detailed.

The paragraph that begins with "We understand that rational decisions on scale-up and targeting of CHWs, like with health..." is a good segue way to implications for policy. Please name this section as that and develop further. Yes, there are other considerations, but if these were optimal, what additional insights has this study offered? These need to be specified in the narrative.

Not sure how this paper fits the bill of "a call to action for establishing a geography of CHWs globally"!! Please remove and update conclusion to match changes made based on feedback received.

Please remove all instances of "toward geography..."

Update abstract also to match changes made based on feedback received.

Date Sent: 27-Mar-2021

Close Window

Reviewer: 1

1. What do the new findings imply? In this section, mention the actual scale-up approach (point 1) instead of leaving it open, the same applies to the optimizing approach (point 2)

Response: Thank you for the question and helpful comment. We have adjusted the text in the section "What do the new findings imply?" of the Key Questions box to mention the actual scale-up and targeting approaches and clarify that the findings imply that the actual scale-up of the community health posts staffed by paid, full-time CHWs increased geographic accessibility to PHC services at community level but geographical targeting of the community health posts was inefficient. We added that the approaches to optimizing geographical targeting and scale-up described in the study could inform re-targeting of the existing network of community health posts and future scale-up efforts to optimize geographic accessibility to PHC services at community level in Niger and that the approaches could be adapted to similar contexts within sub-Saharan Africa.

2. Are there any particular reasons why the study was done between 2000-2013 and not update? Justify in the manuscript. Even if scaling up was done between this epoch, a policy maker would be more interested with recent years (2019, 2020). I would recommend carrying out the optimization and scale up analysis using recent data. This would be more meaningful to decision makers in Niger.

Response: Thank you for the question and recommendation. Indeed, the scaling up of the health posts (Case de santé) and CHWs (ASC) was done during this period. We planned to write this paper some years ago but unfortunately, we didn't manage to do so until now. We agree an updated analysis would be more relevant to policy makers. Currently, several of the co-authors are working with the MOH to update this analysis with data from 2020-2021 to inform health sector planning and inform a review and update to the national community health strategy – and we plan a publication with the MOH based on this updated analysis in the near future. We have added text to this effect in the background (lines 322-323). In the meantime, the analysis in the current paper will be interesting for policy makers in Niger and similar contexts.

3. Why the focus on the first level and not all the health facilities within the country?

Response: Thank you for the question. We focused on the community health posts (Case de Santé or CS), the cadre of paid, full-time CHW (Agent de Santé Communautaire or ASC) and first level referral facilities (Centre de Santé Intégrée or CSI to which the CS refer) because there is ongoing discussion in Niger among policy makers and partners on optimization of primary health care at the community level. To this effect, we have added the following information in the Background section as additional context: the MOPH is planning a midterm review of the current National Strategic Plan for Community Health in 2022 and an update in 2023 for the 2024-2028 period, a GFF investment case is being developed, the current Health Sector Development Plan (2017-2021) expires this year, and discussions are ongoing concerning a new health sector plan (lines 44-46). We have underscored in the Background section that our analysis is intended to inform these processes and discussions among policy makers in Niger

(lines 47-58). An update to this analysis is being planned by co-authors and the MOPH. The update will use data from 2020/2021 and will extend the current work by including an analysis of all types of facilities with the intent of further informing the ongoing processes and discussions noted above.

4. The datasets are listed, but would be useful to qualify why each is needed very briefly in a preamble or when each data is first mentioned. At the moment one is left wondering why Pf data why U5M data etc.

Response: Thank you for the comment. In the methods section under "Data", we have added clarifications on why each data set is needed. See lines 88-100. Further details on each dataset are provided in Supplementary Annex 1.

5. The choice of doing analyses in dry season only is not substantiated. It would also have been useful to include an uncertainty range by increasing/decreasing the speeds by 20%, this might cater for wet seasons and fluctuations in travelling speeds.

Response: Thank you for this comment. We have a detailed rational for not including (at this time) a rainy season scenario (lines 352-362) or uncertainty estimates based on uncertainty of the travel speed scenarios (lines 367-371). We recognize pertinence of the points raised and plan to address these limitations in future analysis with the MOPH using a robust process to inform the assumptions using empirical data and/or local expert knowledge.

6. Mention the actual Niger coordinate system alluded to

Response: Thank you for the comment. We originally included this detail in Supplementary Appendix 1. We have added this information to the main document in the Methods section under "Data" (line 101).

7. Discus the limitation of resampling rasters at 5 by 5km to 1km due to lack of data at 1km*1km

Response: Thank you for the comment. We have included discussion of this limitation as it pertains to the geographical targeting analysis in the discussion section (lines 376-383).

8. Accessibility has been done to different combination of health networks. I would suggest minimizing the results in the main manuscript to those that are key and shifting some to the SI. At the moment the paper is bulky in terms of the results presented and the main results/messages might be diluted.

Response: This is well noted. We have adjusted the main text of the section on accessibility coverage and Table 1 to focus on the key results. We now refer the reader to Supplementary Appendix 2 for the full results on accessibility coverage.

9. The authors seem to have concentrated more on the strengths and limitations of the paper and

less about what the results imply. I would suggest adding more discussion points as this is a good paper and by contextualizing the results in Niger and SSA would make it a great paper

Response: We thank the reviewer for this comment and helpful suggestion. We have adjusted the discussion section accordingly, adding a section on implications for policy in Niger and countries of SSA with similar contexts.

Reviewer: 2

Consider changing title From "Toward a geography of community health workers in Niger: a geospatial analysis" to "Optimising geographical accessibility of community health workers in Niger: a geospatial analysis" OR "Optimising geographical accessibility to primary health care in Niger: a geospatial analysis" (Clarification below).

Response: Thank you for this helpful suggestion. We agree. We have changed the title to: "Optimizing geographical accessibility to primary health care at community level in Niger: a geospatial analysis".

Overall need to be clear if it the care site (PHC) or the provider (ASCs/CHWs) that are being optimised. The authors appear to use these two interchangeably all through the manuscript.

Response: Thank you for this very pertinent comment. The focus is on optimizing PHC at community level – and in that way it is both, but we have clarified how it is both and underscored the focus on optimizing PHC at community level. The targeting analysis is focused on optimizing geographical targeting of the community health post (Case de Santé or CS) – most of which are staffed by ASC (full-time, paid CHW) as means to optimize physical accessibility to PHC at community level. The scale-up analysis is focused on optimizing the extension of PHC at community level beyond the network of existing community health posts through the volunteer cadre of CHW (relais communautaire or RC). We have adjusted the text in the Background section (see lines 46-56), adjusted the text in the relevant results sections (Targeting section for CS and Scale-up section for the RC), and adjusted the Discussion section to align.

No need to include citations in the "What is already known section" (Citation 1-5). Rather these citations and text built around them need to move to the introduction of the manuscript, as part of the rationale for this paper.

Response: Thank you for comment. We have moved this text to the Background section, linking it to gaps in the literature that remain and a stronger rationale for the paper. See lines 48-52.

The point above links to the next. The rationale for the paper needs to come out more strongly in the introduction section. This can be done by including a brief review of the existing literature and what is known at the moment, as well as the gaps that remain.

Response. Thank you for the comment. In the Background section, we have underscored the rational of the paper – optimizing PHC at community level. We have also included the relevant references from the literature, as well as brief description of what is known and the gaps that remain (lines 48-56).

Please only include the most pertinent details on 'settings'. This paper has no relevance to the "predominantly herbaceous vegetation" in Niger!

Response: Thank you for the comment. We have adjusted the text in the Settings section accordingly.

Methods section is mostly well described. Kudos to the authors.

Response: Thank you.

"The maximum population capacity was set at 10000 for CSI and 2500 for CS-ASC based on norms of the MOPH of Niger". This statement could not be verified in the cited reference (citation 18). Did the MOPH set this standard? Or was it Countdown? Any sense on how this was done? It is a central underpinning assumption for the modelling. As such, it needs to be well justified.

Response: Thank you for spotting this error. It reflects the MOPH norm for the period of the study, it is not from Countdown. The citation should be 14 (Ministère de la Santé Publique et de la Lutte contre les Endémies. 2006. Normes et standards des infrastructures, équipements et personnel du système de santé). Note that we have updated the numbering of the references due to changes to the main text (some references have been deleted and others added in response to reviewer feedback).

Even though ethics was not required based on the use of secondary data for this analysis. This still needs to be stated and any relevant ethical considerations from the original survey acknowledged.

Response: Thank you for the comment and guidance. We have added a section entitled Ethical considerations in the Methods section.

The discussion is probably the section where more work is required. It is only a rehash of the results, strengths and limitations. there has been no attempt to discuss the findings.

Response: Thank you for the very helpful comment. We have overhauled the Discussion section, adding a section on Implications for policy, with detailed discussion on implications of our analysis for policy makers in Niger, as well other countries of sub-Saharan Africa with similar contexts and interest in optimizing PHC at community level.

For example:

What contributed to the improvement in geographical accessibility of PHC services between

2000-2013? Were there specific government interventions that led to the observed improvements? Recruitment drives, Redistribution etc.?

Response: Thank you for this very relevant question. We have added text in the Discussion section (lines 275-286) to respond to this question.

Second, where are the gaps? Urban, rural, poorer Communities? etc. The authors already talked about "large variation at subnational levels, given a 60-minute cutoff and walking scenario" in the results. This needs to be in the narrative

Response: Thank you for this very relevant question. We have added text in the Results section under Geographic Coverage to clarify where the gap is located (lines 228-232). We have added Supplementary Figures 6b-c to visualize the distribution of the gap. We have also added text in the Discussion section to elaborate on implications (how inefficient targeting undermined filling these gaps in the past and how optimizing targeting and scale-up could help efficiently fill the gaps and strengthen the health system moving forward).

The authors talk about "rational scale up". This needs to be given more attention and detailed.

The paragraph that begins with "We understand that rational decisions on scale-up and targeting of CHWs, like with health..." is a good segue way to implications for policy. Please name this section as that and develop further. Yes, there are other considerations, but if these were optimal, what additional insights has this study offered? These need to be specified in the narrative.

Response: Thank you for the helpful suggestion. We have moved this paragraph to the start of the section on Implications for policy and developed it further as suggested.

Not sure how this paper fits the bill of "a call to action for establishing a geography of CHWs globally"!! Please remove and update conclusion to match changes made based on feedback received.

Response: This is well noted. We have removed the relevant text and updated the conclusion to match the changes based on feedback received.

Please remove all instances of "toward geography..."

Response: This is well noted. We have removed all the relevant text.

Update abstract also to match changes made based on feedback received.

Response: We have updated the abstract to match the changes made based on feedback received.

Note to both reviewers on additional changes made

- We identified an error in the Accessmod algorithm for calculating geographic coverage. This was due to an error in a recent update to Accessmod. The error impacted results for geographic coverage, scale-up and targeting. We corrected the issue and made the relevant corrections in track changes in the main document as well as all relevant figures, tables, and appendices. This correction resulted in minor impacts to our estimates of geographic coverage but did not change our conclusions. The algorithm for the geographic coverage calculation in Accessmod has also been updated.
- For the targeting analysis, we made an error in calculating the estimated number of under-five deaths. We incorrectly used the estimated population under-five in the calculation. However, per IGME/UNICEF guidance we should have used the estimated number of live births in the calculation. We made this correction and updated the targeting analysis for under-five mortality, accordingly, including all figures, tables, and appendices. Note, with this change, our estimates for the estimated number of under-five deaths align with IHME's estimates. This correction (in addition to the correction to the Accessmod algorithm and adjustment to assumptions noted below) contributed to a moderate change in the size of the efficiency gain achieved through optimized targeting of the estimated under-five deaths but did not change the conclusions.
- For the targeting analysis for under-five mortality and *Pf* malaria, we adjusted our assumptions to reflect a more accurate comparison. This is explained in lines 165-177 of the main document. We updated the results in the main text, as well as the figures, tables and appendices. This (in addition to the correction to the Accessmod algorithm and correction of under-five deaths calculation noted above) resulted in a moderate impact on the size of the efficiency gain achieved through optimized geographical targeting but did not change the conclusions.
- For the targeting analysis, we simplified the workflow. The updated workflow is shown in Supplementary Figure 1 in Supplementary Appendix 1.

Decision Letter (bmjgh-2021-005238.R1)

From: info.bmjgh@bmj.com

To: npoliphant@gmail.com

CC:

Subject: Your submission to BMJ Global Health has been accepted

Body: Unable to Display Letter Tag (###TAG_HEADER_PORTFOLIO_WIDE##)

13-May-2021
bmjgh-2021-005238.R1 - Optimizing geographical accessibility to primary health care at community level in Niger: a geospatial analysis

Dear Mr. Oliphant:

We are pleased to accept your article for publication in BMJ Global Health. Well done and many congratulations on an excellent article!

Within 2-3 working days, you will receive an email with payment options and instructions from BMJ's e-commerce partner, Copyright Clearance Center. You will be able to choose either to pay by credit card or invoice. If you are not making the payment yourself, you may forward the email to the person or organisation that will be paying on your behalf. Your article will not be processed by production until you have paid the article processing charge or requested an invoice. For more details on open access publication please visit our Author Hub: https://authors.bmj.com/open-access/.

Please note, that if your institution is part of one of BMJ's Publish and Read or prepay agreements your request for funding will be automatically processed based on this acceptance and you will only receive an email accepting or denying your funding request. To find out if your institution is part of a Publish and Read or prepay agreement visit BMJ's open access agreements page: https://authors.bmj.com/open-access/institutional-programme/.

Once payment is confirmed and your article is sent to Production, copyediting and typesetting will be completed. We will email you a proof to check via our online tool usually within 10-15 days of this time; please check your junk mail folder.

The proof is your opportunity to check for typesetting errors and the completeness and accuracy of the text; including author names and affiliations, tables and figures; including legends, numerical, mathematical, or other scientific expressions. We ask that you only make minor corrections at this stage. Please provide any comments within 48 hours. There will be no further opportunities to make corrections prior to publication.

See https://authors.bmj.com/after-submitting/accepted/ for more information about what to expect once your article has been accepted.

We publish most articles online in their final form around three weeks after acceptance. See https://authors.bmj.com/after-submitting/online-publication/ for more information about online publication. BMJ will deposit your article in all indexes affiliated with the journal.

If your article is selected for press release by BMJ's Press Office you will be informed as soon as possible.

If you have any queries, please contact the Editorial Office at info.bmjgh@bmj.com.

Kind regards,

Dr. Seye Abimbola
Editor in Chief, BMJ Global Health

https://gh.bmj.com/

Date Sent: 13-May-2021

Appendix 2: Journal editor and peer reviewer comments for Study 2, Optimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis

Decision Letter (bmjgh-2021-008141)

From: info.bmjgh@bmj.com

To: npoliphant@gmail.com

CC:

Subject: BMJ Global Health - Decision on Manuscript ID bmjgh-2021-008141

Body: ----------

COVID-19: A message from BMJ: https://authors.bmj.com/policies/covid-19

20-Jan-2022

bmjgh-2021-008141 - "Optimising scale and deployment of CHWs in Sierra Leone: a geospatial analysis"

Dear Mr. Oliphant,

Following review of your article to BMJ Global Health, we invite you to submit a major revision.

The review comments can be found at the end of this email, together with any comments from the Editorial Office regarding formatting changes or additional information required to meet the journal's policies at this time.

Please note that your revision may be subject to further review and that this initial decision does not guarantee acceptance
at this time.
To submit your revised article please click this link: *** PLEASE NOTE: This is a two-step process. After clicking on the link, you will be directed to a webpage to confirm. ***

https://mc.manuscriptcentral.com/bmjgh?URL_MASK=ff37224209d24814820a1e9c5465e738. Alternatively, you can log on to your Author Dashboard in ScholarOne and under "Action" click "create a revision".

Please read and respond to all of the peer review comments. You should provide a point-by-point response to explain any changes you have (or have not) made to the original article and be as specific as possible in your responses.

The original files will be available to you when you start your revision. Please delete any files that you intend to replace with updated versions and upload the following using the appropriate file designation:
- ''Main Document'' - This is a clean copy (without tracked or highlighted changes) of your revised article. Please delete your original submission file.
- "Main Document - marked copy" - This is the edited version of your original article, including edits to address the peer review comments. Any changes have been highlighted using a track change function or bold or coloured text.
Please replace any other files that have been updated e.g. Images, forms

Information relating to your article, including author names and affiliations, title, abstract and required statements (e.g. competing interests, contributorship, funding) will be taken directly from the information held in ScholarOne, and not from the article file. Please check that this information has been entered correctly and has been updated as appropriate. If your revised article is accepted, you will only be able to make minor changes (e.g. correction of typesetting errors and proof stage) prior to publication.

Please submit your revised article by 18-Feb-2022. If we have not received it by this date, the opportunity to submit a revision will expire and your article may be treated as a new submission. If you need to request an extension, please contact the Editorial Office as soon as possible.

Thank you for submitting your article to BMJ Global Health; we look forward to receiving your revision.

If you have any queries, please contact the Editorial Office at info.bmjgh@bmj.com.

Kind regards,

Editor in Chief, BMJ Global Health

Dr. Seema Biswas
Associate Editor, BMJ Global Health

Formatting Amendments (where applicable):

Reviewer(s)' Comments to Author (if any):

Reviewer: 1

Comments to the Author
Thank you very much giving me the opportunity to read this interesting and relevant manuscript. This manuscript clearly presents potential impact of geospatial analysis for health policy and planning. I am very impressed with the detailed description of the methodology. I have a couple of suggestions to improve this work.

In general, the manuscript quite complex with many variables tested. It requires quite some effort to grasp all the different elements. In addition, the consists of many long sentences (4-5 lines) (for example page 15, line 5; page 17, line 12). I would like to advise the authors to revise the text to make it more accessible to the broad readership of the BMJ.

Other comments and suggestions:
Page 6, line 17. Here you introduce the CHWs. I miss some background information, regarding their selection, employment, supervision and remuneration. Alternatively write this in the method section page 7, line 53.

Page 6, line 34. Here you introduce the CHW in Sierra Leone. If I remember correctly, the Ebola crisis had a major impact on the number and status of the CHWs. Part of the reason was the employment of CHWs by NGOs during this period, leading the need to standardization which was picked up by the ministry. Maybe good to dedicate a few words to this as it helps the reader to understand the setting.

Page 8, line 6. "the CHW policy of 2021-2025 sought to rightsize…". As the "optimized networks" are an essential concept and part of this manuscript, I would suggest providing a brief explanation what you mean with this. Is relocating the CHWs to a more strategic location or does this also include the 40% decrease that is suggested later in the text (page 16, line 17)?

Page 15, line 50. Here you mention that the political economy is difficult to capture in models. Totally agree, however I miss a reflection on the challenges that the implementation of this geoptimization CHW entails. First of all, I assume that stopping the employment of certain CHWs have consequences for them and their families. Moving CHWs to a geoptimized location (see figures on page 25 and 26), might theoretically make sense but has enormous practical consequences. Finally, employment of new CHWs in locations that are not covered has also implications.
Page 29, line 31. All study limitations are technical limitations. I would expect a reflection on the challenges introducing this into practice.

Reviewer: 2

Comments to the Author
Dear authors,

Congratulations on a very complex and useful analysis. Your work is highly relevant and the methodology provides a useful example to any country working to improve the efficiency and reach of their CHW programs. Further, your contextualization of the results within Sierra Leone's policy and CHW programmatic history is well-expressed and further strengthens your article's relevance to other countries.

You have done an impressive job describing a very complex analysis; however, there is substantial room to simplify language and reduce scope within the manuscript to make it more accessible to readers.

Attached, in Word, are specific comments on the document.

Again, congratulations on producing a very relevant and important contribution to field.

Reviewer: 3

Comments to the Author
Method listed for obtaining the data sets are not described. There is need for clarification especially

as the method was stated as being adapted from similar work in the region.
The limitation needs to describe the constants /factors used to arrive at the estimated distances between health facilities.

Date Sent: 20-Jan-2022

File 1: bmjgh-2021-008141-Optimising-scale-and-deployment-of-CHWs-in-Sierra-Leone.docx

Files attached

bmjgh-2021-008141-Optimising scale and deployment of CHWs in Sierra Leone.pdf

Close Window

Response to reviewer's comments for the manuscript "Optimising scale and deployment of CHWs in Sierra Leone: a geospatial analysis"

Note: Page and line numbers referred to in our responses correspond to the "Main document – marked copy".

Reviewer: 1

Comments to the Author

Thank you very much giving me the opportunity to read this interesting and relevant manuscript. This manuscript clearly presents potential impact of geospatial analysis for health policy and planning. I am very impressed with the detailed description of the methodology. I have a couple of suggestions to improve this work.

In general, the manuscript quite complex with many variables tested. It requires quite some effort to grasp all the different elements. In addition, the consists of many long sentences (4-5 lines) (for example page 15, line 5; page 17, line 12). I would like to advise the authors to revise the text to make it more accessible to the broad readership of the BMJ. **Response:** Thank you for the comment and suggestion. We have shortened sentences, where possible, and revised the text as suggested to make it more accessible.

Other comments and suggestions:

Page 6, line 17. Here you introduce the CHWs. I miss some background information, regarding their selection, employment, supervision and remuneration. Alternatively write this in the method section page 7, line 53. **Response:** Thank you for comment and suggestion. We provide a brief overview of the CHWs on page 4 (lines 18-28) page 5 (line 25) through page 6 (line 12) of the marked copy. On page 6 (lines 9-12) we indicate that additional detail on the CHWs (e.g., definition of CHW, package of services, selection, training, certification, deployment, CHW per population ratios, and supervision) is provided in Supplementary Appendix 1.

Page 6, line 34. Here you introduce the CHW in Sierra Leone. If I remember correctly, the Ebola crisis had a major impact on the number and status of the CHWs. Part of the reason was the employment of CHWs by NGOs during this period, leading the need to standardization which was picked up by the ministry. Maybe good to dedicate a few words to this as it helps the reader to understand the setting. **Response:** Thank you for the comment

and suggestion. We have added text to page 4 (lines 19-22) of the marked copy to clarify that the rapid scale-up coincided (in part) with the Ebola crisis and that the CHWs were employed by NGOs. In the results section (page 11, lines 19-22) we note that indeed there was a rapid increase in CHW deployment from 2010 onward, which continued during the Ebola crisis (i.e. the rapid scale-didn't start with the Ebola crisis and it wasn't accelerated by the Ebola crisis but it did continue during the Ebola crisis).

Page 8, line 6. "the CHW policy of 2021-2025 sought to rightsize…". As the "optimized networks" are an essential concept and part of this manuscript, I would suggest providing a brief explanation what you mean with this. Is relocating the CHWs to a more strategic location or does this also include the 40% decrease that is suggested later in the text (page 16, line 17)? **Response:** Thank you for the comment and suggestion. We have added text on page 8 (line 28) through page 9 (line 2) of the marked copy to clarify the meaning of an "optimized" CHW network i.e. one deployed with optimal efficiency. Additionally, we have added text as suggested to page 16 (line 26-28) to clarify the meaning of "rightsize" and "retarget". The 40% reduction in the CHW workforce is per the MOHS current plans for rightsizing and retargeting and is a function of both ending contracts for CHWs within 3 km of a health facility (in our analysis 64.5% of CHWs were within 3 km of a health facility) and adding new CHWs recruited from and deployed to ETR and HTR areas. The new CHWs in ETR and HTRs offset to some extent the loss of CHWs within 3 km, hence the MOHS arrive at a 40% reduction and not a 64.5% reduction. To simplify the above for readers, we have used the language "rightsize" and "retarget", and with the added text as suggested we think the meaning is clarified. Thank you for the helpful suggestion.

Page 15, line 50. Here you mention that the political economy is difficult to capture in models. Totally agree, however I miss a reflection on the challenges that the implementation of this geoptimization CHW entails. First of all, I assume that stopping the employment of certain CHWs have consequences for them and their families. Moving CHWs to a geoptimized location (see figures on page 25 and 26), might theoretically make sense but has enormous practical consequences. Finally, employment of new CHWs in locations that are not covered has also implications. **Response:** Thank you for the comments. We agree there will be challenges to implementation and difficult decisions to be made. We have added text as suggested on page 16, line 31 through page 17, line 7 of the marked copy.

Page 29, line 31. All study limitations are technical limitations. I would expect a reflection on the challenges introducing this into practice. **Response:** Thank you for the comment. We have added text on page 19, lines 25-32 of the marked copy.

Reviewer 2

Comments to the Author (in email)

Dear authors,

Congratulations on a very complex and useful analysis. Your work is highly relevant and the methodology provides a useful example to any country working to improve the efficiency and reach of their CHW programs. Further, your contextualization of the results within Sierra Leone's policy and CHW programmatic history is well-expressed and further strengthens your article's relevance to other countries.

You have done an impressive job describing a very complex analysis; however, there is substantial room to simplify language and reduce scope within the manuscript to make it more accessible to readers.

Attached, in Word, are specific comments on the document.

Again, congratulations on producing a very relevant and important contribution to field.
Response: Thank you for the helpful comments. Please see our responses below in blue font.

Comments to the Author (in the attached Word document)

Overarching

You have done a stellar job contextualizing the CHW program, policy changes, and application and implication of your findings. Because this analysis and discussion is so relevant for so many other contexts, it would be worth ensuring the article is accessible and understandable to a larger audience. **Response:** Thank you very much for your very helpful, thoughtful comments and suggestions. We agree and provide responses below.

For that reason, I recommend you:

- **review the article with an eye to shorten sentences and remove jargon.** The concepts and nuances of your analysis are hard to comprehend, and shorter sentences and more direct wording would really help the reader to grasp the information. See below for some specific examples. **Response:** Thank you for your comment and very

helpful suggestion. We have revised the text to shorten sentences and simplify, where possible. We have provided responses to the specific examples below.

- **consider reducing the scope of what is described in the manuscript**. For example, under the Data section (page 8, line 52) you describe the four scenarios you modelled; however, the results presented in the manuscript only describe and discuss results for model 1: walking in dry conditions – or at least model 1 is the primary focus of the manuscript. The results and discussion do not include comparisons of dry conditions to wet conditions, for example. I think that is fine because the content of the manuscript is very rich and complex. Keeping results and discussion of the other models and their differences to the Supplementary Material is wise. Given that, you might remove the details throughout the methods about these other models and simply point readers to the Supplementary Materials for information on other models. Then, in the manuscript, you do not need to continuously clarify that you are reporting results of walking in dry conditions. The reader will understand that. **Response:** Thank you for your comment and suggestion. We agree and have adjusted the text to remove the details on the other models on page 7, lines 12-14 of the marked copy, and pointed readers to the Supplementary Materials for further information.

Specific edits

Key Questions section

You use the term "newly defined" to describe the ETR and HTR areas. You might add who defined them – I assume from the manuscript body that it was MOHS. Consider adding that detail here, and in the abstract. **Response:** Thank you for your helpful comment. We have adjusted the text accordingly throughout, replacing "newly defined" with MOHS-defined (other language making it clear that it is per national policy). This includes the abstract, Key Questions box (page 3), and Discussion section (page 15, line 30) of the marked copy.

Background

Page 6 Line 18 – spell out HRH upon first use **Response:** Thank you. We have adjusted the text on page 4, line 8 of the marked copy.

Page 6 Line 42 – (an example of a sentence that could be shortened and simplified.) Consider rewording to: "A 2019 assessment of the national CHW program incorporated findings from earlier iterations of our analysis , and informed the new MOHS CHW policy for the peridd 2021-2025. The new policy included three key policy shifts: harmonization…. " **Response:** Thank you. We have adjusted the text as suggested on page 4, lines 23-25 of the marked copy.

Study setting

Page 7 Line 45 - remove the phrase "including prevention, promotion, and curative services" as this same phrase is included on line 57. **Response:** Thank you. We have adjusted the text in both sentences to remove redundancy on page 5, lines 25-27 of the marked copy.

Data

Page 8 Line 46 – "…(99.6%) had geographic coordinates and for the main settlement in which they worked and 14 494 CHWS (99.1%) ~~had geographic coordinates and~~ received the

standard 10-day pre-service training…" I believe the section that is unnecessary and can be removed. **Response:** Thank you. We have adjusted the text as suggested on page 6, lines 18-21 of the marked copy.

Geographic areas relevant to CHW policy

Page 9 Lines 13 and 19 – the parentheses include notes on how you define "not in difficult terrain" and "difficult terrain". I think the relationship between distance and time, relative to terrain may not be immediately apparent to the reader. Consider adding a direct statement about how/why you needed to convert the MOHS definitions which used distance to definitions that use time, and how time across distance is different depending upon terrain. **Response:** Thank you. We have adjusted the text as suggested on page 7, lines 17-22 of the marked copy.

Assessing accessibility coverage

Page 9 Line 50 – "…time to the nearest health service delivery location of a given health service delivery network, accounting for travel speeds of different modes of …." Is the yellow highlighted phrase necessary? It seems you could drop it without losing the meaning. **Response:** Thank you. We have adjusted the text as suggested on page 8, line 12.

Page 9 Line 58 – The sentence beginning "We estimated accessibility coverage at 100 meters…" is very long. Consider revising to be two or three sentences. **Response:** Thank you. We have adjusted the text as suggested on page 8, lines 17-19.

Assessing efficiency of geographical targeting

In general, this section could benefit from a careful editing with an aim to simplify language. For example:

Page 10 Line 22 – Consider simplifying the sentence to something like: "We assessed the geographical efficiency of the existing CHW network to inform the 2021 CHW strategy and future fine tuning of the CHW network." **Response:** Thank you. We have simplified the text as suggested on page 8 (line 28) while also addressing comments from Reviewer 1 on that same passage (they sought more detail on the definition of a "optimized network"). See page 8, lines 28 through page 9, lines 1-2.

Phrases such as "technical efficiency of geographical targeting" could be made less jargony and more direct. **Response:** Thank you for this suggestion. We have replaced the words "geographical targeting" with "efficiency of deployment" throughout the document, relevant figures, and relevant supplementary appendices to be more coherent. We have kept the terms "technical efficiency" only to reference Palmer and Torgerson's definition of technical efficiency, which we adapted for our definition of a CHW network deployed with optimal efficiency. We have defined "efficiency of deployment" on page 8, line 30-32 of the marked copy for clarity.

Page 10 Lines 10-60: The phrases …"in ETR and HTR areas" is repeated many times. Consider revising the section heading to "Assessing the efficiency of geographical targeting in ETR and HTR areas" and then there is no need to continually specify that these methods were applied for those areas. **Response:** Thank you. We have adjusted the text as suggested on pages 8-10 of the marked copy.

Page 10 Line 60: Consider simplifying the sentence to something like: "The maximum extent of a catchment was therefore delimited by 30-minute travel time except in cases where the estimated population exceeded the maximum population capacity. In this case, the extent of the catchment was defined by the area containing the maximum population." Changes such as this would be helpful throughout the manuscript, and particularly within this section. **Response:** Thank you. We have simplified the text as suggested on page 9, line 27-29 of the marked copy. Similar simplifications were throughout the manuscript.

Page 11 Line 9: Similar to above, the description of the comparison between actual and hypothetical networks is unnecessarily complex. If you revise to be more direct, it will help the reader to comprehend the methods. For example, " For (a) we compared the efficiency of the existing network of 1521 CHWs to a hypothetical distribution of the same number of CHWs in both ETR and HTR areas. For the hypothetical scenarios, we used the MOHS norms for CHWs to population stated above." **Response:** Thank you. We have simplified the text as suggested (see page 9, line31 through page 10, line 2) and broader section. As noted above, we changed the terms to "efficiency of deployment".

Results

I love the video. A very nice addition. Consider using the whitespace in the video to succinctly describe what the video is showing in large font, the year(s) as the video cycles through. **Response:** Thank you. We have adjusted the video as suggested.

Page 12 Line 11: Another example of a potential way to simplify language: "Three quarters (76%) of the population in 2015 had walking access to a health facility within 60 minutes." **Response:** Thank you. We have adjusted the text as suggested on page 11, lines 1-2.

If you want to present absolute values of changes in population (Page 12, Line 33) consider introducing this earlier in the results section. **Response:** Thank you. We have brought forward the findings with the absolute numbers of people covered in ETR and HTR areas, see page 11, lines 15-18.

Page 14 Line 17: Do you mean to refer to Figure 1 and Figure 2 (rather than 2A)? **Response:** It should be Figure 1 (this includes panels A and B) and Figure 2A (only 2A, not 2B or 2C).

Page 15 Line 23: This paragraph about uncertainty analysis needs to be rewritten for clarity. If results are only presented in the Supplementary Materials, consider leaving these details out of the manuscript. **Response:** Thank you. We have rewritten for clarity in Supplemental Appendix 1 and removed the details from the manuscript as suggested.

Discussion

First sentence of the Discussion section is too long and should be rewritten for clarity and simplicity. **Response:** Thank you. We have shortened and simplified the text as suggested, see page 15, lines 27-28.

In general, sentences in the Discussion section could be shortened and made more accessible. **Response:** Thank you. We have shortened and simplified the text as suggested.

Consider incorporating some implications from the client perspective – for example, improved gender equity within the CHW network could increase use of some services by

women, for example antenatal care, postnatal care and family planning services. **Response:** Thank you. We have added text on this point (page 17, lines 18-19 of the marked copy).

Table 1

What is the difference between CHW in 2000 with preservice training, and CHW with pre service training rows? **Response:** Thank you for the question. Row three ("CHW in 2000 with pre-service training) provides the results for CHWs in the year 2000 that had pre-service training. Row four ("CHW with pre-service training") provides the results for CHWs in the year 2016 that had pre-service training. We have added text to the asterix at the bottom of the table to clarify this point.

Define acronyms: RMNH, CCM, EVD. **Response:** Thank you. We have added definitions below Table 1.

You do not describe how the CHW pre-service training is measured. Please add some details to the methods – is this self-reported data, is it reported by MOHS as per attendance records for each CHW, and if CHWs are expected to participate in a standard MOHS training, why the variation in completion of these content areas? **Response:** Thank you for the question. It was self-reported by CHWs in the 2016 national georeferenced census of CHWs (the CHWML). We have added details to the "Data" sub-section of the "Data and Methods" section (page 6, lines 20-23 of the marked copy), and further details in Supplementary Appendix 1 (page 45 of the marked copy). We also note this point in the "Implications for policy" section (page 17, line 30 through page 18, line 7 of the marked copy) and "Limitations" section (page 19, lines 12-13 of the marked copy). We also refer readers to Supplementary Appendix 1 for details on the CHWML (where we have added text, see page 45 of the marked copy). CHWs were expected to receive the standard MOHS pre-service training prior to deployment. The standard MOHS training was 10 days and included the following modules:
Module 1: Introducing participants to the standard CHWs training programme
Module 2: Working effectively with communities and households
Module 3. Water, sanitation and hygiene
Module 4: Maternal and newborn health
Module 5: Infant and young child high impact preventive and treatment interventions
Module 6: Community integrated management of newborn and childhood illnesses, including neglected tropical diseases
Module 7: Adolescent sexual and reproductive health rights
Module 8: Sexual and gender based violence
According to the CHW self-reported data in the 2016 national georeferenced census of CHWs (used as the basis of our analysis), nearly all CHWs reported receiving pre-service training. But there was large variation in terms of receipt of training for specific services (e.g. for reproductive, maternal, and newborn health), including services that were a part of the standard MOHS pre-service training. This indicates that while nearly all CHWs reported receiving pre-service training, the requirements of the standard MOHS pre-training may not have been systematically implemented. We note this in the "Results" section and "Implications for policy" section.

Figures

Figures do not have titles that easy to see. **Response:** Thank you for the comments. We notice that the figure titles they do not appear in the PDF form of the manuscript. Please see the powerpoint "Figure guide" for an indication of how the figures will look following professional layout. The titles (in bold) and the accompanying text will be placed below the figures with font and font size per BMJ guidance. Also note that we have reformatted the figures (maps) for clarity in TIFF format and increased the legend font size for clarity. We will work with the BMJ copy-editors to ensure the figures are clear.

Reviewer 3

Comments to the Author

Method listed for obtaining the data sets are not described. There is need for clarification especially as the method was stated as being adapted from similar work in the region. **Response:** Thank you for the comment. We have clarified on page 5, lines 9-11 (marked copy) that we provide a detailed description of the data and methods in Supplementary Appendix 1. This detailed description includes information on how the data sets were obtained. We note that the methods were adapted from previous work by Oliphant *et al*. to give due credit (note that the lead author and several co-authors of that paper are also authors of this paper).

The limitation needs to describe the constants /factors used to arrive at the estimated distances between health facilities. **Response:** Thank you for the comment. Our analysis modelled travel time to the nearest service delivery location, not distance between health facilities. The "Limitations" section (page 18, line 24 in the marked copy) includes a comprehensive summary of the limitations of the data and methods, including factors affecting the travel time model. One of the main limitations is that the estimated travel speeds used as an input to the travel time model were derived from other studies in sub-Saharan Africa and this is duly noted in the limitations section. The constants/factors used to derive the travel time model are described briefly in the section "Assessing accessibility coverage" (page 8, lines 11-26). The section "Assessing efficiency of deployment in ETR and HTR areas" briefly describes the methods for estimating service delivery catchment areas (page 9, lines 11-14. At start of the "Data and Methods" section we refer the reader to Supplementary Appendix 1 for a detailed description of the data and methods (this includes a detailed description of the input datasets, assumptions and methods used to derive the travel time model).

Decision Letter (bmjgh-2021-008141.R1)

From: info.bmjgh@bmj.com

To: npoliphant@gmail.com

CC:

Subject: BMJ Global Health - Decision on Manuscript ID bmjgh-2021-008141.R1

Body: 13-Apr-2022

bmjgh-2021-008141.R1 - "Optimising scale and deployment of CHWs in Sierra Leone: a geospatial analysis"

Dear Mr. Oliphant,

Following review of your article to BMJ Global Health, we invite you to submit a minor revision.

The review comments can be found at the end of this email, together with any comments from the Editorial Office regarding formatting changes or additional information required to meet the journal's policies at this time.

Please note that your revision may be subject to further review and that this initial decision does not guarantee acceptance at this time.

To submit your revised article please click this link: *** PLEASE NOTE: This is a two-step process. After clicking on the link, you will be directed to a webpage to confirm. ***

https://mc.manuscriptcentral.com/bmjgh?URL_MASK=3a099bb1fe5047eca9f0576d6208bcd1. Alternatively, you can log on to your Author Dashboard in ScholarOne and under "Action" click "create a revision".

Please read and respond to all of the peer review comments. You should provide a point-by-point response to explain any changes you have (or have not) made to the original article and be as specific as possible in your responses.

The original files will be available to you when you start your revision. Please delete any files that you intend to replace with updated versions and upload the following using the appropriate file designation:
- ''Main Document'' - This is a clean copy (without tracked or highlighted changes) of your revised article. Please delete your original submission file.
- "Main Document - marked copy" - This is the edited version of your original article, including edits to address the peer review comments. Any changes have been highlighted using a track change function or bold or coloured text.
Please replace any other files that have been updated e.g. Images, forms

Information relating to your article, including author names and affiliations, title, abstract and required statements (e.g. competing interests, contributorship, funding) will be taken directly from the information held in ScholarOne, and not from the article file. Please check that this information has been entered correctly and has been updated as appropriate. If your revised article is accepted, you will only be able to make minor changes (e.g. correction of typesetting errors and proof stage) prior to publication.

Please submit your revised article by 27-Apr-2022. If we have not received it by this date, the opportunity to submit a revision will expire and your article may be treated as a new submission. If you need to request an extension, please contact the Editorial Office as soon as possible.

Thank you for submitting your article to BMJ Global Health; we look forward to receiving your revision.

If you have any queries, please contact the Editorial Office at info.bmjgh@bmj.com.

Kind regards,

Editor in Chief, BMJ Global Health

Dr. Seema Biswas
Associate Editor, BMJ Global Health

Formatting Amendments (where applicable):

Comments to Author (if any):
Editorial comments:
1. Please change your title to: 'ptimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis'

2. As requested in our 'information for authors' please note that authors submitting research from international partnerships between high-income countries and low- and/or middle-income countries are required to include an author reflexivity statement. For guidance, please see the article "Consensus statement on measures to promote equitable authorship in the publication of research from international partnerships (please provide answers to the questions in Table 1, guided by the example in Appendix S1): https://associationofanaesthetists-publications.onlinelibrary.wiley.com/doi/10.1111/anae.15597 Please also see the BMJ Global Health editorial on Using scientific authorship criteria as a tool for equitable inclusion in global health research: https://gh.bmj.com/content/6/10/e007632
****Please note that this reflexivity statement will be published as a Supplementary Appendix

Reviewer: 1

Comments to the Author
No further comments

Reviewer: 2

Comments to the Author
Thank you for your thorough job addressing all reviewer comments. The language in the article is much more accessible, and I expect it will be widely read and useful to many who seek to improve service accessibility and community health efficiency. Thanks for your work!

Date Sent: 13-Apr-2022

Close Window

Decision Letter (bmjgh-2021-008141.R2)

From: info.bmjgh@bmj.com

To: npoliphant@gmail.com

CC:

Subject: Your submission to BMJ Global Health has been accepted

Body: 04-May-2022
bmjgh-2021-008141.R2 - Optimising scale and deployment of community health workers in Sierra Leone: a geospatial analysis

Dear Mr. Oliphant:

We are pleased to accept your article for publication in BMJ Global Health. Well done and many congratulations on an excellent article!

Within 2-3 working days, you will receive an email with payment options and instructions from BMJ's e-commerce partner, Copyright Clearance Center. You will be able to choose either to pay by credit card or invoice. If you are not making the payment yourself, you may forward the email to the person or organisation that will be paying on your behalf. Your article will not be processed by production until you have paid the article processing charge or requested an invoice. For more details on open access publication please visit our Author Hub: https://authors.bmj.com/open-access/.

Please note, that if your institution is part of one of BMJ's Publish and Read or prepay agreements your request for funding will be automatically processed based on this acceptance and you will only receive an email accepting or denying your funding request. To find out if your institution is part of a Publish and Read or prepay agreement visit BMJ's open access agreements page: https://authors.bmj.com/open-access/institutional-programme/.

Once payment is confirmed and your article is sent to Production, copyediting and typesetting will be completed. We will email you a proof to check via our online tool usually within 10-15 days of this time; please check your junk mail folder.

The proof is your opportunity to check for typesetting errors and the completeness and accuracy of the text; including author names and affiliations, tables and figures; including legends, numerical, mathematical, or other scientific expressions. We ask that you only make minor corrections at this stage. Please provide any comments within 48 hours. There will be no further opportunities to make corrections prior to publication.

See https://authors.bmj.com/after-submitting/accepted/ for more information about what to expect once your article has been accepted.

We publish most articles online in their final form around three weeks after acceptance. See https://authors.bmj.com/after-submitting/online-publication/ for more information about online publication. BMJ will deposit your article in all indexes affiliated with the journal.

If your article is selected for press release by BMJ's Press Office you will be informed as soon as possible.

If you have any queries, please contact the Editorial Office at info.bmjgh@bmj.com.

Kind regards,

Dr. Seema Biswas
Associate Editor, BMJ Global Health

Dr. Seye Abimbola
Editor in Chief, BMJ Global Health

https://gh.bmj.com/

Date Sent: 04-May-2022

Appendix 2: Journal editor and peer reviewer comments for Study 3, Improving the efficiency of scale-up and deployment of community health workers in Mali

From: PLOS Global Public Health
Sent: Tuesday, May 17, 2022 10:35 PM
To: Nicholas P Oliphant
Subject: Submission Confirmation for Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis - [EMID:54bdadb0898b48f8]

PGPH-D-22-00839
Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis
PLOS Global Public Health

Dear Dr. Oliphant,

Thank you for submitting your manuscript entitled 'Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis' to PLOS Global Public Health. Your assigned manuscript number is PGPH-D-22-00839.

We will now begin processing your manuscript and may contact you if we require any further information. You will receive an update once your manuscript passes our in-house technical check; you can also check the status of your manuscript by logging into your account at https://www.editorialmanager.com/pgph/.

If you have any inquiries or other comments regarding this manuscript please contact globalpubhealth@plos.org.

Thank you for your support of PLOS Global Public Health.

Kind regards,
PLOS Global Public Health

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/pgph/login.asp?a=r). Please contact the publication office if you have any questions.

PGPH-D-22-00839

Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis

PLOS Global Public Health

Dear Dr. Oliphant,

Thank you for submitting your manuscript to PLOS Global Public Health. After careful consideration, we feel that it has merit but does not fully meet PLOS Global Public Health's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

Please submit your revised manuscript by . If you will need more time than this to complete your revisions, please reply to this message or contact the journal office at globalpubhealth@plos.org. When you're ready to submit your revision, log on to https://www.editorialmanager.com/pgph/ and select the 'Submissions Needing Revision' folder to locate your manuscript file.

Please include the following items when submitting your revised manuscript:

- A rebuttal letter that responds to each point raised by the editor and reviewer(s). You should upload this letter as a separate file labeled 'Response to Reviewers'.
- A marked-up copy of your manuscript that highlights changes made to the original version. You should upload this as a separate file labeled 'Revised Manuscript with Track Changes'.
- An unmarked version of your revised paper without tracked changes. You should upload this as a separate file labeled 'Manuscript'.

Guidelines for resubmitting your figure files are available below the reviewer comments at the end of this letter.

We look forward to receiving your revised manuscript.

Kind regards,

Young-Rock Hong

Academic Editor

PLOS Global Public Health

Journal Requirements:

1. Please ensure that you refer to Fig 2 in your text as, if accepted, production will need this reference to link the reader to the figure.

2. We have noticed that you have cited Supporting Information files in your manuscript. However, there are no corresponding files uploaded to the submission. Please upload them as separate files with the item type 'Supporting Information'. Please also ensure that each Supporting Information file has a legend listed in the manuscript after the references list.

3. Please review your reference list to ensure that it is complete and correct. If you have cited papers that have been retracted, please include the rationale for doing so in the manuscript text, or remove these references and replace them with relevant current references. Any changes to the reference list should be mentioned in the rebuttal letter that accompanies your revised manuscript. If you need to cite a retracted article, indicate the article's retracted status in the References list and also include a citation and full reference for the retraction notice.

Additional Editor Comments (if provided):

The manuscript has been examined by the Editors and by external peer reviewers. We would be interested in evaluating a revised version that addresses the Comments and Editorial Requirements listed below.

[Note: HTML markup is below. Please do not edit.]

Reviewers' comments:

Reviewer's Responses to Questions

Comments to the Author

1. Does this manuscript meet PLOS Global Public Health's publication criteria? Is the manuscript technically sound, and do the data support the conclusions? The manuscript must describe methodologically and ethically rigorous research with conclusions that are appropriately drawn based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

Reviewer #3: Yes

****

2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

Reviewer #3: Yes

****

3. Have the authors made all data underlying the findings in their manuscript fully available (please refer to the Data Availability Statement at the start of the manuscript PDF file)?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception. The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should

be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: Yes

Reviewer #3: Yes

****

4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS Global Public Health does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

Reviewer #3: Yes

****

5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: I hope it to be a fine work of the authors. The study has highlighted the importance of access and coverage of the essential health services. It has attempted to finely present the geospatial analysis on improving the population coverage and distribution of public health services to the unreached communities. It further signifies the importance of Community Health Workers (CHWs) on health service delivery.

Regarding language revisions; the author might need some proof readings. I hope it will sound better to rephrase the first sentence on the introduction as recurrently conjunction "and" has been used.

Though the national community health strategy defined the catchment area of a CHW as 3-4 km of the CHW site; what is is the rationale behind considering three populations of interest beyond 5 km of a CSRef or CSCom.

Please review the citation in the line number 17 of page 15. Please include reference for line number 22/23 for any evidence.

Besides various limitations of the study; the authors has recommended to be addressed by further researches, i hope the current modeling study could help make better policy decisions regarding the distribution of human resources for health especially at the community levels.

Reviewer #2: This is a very resourceful piece for community strategy in primary health care delivery and may be utilized to duly inform decisions around CHW deployment.

It is worth noting however, that mere physical presence of a CHW may not translate to efficiency of care delivery. This is because often these are not people with a background in health training. Their efficacy so much depends on education, day to day training, lived experience and experience working with specific populations. Perhaps, it would have been more useful touching on the level of utilization of the existing CHV network to firm up the rationale for the current study. (How well are we utilizing what we already have before reaching out for what we do not have, which we might not even afford by the way)? Would it benefit the Ministry of health more if it focused on recruiting more CHWs or managing the available CHWs? What has been the opportunity cost (what has the ministry had to forgo in order to cover/take care of the CHW shortage?

In short, if we define shortage in terms of absolute numbers/counts vs. the population then the results for the study are sound. If we look at shortage as a systemic issue that goes beyond just numbers, then we should feel the need to align investments in HRH with the current and future needs of the population and health systems. The scope of the study is well defined, therefore meets its objective. The above recommendations can open room for future research.

Reviewer #3: The paper focused on the need of scaling up human resources for health. found the paper to be analytically robust. No doubt, it has strong potential for influencing distribution policies on medical personnel particularly community health workers in Mali and elsewhere.

****

6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

Do you want your identity to be public for this peer review? If you choose “no”, your identity will remain anonymous but your review may still be made public.

For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: **Yes:** Maurine Awuor Ngoda

Reviewer #3: No

****

[NOTE: If reviewer comments were submitted as an attachment file, they will be attached to this email and accessible via the submission site. Please log into your account, locate the manuscript record, and check for the action link "View Attachments". If this link does not appear, there are no attachment files.]

While revising your submission, please upload your figure files to the Preflight Analysis and Conversion Engine (PACE) digital diagnostic tool, https://pacev2.apexcovantage.com/. PACE helps ensure that figures meet PLOS requirements. To use PACE, you must first register as a user. Registration is free. Then, login and navigate to the UPLOAD tab, where you will find detailed instructions on how to use the tool. If you encounter any issues or have any questions when using

PACE, please email PLOS at figures@plos.org. Please note that Supporting Information files do not need this step.

https://doi.org/10.1371/journal.pgph.0000626.r001

Response to the editor and reviewers' comments for the manuscript "Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis"

Dear Editor and reviewers,

Thank you for your feedback and opportunity to resubmit a revised manuscript. Please find below line-by-line responses (in blue font) to your feedback.

Best regards,

Nicholas Oliphant (on behalf of the authors)

Note: Page and line numbers referred to in our responses correspond to the "Revised Manuscript with Track Changes".

Editor on journal requirements (responses on blue):

1. Fig 2: please (a) provide a direct link to the base layer of the map used and ensure this is also included in the figure legend; (b) provide a link to the terms of use / license information for the base layer. We cannot publish proprietary or copyrighted maps (e.g. Google Maps, Mapquest) and the terms of use for your map base layer must be compatible with our CC-BY 4.0 license.

Response: Thank you. Fig 2 does not use a base layer. The layers in the map include: 1) raster of the population distribution 2) administrative boundaries 3) hypothetical (modelled) ASC site location 4) catchment of the hypothetical ASC site (30-minute walk) and 5) CSCom/CSRef location. The data sources for layers 1, 2, and 5 are referenced in the manuscript and are openly available either at the location indicated in the reference or via the link to the publicly available repository in the Data Availability Statement. The references for the data underpinning the hypothetical (modelled) ASC site location and catchment areas (layers 3 and 4 mentioned above) are referenced in the manuscript and accessible via the link to the publicly available repository in the Data Availability Statement.

If your map was obtained from a copyrighted source please amend the figure so that the base map used is from an openly available source. Alternatively, please provide explicit written permission from the copyright holder granting you the right to publish the material under our CC-BY 4.0 license.

Response: Thank you. All layers used are openly available.

Please note that the following CC BY licenses are compatible with PLOS license: CC BY 4.0, CC BY 2.0 and CC BY 3.0, meanwhile such licenses as CC BY-ND 3.0 and others are not compatible due to additional restrictions.

If you are unsure whether you can use a map or not, please do reach out and we will be able to help you. The following websites are good examples of where you can source open access or public domain maps:

* U.S. Geological Survey (USGS) - All maps are in the public domain. (http://www.usgs.gov)
* PlaniGlobe - All maps are published under a Creative Commons license so please cite "PlaniGlobe, http://www.planiglobe.com, CC BY 2.0" in the image credit after the caption. (http://www.planiglobe.com/?lang=enl)
* Natural Earth - All maps are public domain. (http://www.naturalearthdata.com/about/terms-of-use/)

2. Please send a completed 'Competing Interests' statement, including any COIs declared by your co-authors. If you have no competing interests to declare, please state "The authors have declared that no competing interests exist". Otherwise please declare all competing interests beginning with the statement "I have read the journal's policy and the authors of this manuscript have the following competing interests:"

Response: Thank you. We have added a Competing Interests Statement and the accompanying ICMJE COI forms.

Please ensure that you refer to Fig 2 in your text as, if accepted, production will need this reference to link the reader to the figure.

Response: Thank you for noticing this. We have added the reference to Fig 2 in the text on page 14.

We have noticed that you have cited Supporting Information files in your manuscript. However, there are no corresponding files uploaded to the submission. Please upload them as separate files with the item type 'Supporting Information'. Please also ensure that each Supporting Information file has a legend listed in the manuscript after the references list.

Response: Thank you for the comment. We have removed mention of "Supporting Information Files". The relevant files (references from the MSDS which do not have a DOI or permanent publicly available web address) are included in the Public Data Repository: https://doi.org/10.5281/zenodo.6551988 so that readers may access them.

Please review your reference list to ensure that it is complete and correct. If you have cited papers that have been retracted, please include the rationale for doing so in the manuscript text, or remove these references and replace them with relevant current references. Any changes to the reference list should be mentioned in the rebuttal letter that accompanies your revised manuscript. If you need to cite a retracted article, indicate the article's retracted status in the References list and also include a citation and full reference for the retraction notice.

Response: Thank you for the comment. We have reviewed the reference list and made adjustments. We corrected one reference number and added two references (#56 Yang *et al.*,

and #57 Besada *et al*.) – which required us to update the subsequent reference numbers in the text and reference list. The references are now complete and correct.

Guidelines for resubmitting your figure files are available below the reviewer comments at the end of this letter.

Response: Thank your for the comment. We have used the PACE online tool and resubmitted the Figures after using PACE.

Reviewer: 1

Comments to the Author (responses in blue)

I hope it to be a fine work of the authors. The study has highlighted the importance of access and coverage of the essential health services. It has attempted to finely present the geospatial analysis on improving the population coverage and distribution of public health services to the unreached communities. It further signifies the importance of Community Health Workers (CHWs) on health service delivery.

Response: Thank you.

Regarding language revisions; the author might need some proof readings. I hope it will sound better to rephrase the first sentence on the introduction as recurrently conjunction "and" has been used.

Response: Thank you for the suggestion. We have proofread the document and revised the first sentence accordingly.

Though the national community health strategy defined the catchment area of a CHW as 3-4 km of the CHW site; what is is the rationale behind considering three populations of interest beyond 5 km of a CSRef or CSCom.

Response: Thank you for the comment and question. CHWs are intended to extend equitable access to community-based primary health care services and reduce morbidity and mortality among mothers and children under-five in communities beyond 5 km of a health facility. Malaria is a main cause of morbidity and mortality among children under-five years of age. The Ministry of Health and Social Development (MSDS is the French acronym) was interested in optimizing scale-up and deployment of CHWs in the context of updates to the national community health strategy and ongoing health sector reform. To this end the MSDS was interested in two policy questions (these are described on page 4). We have revised the

text in the Introduction section and moved the policy questions from the Data and Methods section to the Introduction section. We think this helps to frame the analysis and responds to your question.

Please review the citation in the line number 17 of page 15.

Response: Thank you for the comment. We have added an appropriate reference as suggested.

Please include reference for line number 22/23 for any evidence.

Response: Thank you for the comment. We have added appropriate references as suggested.

Besides various limitations of the study; the authors has recommended to be addressed by further researches, i hope the current modeling study could help make better policy decisions regarding the distribution of human resources for health especially at the community levels.

Response: Thank you for the comment. We agree!

Reviewer: 2

This is a very resourceful piece for community strategy in primary health care delivery and may be utilized to duly inform decisions around CHW deployment.

Response: Thank you!

It is worth noting however, that mere physical presence of a CHW may not translate to efficiency of care delivery. This is because often these are not people with a background in health training. Their efficacy so much depends on education, day to day training, lived experience and experience working with specific populations. Perhaps, it would have been more useful touching on the level of utilization of the existing CHV network to firm up the rationale for the current study. (How well are we utilizing what we already have before reaching out for what we do not have, which we might not even afford by the way)? Would it benefit the Ministry of health more if it focused on recruiting more CHWs or managing the available CHWs? What has been the opportunity cost (what has the ministry had to forgo in order to cover/take care of the CHW shortage?

In short, if we define shortage in terms of absolute numbers/counts vs. the population then the results for the study are sound. If we look at shortage as a systemic issue that goes beyond just numbers, then we should feel the need to align investments in HRH with the current and future needs of the population and health systems. The scope of the study is well defined, therefore meets its objective. The above recommendations can open room for future research.

Response: Thank you for the thoughtful comment. The Ministry of Health and Social Development (MSDS) has outlined its priorities in the new National Health Sector

Development Plan, the health sector reform (Mali Action Plan), and update to the national community health strategy (forthcoming). Developing the priorities entailed various situational analyses, implementation research, and modelling efforts to aid planning with the aim of aligning investments (including for HRH such as CHWs) with current and future needs of the Malian population and the health system, as well as balancing tradeoffs. Previous analyses and implementation research has highlighted the strengths and weaknesesses of CHW performance in Mali and suggested health policy and systems supports to improve performance.[1] Among the MSDS priorities, two are most relevant here. The first is to strengthen CHW performance, efficiency and impact through optimization of health policy and systems support, following WHO normative guidance on the subject and robust evidence from implementation research in Mali on what works to strengthen CHW performance. For example, the Government of Mali recently legally recognized the status of CHWs in Mali as workers within the health system,[2] opening the door for the Government of Mali to progressively take over the costs of payment of CHWs (currently supported by donors) in the context of a long-term sustainable financing pathway. Meanwhile, development partners have committed to accompany the MSDS in its vision by supporting CHWs costs in the interim period while the Government of Mali progressively increases domestic financing for CHWs. Further, on the basis of rigorous implementation research in Mali, the MSDS has prioritized scale-up of a robust CHW supervision model and the use of digital tools to drive CHW performance.[1] It should be noted that Mali will continue its robust program of implementation research on community health with the aim of fine-tuning future policy and practice and capitalizing on innovation. Thus optimization of CHW performance and analysis of the health policy and planning choices to do so were already covered by other analyses (situational analyses and implementation research) in the context of the strategic planning noted above – and referenced in the paper (e.g., references 54, 55). A second priority of the MSDS is to efficiently expand the CHW network to optimize coverage of the population. This was the subject of our research. We hope this explains the focus of our research. We have adjusted text in the discussion section (page 15) accordingly. We completely agree that both research on CHW performance (and the health policy and systems strengthening to optimize this) AND research on optimizing scale and efficiency of deployment is needed for maximizing impact, efficiency, and sustainability. Our research is intended to serve the needs and vision of the MSDS – which intends to progress on both fronts. And we agree that research is still needed in key areas and will continue to be needed as needs evolve. We hope that our research will be useful, inspire future analyses, and contribute to the culture of continuous improvement and learning that has taken shape in Mali.

[1] https://gh.bmj.com/content/3/2/e000634.abstract; https://www.samrc.ac.za/sites/default/files/files/2016-07-11/MaliReport.pdf; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6162089/; and https://gh.bmj.com/content/6/11/e007205.abstract;

[2] https://www.musohealth.org/post/d%C3%A9cret-historique-au-mali-les-asc-au-c%C5%93ur-de-la-r%C3%A9forme-du-syst%C3%A8me-de-sant%C3%A9?lang=fr

Decision Letter - Rohina Joshi, Editor

Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis

PGPH-D-22-00839R1

Dear Oliphant,

We are pleased to inform you that your manuscript 'Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis' has been provisionally accepted for publication in PLOS Global Public Health.

Before your manuscript can be formally accepted you will need to complete some formatting changes, which you will receive in a follow up email. A member of our team will be in touch with a set of requests.

Please note that your manuscript will not be scheduled for publication until you have made the required changes, so a swift response is appreciated.

IMPORTANT: The editorial review process is now complete. PLOS will only permit corrections to spelling, formatting or significant scientific errors from this point onwards. Requests for major changes, or any which affect the scientific understanding of your work, will cause delays to the publication date of your manuscript.

If your institution or institutions have a press office, please notify them about your upcoming paper to help maximize its impact. If they'll be preparing press materials, please inform our press team as soon as possible -- no later than 48 hours after receiving the formal acceptance. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information, please contact globalpubhealth@plos.org.

Thank you again for supporting Open Access publishing; we are looking forward to publishing your work in PLOS Global Public Health.

Best regards,

Rohina Joshi

Academic Editor

PLOS Global Public Health

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Reviewer Comments (if any, and for reference):

Reviewer's Responses to Questions

Comments to the Author

1. If the authors have adequately addressed your comments raised in a previous round of review and you feel that this manuscript is now acceptable for publication, you may indicate that here to bypass the “Comments to the Author” section, enter your conflict of interest statement in the “Confidential to Editor” section, and submit your "Accept" recommendation.

Reviewer #1: All comments have been addressed

Reviewer #2: All comments have been addressed

****

2. Does this manuscript meet PLOS Global Public Health's publication criteria? Is the manuscript technically sound, and do the data support the conclusions? The manuscript must describe methodologically and ethically rigorous research with conclusions that are appropriately drawn based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

****

3. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

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4. Have the authors made all data underlying the findings in their manuscript fully available (please refer to the Data Availability Statement at the start of the manuscript PDF file)?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception. The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS Global Public Health does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: No

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6. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: Thank you for taking time to address the comments and suggestions. I hope the article will be an added value to the scientific community and people out there.

Reviewer #2: Authors of this manuscript have adequately addressed the comments earlier raised in the first instance of the review. The analysis is statistically sound and the study objective is reflected in the main findings.

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7. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

Do you want your identity to be public for this peer review? If you choose "no", your identity will remain anonymous but your review may still be made public.

For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: **Yes:** Rabindra Bhandari

Reviewer #2: No

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Appendix 2: Journal editor and peer reviewer comments for Study 4, Integrated community case management of childhood illness in low- and middle-income countries

Cochrane
Effective Practice and Organisation of Care

Peer review comments for review

Title of review: Integrated community case management of childhood illness in low- and middle-income countries
Contact Editor: Celeste Naude
Managing Editor: Liz Paulsen
Contact Author: Nick Oliphant

Instuctions: Please respond to the comments in the table below under "Authors' Response" by stating what, if any, changes were made to the review. Also, please be sure to use track changes within RevMan for any edits you make to the review.

Peer reviewers: Witness Wapanga (WW), Patrick Okwen (PO), Chris Rose – EPOC statistical editor (CR)

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
GENERAL COMMENTS			
1.	Some of the references seem to be wrong. For example, the are studies labelled "new studya", "new studyb", "new studyc", etc. (CR)	Thank you for the comment. We have corrected the study labels and other study information for the relevant studies in the references section. Several of the corrected studies were duplicates of other studies. This resulted in some changes to the counts for reasons for exclusion (increasing the number of studies excluded for being "Duplicate study" and decreasing the counts for other reasons). The changes have been made in track changes to the relevant studies the references section, the sub-section on "Excluded studies" in the section "Description of studies" and in Figure 1.	
ABSTRACT			
2.	*Data collection and analysis (MECIR R8)*	Thank you for the comment. We adjusted the text accordingly: "We reported risk ratios (RR) or hazard ratios (HR) for dichotomous outcomes and hazard ratios (HR) for time to event outcomes, adjusted for clustering, where possible."	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	It would be helpful to clarify that RR is used for dichotomous outcomes, while HR is used for time to event outcomes. (CR)	We also added to following to the text in this section: "We contacted study authors for clarification or additional details when necessary."	
3.	*Results (MECIR R9-R17)* It is highly desirable (MECIR R15) that authors re-express relative treatment effect estimates in an interpretable way.	Thank you for the comment. We understand why the reviewer has raised this point and we understand the utility of MECIR 15 for effective communication of results. For coverage of appropriate treatment from an appropriate provider for any iCCM illness, the estimated effect is negligible (not meaningful from a public health or clinical perspective), the confidence intervals are wide and the certainty of the evidence is *very low*. With *very low-certainty evidence*, the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-15-2). For these reasons, we have not expressed the estimate of effect in absolute terms. Doing so could mislead policy makers into thinking we conclude that there is 4% less risk of seeking appropriate treatment from an appropriate provider with iCCM. The data support the conclusion that we are uncertain of the effect of iCCM on this outcome and we want to be clear with policy makers on this point. In their Cochrane review of IMCI, Gera et al followed this approach for outcomes where the estimated effect was negligible and uncertainty of the evidence was *very low* (see https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD010123.pub2/full). Other Cochrane reviews have also followed this approach. That said, we understand why the reviewer raised this point and the utility of MECIR R15. Had the estimated effect been larger AND the confidence in the evidence moderate or high, we would be inclined to express the estimate of effect in absolute terms. For neonatal mortality, the estimated effect is negligible, the confidence intervals are wide and the certainty of the evidence is *low*. With *low-certainty evidence,* the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		15-2). For these reasons, we have not re-expressed the relative estimate effect in absolute terms. Doing so could be mislead policy makers into thinking that we conclude there is a 1% increase in risk of infant mortality with iCCM. The data support the conclusion that "iCCM may have little to no effect on neonatal mortality". Other Cochrane reviews have reported results this way when the estimated effect is negligible, the confidence intervals wide and the certainty of evidence low. Had the estimated effect been larger AND the confidence of the evidence moderate or high, we would be inclined to express the estimate of effect in absolute terms. For infant mortality, the estimated effect is negligible, the confidence intervals are wide and the certainty of the evidence is *very low*. With *very low-certainty evidence,* the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-15-2). For these reasons, we have not re-expressed the relative estimate effect in absolute terms. Had the estimated effect been larger AND the confidence in the evidence moderate or high, we would be inclined to express the estimate of effect in absolute terms. For under-five mortality, while reviewing the text for this response we found that we neglected to downgrade the certainty of evidence due to the estimate coming from one cRCT. Taking into to this additional downgrade (downgrade 3 instead of 2), the certainty of the evidence is *very low* (rather than *low*). We have adjusted the text and tables accordingly. With the certainty of evidence *very low*, the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-15-2). For these reasons, have not re-expressed the relative estimate effect in absolute terms. Had the confidence in the evidence been moderate or high, we would be inclined to express the estimate of effect in absolute terms. For coverage of careseeking to an appropriate provider for any iCCM illness, the certainty of evidence is moderate. For this reason we have re-expressed the estimate of relative effect for this outcome in absolute terms as suggested. "iCCM probably increases coverage of careseeking to an appropriate provider for any iCCM illness by 68% (RR 1.68, 95% CI 1.24 to 2.27; two trials; 9853 children, *moderate-certainty evidence*).	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		For coverage of appropriate treatment from an appropriate provider for any iCCM illness, in the comparison with usual facility services plus CCM for malaria, the certainty of evidence is very low. With the certainty of evidence very low, the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-15-2). For these reasons, have not re-expressed the relative estimate effect in absolute terms. We have kept the conclusion that "we are uncertain of the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness". Had the confidence in the evidence been moderate or high, we would be inclined to express the estimate of effect in absolute terms. For careseeking to an appropriate provider, in the comparison with usual facility services plus CCM for malaria, the effect is negligible and the certainty of the evidence is *low*. With the certainty of evidence very low, the certainty range has unknown width and therefore the likelihood of a result within that range is unknown (15.3.3 of the Cochrane Handbook, https://training.cochrane.org/handbook/current/chapter-15#section-15-2). For these reasons, have not re-expressed the relative estimate effect in absolute terms. We have kept the conclusion that "iCCM may have little or no effect on careseeking to an appropriate provider for any iCCM illness". Had the estimated effect been larger AND the confidence in the evidence moderate or high, we would be inclined to express the estimate of effect in absolute terms.	
BACKGROUND			
4.	It will be interesting to discuss other existing contextual dynamics in the background, for example the role played by ministries of health in the development and uptake of iCCM – considering that policy makers will be using this reviews to	Thank you for this comment. We agree. The policy transfer process for iCCM has been complex, with early and later adopters and complex dynamics with regard to the roles international organizations and ministries of health played in particular contexts. These dynamics are beyond the scope of this review but we reference the work by Bennett et al (Bennett 2015) – which provides a good analysis on this topic. We have adapted the text in the section Background, Description of the Intervention, accordingly to say : "The transfer of iCCM policy from the global level to national levels has been complex, characterised by "early" and "later" adopters and variation in the role of international organizations and policy transfer strategies used (Bennett 2015). Overall, the adoption of iCCM and its adaptation to national contexts by ministries of health has been rapid, particularly in sub-Saharan Africa where most countries have some form of written policy to enable implementation of iCCM (Rasanathan 2014). " We also added the topic for further research in the section on Implications for research: "Whether and how policy transfer mechanisms influence the effect of iCCM on outcomes."	It would be hard to describe these numerous factors in great detail without adding many additional words, as there will be many factors, and they are likely to be diverse

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	guide decision making, it will be useful to let them recall that this is an intervention they have been a part of. I didn't immediately see this come through in the background. (PO)		across settings, regions, countries. A brief generic sentence on these contextual factors may be adequate to ensure the reader is aware of these.
5.	The use of the term "Lay Health Workers" although used in most research and reviews is not very popular in practice in sub-saharan workers, my experience with work at district health services is that community health workers is a more motivating term. (PO)	Thank you for the comment. We recognize that a wide range of terms is used to describe health workers of this type. Their guideline "Health policy and system support to optimize community health worker programmes" (https://apps.who.int/iris/bitstream/handle/10665/275474/9789241550369-eng.pdf?ua=1) the WHO recognizes the ambiguity of the various terms used in research and practice. It also indicates that the International Standard Classification of Occupations (ISCO) of the International Labour Organization (ILO) refers to community health workers as a distinct occupational group (ISCO 3253) with an official definition. Not all uses of the term community health worker in studies and practice reflect this definition – and studies or practice may use other terms for health workers that meet the ISCO definition of community health workers. For this reason, in our search strategy, like the search strategy used for the 15 systematic reviews underpinning the WHO guidelines, our review considered, in addition to "community health workers", a broad range of terms. We also agree with the reviewer that the perspectives and preferences of the health workers themselves on this matter are paramount to consider in research. Researchers should use language that reflects the preferences of the groups participating in the research. In the studies included in this review, various terms were used. We use the term "lay health workers" to extend beyond the ISCO definition of community health workers and to be inclusive of the various terms used in the included studies. We have added "also called community health workers" in brackets at the first mention of 'lay health workers'.	Suggest adding the phrase "also called community health workers" in brackets at the first mention of 'lay health workers'
6.	There is not mention of performance-	Thank you for the comment. We included "Interventions for the payment of iCCM providers such as salary, fees for service, capitation" as one of the iCCM inputs. PBF/RBF would be included	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	based financing (or results-based management) in this paper and in most LMIC this practice has become more popular and uses indicators from iCCM as performance measures. (PO)	here, however none of the included studies reported using this payment mechanism. It is beyond the scope of this review to comment on the general state of PBF/RBF in the context of iCCM. However, we have indicated in the section on Implications for research that further information on interventions for the payment of iCCM providers (which is inclusive of PBF/RBF) in future studies would help policy makers and program managers.	
7.	It is not immediately clear how the authors arrived at an iCCM intervention given that most community practice in the contexts being considered are iCCM and may not have been called as such by the authors. This may leave a gap in studies they will identify, include or report. (PO)	Thank you for the comment. This is clearly described under 'Types of Interventions' in the Methods section.	This is clearly described under 'Types of Interventions' in the Methods section.
METHODS			
8.	*Data extraction and management (MECIR R43 -R44)* The authors report that, while extracting data from	Thank you for the comment. Here we provide a response per study and then summarize the changes we made to the text. **Mubiru 2015** For Mubiru 2015, we wanted to confirm two things: 1) that the results presented in Table 3 of their paper aligned to our indicator definitions (we were unsure whether the results they presented for careseeking reflected careseeking to an "appropriate provider" and whether the results they presented for treatment reflected treatment by an "appropriate provider") and 2)	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	Mubiru 2015 and Yansaneh 2014, they could not replicate the authors' results. I think some additional detail should be added to explain why it was necessary to try to replicate the analysis, whether it would be reasonable to expect to replicate the results (e.g., if the original authors performed an analysis that required individual-level data that was not available to the reviewers), and the nature of the discrepancy (e.g., how large was the discrepancy and which treatment did it favor?). If there was a serious error, was a retraction requested or an erratum published? (CR)	how they adjusted the results. Mubiru et al provided a dataset with their published paper, so it would be reasonable to expect to be able to check on the above and replicate their results. We found that the dataset was incomplete, so we were unable to confirm 1-2 above or replicate their results. We contacted Mubiru et al for clarification. We also sent an excel file with our outcome definitions and requested that they provide results based on our definitions. Mubiru et al did not respond to our requests. We therefore extracted the relevant unadjusted n(s) and N(s) from Table 3 in their pubished paper and worked under the assumption that what they presented in Table 3 aligned with our outcome indicator definitions. Our unadjusted RRs were generally lower than the adjusted ORs (diff in diff estimator) reported by Mubiru but our confidence intervals overlapped for all outcomes and our results tended to be consistent in terms of direction. For coverage of careseeking to an appropriate provider for fever, the reported AOR by Mubiru was higher than our unadjusted RR. This was also the case for coverage of careseeking to an appropriate provider for suspected pneumonia. Here we provide a comparison of our unadjusted RRs and the adjusted ORs published in Mubiru 2015: Coverage of appropriate tx by an appropriate provider of treatment services for diarrhoea Our unadjusted RR = 10.11 (3.14-32.55) Mubiru 2015 adjusted OR = 22.09 (3.66-142.99) Coverage of appropriate tx by an appropriate provider of treatment services for malaria Our unadjusted RR = 0.95 (0.86-1.04) Mubiru 2015 adjusted OR = 1.57 (0.91-2.70) Coverage of careseeking to an appropriate provider of treatment services for diarrhoea Our unadjusted RR = 1.07 (0.90-1.27) Mubiru 2015 adjusted OR = 2.55 (1.04-6.27) Coverage of careseeking to an appropriate provider of treatment services for fever Our unadjusted RR = 1.01 (0.97-1.05) Mubiru 2015 adjusted OR = 2.36 (1.1-5.09) Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		Our unadjusted RR = 1.14 (1.04-1.25) Mubiru 2015 adjusted OR = 6.06 (2.79-13.15) **White 2018** For White 2018, they provided estimated effects in Table 2, Table C (appendix e) and Table 3 of the published paper and provided an individual level dataset. We wanted to confirm three things: 1) In Table 2 and Table C (appendix e) White et al provided the estimates of effect for coverage of careseeking to an appropriate provider for any illness and for each disease. They provided the sum of N for the iCCM group + control groups at baseline and endline but not separate n and N for intervention and comparison groups for these outcomes. We wanted to confirm the n and N used for the iCCM group and control group for baseline and endline. 2) In Table 3, White et al present the estimated coverage of careseeking to an iCCM provider for any iCCM illness. They did not present an estimated effect for this outcome. We wanted to confirm the n and N for this outcome and calculate an estimated effect. 3) In Table 3, White et al did not report n, N or estimated effect for careseeking to an iCCM provider by disease. We wanted to confirm whether n and N could be obtained from their dataset and calculate an estimated effect. 4) In Table 3, White et al reported results for coverage of careseeking to an iCCM provider for any iCCM illness but did not report on results by disease: Coverage of careseeking to an iCCM provider of treatment services for diarrhoea Coverage of careseeking to an iCCM provider of treatment services for fever Coverage of careseeking to an iCCM provider of treatment services for suspected pneumonia We wanted to confirm whether results for these outcomes could be calculated from their dataset. For 1-4 above, we were able to recalculate the unadjusted n and N from the dataset. To align with our analysis for Mubiru 2015 and Yansaneh 2014 (see response below) we decided to use the estimates of effect based on the unadjusted n and N. Our unadjusted results are similar to the estimates published in White 2018 in terms of magnitude, direction of effect and the confidence intervals overlap. Coverage of careseeking to an appropriate provider of treatment services for any iCCM illness	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		Our unadjusted RR = 1.37 (1.19-1.57) White 2018 IPT model DID = 56.4% (36.4%-76.3%) White 2018 regression model (unadjusted) = 48.3% (32.7%-64.0%) White 2018 regression model (adjusted) = 49.7% (34.8%-64.6%) Coverage of careseeking to an appropriate provider of treatment services for diarrhoea Our unadjusted RR = 1.45 (1.19-1.78) White 2018 IPT model DID = 43.6% (16.4%-70.8%) White 2018 regression model (unadjusted) = 45.4% (24.7%-66.1%) White 2018 regression model (adjusted) = 51.8% (32.6%-71.1%) Coverage of careseeking to an appropriate provider of treatment services for fever Our unadjusted RR = 1.49 (1.26-1.76) White 2018 IPT model DID = 52.6% (30.2%-74.9%) White 2018 regression model (unadjusted) = 44.3% (27.0%-61.7%) White 2018 regression model (adjusted) = 46.1% (30.0%-62.2%) Coverage of careseeking to an appropriate provider of treatment services for suspected pneumonia Our unadjusted RR = 1.41 (1.04-1.90) White 2018 IPT model DID = 60.5% (27.0%-94.0%) White 2018 regression model (unadjusted) = 49.1% (20.7%-77.5%) White 2018 regression model (adjusted) = 51.5% (23.1%-79.9%) Coverage of careseeking to an iCCM provider for any iCCM illness Our unadjusted estimates of coverage: iCCM pre= 0.0% (0/179) Control pre= 0.0% (0/160) iCCM post= 47.9% (91/190) Control post= 0.0% (0/302) Unadjusted RR= 254.48 (15.91-4070.50) White 2018:	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		iCCM pre= 0.0% Control pre= 0.0% iCCM post= 57.6% (42.8-71.2%) Control post= 0.0% No estimate of effect **Yansaneh 2014** For Yansaneh 2014, we sent Yansaneh et al an excel file with unadjusted n(s) and N(s) extracted from their published tables and that aligned with our indicator definitions. Yansaneh responded by confirming the re-calculated n(s) and N(s). We used these unadjusted and unpublished n(s) and N(s) in our analysis. We specify this in the methods section and in the footnotes of tables where results from Yansaneh 2014 are presented. **Changes to text** In the section "Data Extraction and Management" we adjusted the text as follows: "For Mubiru 2015, it was unclear whether the published results aligned to our outcome indicator definitions and how results were adjusted in analysis. Mubiru et al provided an individual level dataset with their publication. We sought to confirm whether the results they reported aligned to our outcome indicator definitions and to replicate their adjusted results as published, using the individual level dataset. We found that we could not replicate the analysis because the dataset provided was incomplete. We contacted Mubiru et al for clarification and requested the authors to confirm results per our outcome indicator definitions. Mubiru et al did not respond. For our analyses involving Mubiru 2015, we extracted unadjusted counts from Table 3 of Mubiru 2015 and assumed the results reported aligned to our outcome indicator definitions. For Yansaneh 2014, the published results did not align to our outcome indicator definitions. We contacted Yansaneh et al and requested confirmation of results per our outcome indicator definitions. Yansaneh et al confirmed unadjusted event counts per our outcome indicator definitions and we used these unadjusted event counts in our analyses involving Yansaneh 2014. For White 2018, the published results did not align to our indicator definitions. White et al provided an individual level dataset. We used unadjusted event counts recalculated from the individual level dataset to align with our outcome indicator definitions in our analyses involving White 2018."	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
		For the footnotes of relevant tables (Tables 6-12) we included text that indicates that we recalculated results for Mubiru 2015, White 2018 and Yansaneh 2014 based on unadjusted counts and refer the reader to the section "Data extraction and management" for more details.	
9.	*Measures of treatment effect (MECIR R46 -R48)* It would be useful to have a little more information about how data were reanalyzed. The text says a generalized linear model was used, but this is a reasonably flexible model, so clearer reporting would be useful. In particular, the text seems to hint that district/region effects were considered. Were these modelled as fixed or random effects? The text says an adjusted RR was desired but does not make clear what adjustment was deemed necessary. (CR)	Thank you for comment. We have changed the text under the section "Measures of treatment effect" as follows: For outcomes on treatment and careseeking, we entered the extracted or re-calculated unadjusted count data into meta-analyses, using a random effects generalised linear model to account for possible heterogeneity in the studies and calculate adjusted RRs. For outcomes on treatment and careseeking, the control group was used as the reference and estimates of relative treatment effects above 1 were in favour of the intervention. For outcomes on mortality, we used the estimated HRs from the studies. The HRs accounted for stratifcation factors and robust variance estimation for clustering (villages in Boone 2016) or used a frailty model to account for clustering (primary health centres in Bhandari 2012). Both Boone 2016 and Bhandari 2012 used a Cox proportional hazard model to calculate HRs. For outcomes on mortality, the control group was the reference and estimates of relative treatment effects below 1 were in favour of the intervention.	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
10	*Measures of treatment effect (MECIR R46 -R48)* It would be useful to state the direction(s) of relative treatment effects, and to tell the reader if a consistent direction of effect has been used across the comparisons. (CR)	Thank you for the comment. We have clarified the text in the section on "Measures of treatment effect" as follows: For outcomes on treatment and careseeking, the control group was used as the reference and estimates of relative treatment effects above 1 were in favour of the intervention… For outcomes on mortality, the control group was the reference and estimates of relative treatment effects below 1 were in favour of the intervention.	
11	*Unit of analysis issues* It would be useful if a little more detail on "extrapolation" of ICCs could be provided. Specifically, how was this done? (CR)	Thank you for the comment. We have clarified the text as follows: "All cRCTs adequately accounted for clustering in their analysis, therefore further adjustments were not needed. For area level analysis (e.g. CBAs that used districts as the unit of analysis), we did not make inferences about the individuals based on the area to which they belonged, to avoid ecological fallacy (Morgenstern 1982)."	
12	*Dealing with missing data (MECIR R44)* It seems that the authors have used imputation methods to estimate means from quantities such	Thank you for the comment. This reflected information from our protocol. We did not use imputation methods. We have updated the text in section "Unit of analysis issues" as follows: "We contacted study investigators and authors in order to verify key study characteristics and obtain outcome data that aligned to our outcome definitions (see Data extraction and management).	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	as means, ranges, samples sizes, etc. Given there is a literature on such methods (with some having been shown to be problematic), it would be useful for the methods to be name and references provided. (CR)	The included studies analyzed their trial data on an intention-to-treat (ITT) basis, where they attempted to include all participants or clusters randomized to each group in the analyses and analyzed data according to initial group allocation irrespective of whether or not participants received, or complied with, the planned intervention. We assumed this could have varied by studies and we used random effect meta-analyses to account for this."	
13	*Dealing with missing data (MECIR R44)* The authors report that they contacted study authors to obtain missing data, but they do not report (in this section) whether such data was actually obtained. It would be useful to do so, or to point the reader to another section where this information is reported. (CR)	Thank you for the comment. We have adjusted the text in this section. We refer readers to the earlier section "Data extraction and management" which provides further details. "We contacted study trial investigators and authors in order to verify key study characteristics and obtain outcome data that aligned to our outcome definitions (see Data extraction and management). "	
14	*Data synthesis (MECIR R51)*	Thank you for the comment. The zero event counts for the control arms are in two outcomes: 1) coverage of appropriate treatment by an iCCM provider and 2) coverage of careseeking to an iCCM provider. The zero counts in the control arm are likely due to the control arms not being exposed to iCCM providers (i.e. lay health workers trained on iCCM). See for example Table 3	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	It appears that for some comparisons, all of the included studies reported zero event counts in their control arms. This seems somewhat implausible, so it would be worth checking whether there have been any errors. If not, I think it would be sensible to describe how zero event counts have been addressed in the statistical analyses. I also suggest adding text to the discussion about any limitations of the methods used. (CR)	from White 2018 (note we re-calculated results using the individual level dataset they provided with the publication but one can see the zero event counts in their analysis). **TABLE 3—Percentage of Sick Children Who Sought Care From Each Provider Type: Liberia, 2015–2016** Intervention Regions / Control Regions Provider Type — 2015, % (95% CI) — 2016, % (95% CI) — P — 2015, % (95% CI) — 2016, % (95% CI) — P Drugstore — 19.9 (11.4, 32.5) — 5.8 (2.3, 14.1) — .015 — 7.0 (4.3, 11.2) — 9.1 (5.1, 15.7) — .48 Informal drug dispensers — 3.3 (1.2, 9.1) — 6.8 (4.1, 10.9) — .20 — 6.2 (3.2, 11.6) — 11.3 (7.5, 16.7) — .11 gCHV — 2.3 (0.9, 5.9) — 0.2 (0, 1.3) — .005 — 2.7 (0.8, 8.8) — 0 — .09 Hospital or clinic — 41.5 (29.7, 54.4) — 25.7 (16.9, 37.0) — .06 — 60.6 (50.5, 70.0) — 49.3 (42.9, 55.8) — .06 CHW — 0 — 57.6 (42.8, 71.2) — <.001 — 0 — 0 — . . . Traditional providers — 5.0 (2.9, 8.7) — 3.2 (1.4, 6.9) — .34 — 7.6 (1.0, 6.6) — 4.9 (2.9, 8.2) — .22 *Note.* CHW = community health worker; CI = confidence interval; gCHV = general community health volunteer. Estimates in this table incorporate inverse probability of sampling weights. Care could be sought from more than 1 provider. We welcome guidance from the Cochrane statistical editor on whether the approach we used for the CBA studies (comparing RRs form endline counts for the iCCM group to RRs from endline counts for the control group) was appropriate, rather than using difference-in-difference estimators (e.g. comparing mean change from baseline to endline between intervention and control groups, using the difference in proportions from baseline to endline). We could find no information on the use of difference-in-difference within Revman or the Cochrane Handbook.	
SUMMARY OF FINDINGS TABLES AND GRADE			
15	The SoF tables say that the basis for the assumed risks is provided in footnotes, but I do not see this	Thank you for the comment. We have used the control group risk across studies (number of events in control group across studies / total in control group across studies) as the assumed risk. We have corrected the SOF as follows:	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	information. Because these tables are already large, it may be useful to put this information in the methods text. (CR)	*The basis for the **assumed risk** is the control group risk across studies (number of events in control group across studies / total in control group across studies).	
16	In many cases, the units for the assumed and corresponding risks are not clearly reported. For example in "43 per 100", what are the 43 events, and what 100 things are they happening to? (CR)	Thank you for the comment. We have updated the SOF tables accordingly.	
RESULTS			
17	It will improve clarity of results if "appropriate treatment" and "appropriate provider" were defined. It is unclear what these mean. (PO)	Thank you for the comment. We have clarified the text in the methods section in the subsection "Types of outcome measures", under "Primary outcomes" and "Secondary outcomes".	
18	Two late studies reported by the authors (Kante 2019 and Ma 2019) will probably add	Thank you for the comment. We agree that the studies awaiting classification and ongoing studies will likely add to the richness of the review. Regarding Kanté 2019, this is the main trial study which served as an umbrella for other analyses and embedded studies. To our knowledge there have been separate papers published but these are part of the main trial, Kanté 2019. • There is a qualitative paper published in 2017 on which Kanté is a co-author, see:	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	richness to this report. Kante had published earlier results in 2017 which are not included in this review. (PO)	Colin Baynes, Helen Semu, Jitihada Baraka, Hildegalda Mushi, Kate Ramsey, Almamy Malick Kante & James F. Phillips (2017) An exploration of the feasibility, acceptability, and effectiveness of professional, multitasked community health workers in Tanzania, Global Public Health, 12:8, 1018-1032, DOI: 10.1080/17441692.2015.1080750 • There is a conference paper published by Kanté in 2017, see: https://paa.confex.com/paa/2017/mediafile/ExtendedAbstract/Paper16107/U5M%20Impact.pdf • There is a unit cost analysis study published in 2017 on which Kanté is a co-author. Tani, K., Exavery, A., Baynes, C.D. et al. Unit cost analysis of training and deploying paid community health workers in three rural districts of Tanzania. BMC Health Serv Res 16, 237 (2016). https://doi.org/10.1186/s12913-016-1476-5	
19	*Effect of interventions (MECIR R76-R99)* Is the result for Mubiru 2015 (analysis 1.1) correct? The RR is an order of magnitude larger than the other studies, which seems somewhat unlikely. Is this the result that has been re-calculated, as described in the methods? If not, perhaps the methods could be clarified to state	Thank you for the comment. To our knowledge, the results for Mubiru 2015 are correct. We have added additional details on data extraction and management for Mubiru 2015 in the "Data extraction and management" subsection in the methods.	

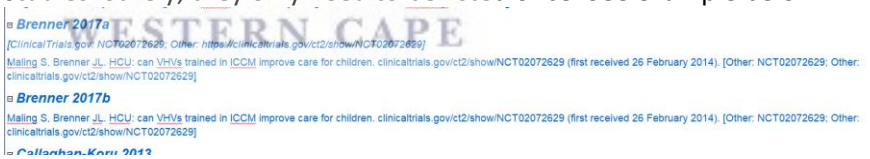
#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	which result was re-calculated. (CR)		
20	*Effect of interventions (MECIR R76-R99)* Are the results for analyses 1.2 and 1.6 (figures 5 and 9) correct? There are zero event counts for the control group, which result in very large treatment effect estimates. (CR)	Thank you for the comment. To our knowledge, the results are correct. The zero event counts in the control group are likely due to the control group not being exposed to iCCM providers.	
21	*Effect of interventions (MECIR R76-R99)* Similarly, please use sensible axis limits for figures 5 to 15 (i.e., it is impossible to see any differences between the confidence intervals if they are no bigger than about 2, but the axis extends to 100). (CR)	Thank you for the comment. We had not thoughtfully considered the scales of the figures. We have reset the scales as recommended. Note that for Figure 5 and 9, the scale had to be set at the max of 1000 in order to show fullest range of data and extent of the confidence intervals.	
DISCUSSION			
22	Implication for policy is not very	Thank you for the comment. In our view, we outline the policy implications clearly – even providing specific examples -- to the extent supported by the evidence in the subsection	This is relevant for the

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	clear, yet this may be the critical part of this review – getting policy makers to invest more in iCCM especially considering approaches to motivate community health workers eg through performance based financing etc. (PO)	"Implications for practice" of the section "Authors' conclusions". We state "iCCM is a complex intervention...While this complexity made it infeasible to disentangle the effects of one component or input from another, it underscores the need for policy makers and program managers to engage with this complexity. The low to modest effects of iCCM found in this review underscore the importance of ensuring all components and inputs of iCCM are adequately addressed in the given context...As low and middle income countries strive to achieve universal health coverage and put into practice their (renewed) commitments to primary health care made at the Global Conference on Primary Health Care in Astana, Kazakhstan in 2018, many will consider the role of iCCM. The evidence presented here underscores the importance of moving beyond training and deployment to valuing iCCM providers, strengthening health systems and engaging community systems. Depending on the context, this could mean adding remuneration of iCCM providers with a financial package commensurate with their work; a greater focus on training and support to facility-based providers to ensure children with severe illness that are referred from iCCM providers receive quality care; expanding the iCCM package to include newborn care; a greater focus on the systems component of iCCM, including referral systems, supply chain, supervision systems, information systems, and monitoring and evaluation; and a greater focus on the social mobilization and community engagement component of iCCM (e.g. engaging women's groups as in the systematic review Prost 2013). quality of care of iCCM providers." Note that research on performance-based financing would fall under the iCCM component "interventions for the payment of iCCM providers such as salary, fees for service, capitation" and we call for for further research on this component. We also added an area for further research, inspired by your comment number 4 on the role of Ministries of Health in the development and uptake of iCCM: "Whether and how policy transfer mechanisms influence the effect of iCCM on outcomes".	Conclusion section. Suggest being guided by the Cochrane Handbook here, Chapter 15, and particularly *Section 15.6 Drawing conclusions* (new handbook). Also take note of the Key points and Introduction to this Chapter
AUTHORS CONCLUSIONS			
23	Because of the complex nature of ICCM and how various components are utilised in different settings, it is ideal that	Thank you for the comment. We understand the desire to disentangle the effects of different components and inputs and we undertand the desire to target investment to particular components and inputs. However the evidence points away from silver bullets to the need for a systems approach, adapted to the given context. Indeed this is one of the main conclusions of the review. We state "The low to modest effects of iCCM found in this review underscore the importance of ensuring all components and inputs of iCCM are adequately addressed in the given context...As low and	Again suggest being guided by the relevant sections of Chapter 15 in the new

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	interpretation of ICCM's effective to be narrowed done to the component that will be utilised by those health workers. Furthermore, components of ICCM can be utilised on their own depedning with available input, training and deployment. (WW)	middle income countries strive to achieve universal health coverage and put into practice their (renewed) commitments to primary health care made at the Global Conference on Primary Health Care in Astana, Kazakhstan in 2018, many will consider the role of iCCM. The evidence presented here underscores the importance of moving beyond training and deployment to valuing iCCM providers, strengthening health systems and engaging community systems. Depending on the context, this could mean adding remuneration of iCCM providers with a financial package commensurate with their work; a greater focus on training and support to facility-based providers to ensure children with severe illness that are referred from iCCM providers receive quality care; expanding the iCCM package to include newborn care; a greater focus on the systems component of iCCM, including referral systems, supply chain, supervision systems, information systems, and monitoring and evaluation; and a greater focus on the social mobilization and community engagement component of iCCM (e.g. engaging women's groups as in the systematic review Prost 2013)."	Cochrane Handbook
24	It is possible to consider research into areas of cost effectiveness of iCCM especially as this will speak better to policy makers. Consider as well, iCCM within performance based financing as is practiced in some African countries. Research could shed more light on how motivating community health workers through	Thank you for the comment. We outline areas for future research to inform improved policy. In the subsection on "Implications for research" in the section "Authors' conclusions" we state: "Future research could aim to identify effective ways to improve iCCM design, implementation, monitoring and evaluation within the context of broader primary health care and community health systems, considering all of the iCCM components and inputs and with particular attention to key gaps identified in the studies included in this review (e.g. training for facility-based providers, inputs within the systems component and inputs within the social mobilization and community engagement component); identify which constellations of iCCM inputs work best in which contexts; identify how iCCM inputs may need to be adapted to address evolving needs such as in urban and peri-urban contexts; identify which approaches to improving iCCM inputs are most effective in which contexts; and identify which modalities (e.g. proactive case detection versus passive case detection) for iCCM implementation work best in which contexts; and quality of care of iCCM providers." Note that in subsection on "Implications for research" we call for further research on the iCCM component "interventions for the payment of iCCM providers such as salary, fees for service, capitation" and performance-based financing would fall within this component. We also added an area for further research, inspired by your comment number 4 on the role of Ministries of	

#	Reviewers' Comments	Authors' Response	Contact Editor's Comments
	performance based financing could affect outcomes. (PO)	Health in the development and uptake of iCCM: "Whether and how policy transfer mechanisms influence the effect of iCCM on outcomes".	

REVIEW DETAILS	
REVIEW SECTIONS	**QtoAs**
Search methods for identification of studies	
Electronic searches	"2018, Issue 12" I have update this. Nick: Ok thanks
Data extraction and management	"Where multiple trial arms were reported in a single trial, we included only the relevant arms in the analyses but listed all arms in the Characteristics of included studies table." I have added 'but listed all arms in the Characteristics of included studies table' as this is a requirement of MECIR. Nick: Ok thanks
Results of the search	"Searches of databases yielded 4763 records to be screened, after duplicates were removed." You say this but there are duplicate refs/studies in the excluded studies section. Nick: Yes, these were only identified as duplicates after screening. We thought that we should maintain the difference between records found to be duplicates during the search and records found to be duplicates during screening (otherwise our records to be screened would have to be changed after-the-fact). Could this be noted somewhere the number of studies that were found to be duplicates during screening?
Included studies	"The authors reported that the funder on the trial steering committee but was not shown interim unmasked analysis" Are there words missing here? Nick: Yes, we have added "was". "The authors reported that the funder was on the trial steering committee but was not shown interim unmasked analysis"
Effects of interventions	"indicated a modest negative effect of iCCM on this outcome (RR 0.97, 95% CI 0.88 to 1.07)," I would suggest that this is no effect. Nick: Agreed. We have adjusted the text.
Comparison 1: iCCM versus usual facility services **Coverage of appropriate treatment** **From an appropriate provider**	You don't mention pneumonia in this section (or under comparison 2) Nick: We say in the Methods section under "Primary Outcomes" that "Coverage of appropriate treatment for pneumonia was not included due to the lack of a valid way to measure this outcome (Bryce 2013)." This is why we have not included information on this outcome in the Results section.
Comparison 2: outcome 6	"The effect based on the CBA (RR 1.24, 95% CI 1.01 to 1.53) is consistent with an effect in favour of the intervention; Analysis 2.4; Figure 13; Table 15)."

	You do not mention this study at the beginning of the paragraph Nick: Thanks for catching this. We have text at the beginning of the paragraph to indicate which CBA.
Differences between protocol and review	You need to mention the change in the authors (i.e. Karsten Lunze is no longer on the team). Nick: Agreed. This section does not appear on the Revman Web version. Could you please add this chang in authors to the appropriate section?
Characteristics of studies	
Characteristics of included studies: Boone	"The authors reported that the funder on the trial steering committee but was not shown interim unmasked analysis" Are there words missing here? Nick: Yes, we have added "was". "The authors reported that the funder was on the trial steering committee but was not shown interim unmasked analysis"
Summary of findings table 1	"I^2 = 96.1%, P = 0.000)" I think this I^2 is incorrect as it doesn't match Analysis 1.1. Please add the full P number Nick: Thanks for catching this. We have corrected the % and p.
Additional table 2	I think 'fever' should read 'malaria'. Nick: Yes, thank you. You are correct.
Additional table 10	"[a]Adjusted for cluster design." There is no 'a'. Please add 'a' to the table and ensure the notes are listed in alphabetical order moving left to right and top to bottom of the table (presently it is b, d, c) Nick: I think this is for "Additional Table 9 Comparison 1 results. Mortality." 'a' appears in the Revman Web version and the superscripts a-d appear in the order you indicate. Maybe you (or we) made the adjustments already? In any case, it appears correct.
References to studies	
Excluded studies	I am unsure why you have multiple entries for some of the excluded studies. Surely, they only need to be listed once. See example below  Brenner 2017a [ClinicalTrials.gov: NCT02072629; Other: https://clinicaltrials.gov/ct2/show/NCT02072629] Maling S, Brenner JL. HCU: can VHVs trained in ICCM improve care for children. clinicaltrials.gov/ct2/show/NCT02072629 (first received 26 February 2014). [Other: NCT02072629; Other: clinicaltrials.gov/ct2/show/NCT02072629] Brenner 2017b Maling S, Brenner JL. HCU: can VHVs trained in ICCM improve care for children. clinicaltrials.gov/ct2/show/NCT02072629 (first received 26 February 2014). [Other: NCT02072629; Other: clinicaltrials.gov/ct2/show/NCT02072629]
Kallander	Please add the journal Nick: Thanks. We have added the journal.

Additional comments on iCCM review – October 2020

1. Analysis 1.3 Figure 6:
   - The analyses in Revman assume that the effect measures are RRs. However, the text suggests that these are HRs. The standard MH approach in Revman is not appropriate for pooling HRs. You need to apply the generic inverse variance approach in Revman, in which the data need to be entered as logs (see the Cochrane Handbook, section 10.3.3 and section 6.8). Please let me know if you are able to apply this approach yourself. Nick: Analysis was updated in Revman Web with support from Simon on videoconference.
   - Please also check if there are any other analyses which also need to be re-analysed for this reason. The re-analysis will probably not make much difference to the point estimates, but may change the Cis. Nick: Done. Not applicable.
2. Analysis 1.6, figure 9:
   - I think that the meta-analysis 'total' should probably not be activated for this analysis, as it is not a relevant number? You can turn off the totals in Revman – let me know if you are not sure how to do this. Please also check if there are other analysis where this needs to be done. Nick: We activated "total" because we want the effect across diseases (for any iCCM illness) and across studies. White 2018 measured the effect for "any iCCM illness". We have deleted the results from White 2018 for "any iCCM illness" as the results from White 2018 for each disease were already captured in the total. We have updated the tables and text accordingly.
   - Because all of the studies included in these meta-analyses have zero events in the control arm, some sort of statistical correction probably should have been considered (see the Cochrane Handbook, section 10.4.4.1: https://training.cochrane.org/handbook/current/chapter-10). However, since all of these results have been assessed as very low certainty, I suggest that you do the following:
     - Add the reasons for downgrading in the results text, where you indicate that the evidence is of very low certainty. Nick: Ok very good. We have adjusted the text accordingly.
     - Omit reporting the RRs and Cis in the results text, since these are very unlikely to be reliable estimates and could mislead readers. Readers can of course look at the results in the analyses and figures. Nick: Ok very good. We have adjusted the text accordingly.
3. Comparison 1, outcome 4: reporting individual trial results for mortality outcomes
   - For neonatal and infant mortality, you report pooled data for the two contributing trials in the results text, which is good. However, you then go on to report the results individually for each trial. It's not clear to me why you have done this, since the pooled result should be the more reliable figure? I would suggest deleting the individual trial results in the results texts unless there is a compelling reason to report these. Nick: Ok thank you. We have moved this text and the text on possible explanations for the heterogeneity to Appendix 2.
   - Linked to the above, the HR and CI data reported in the results text for both neonatal and infant mortality are different to those in comparison 1.3. Is this because you have not used the HR from the published trial, but have used the raw numbers to calculate an RR? If this is the case, it would be preferable to revert to using the HRs in the analysis – see my comment above. Nick: We have corrected this in the text following our videoconference with you where we corrected the results in the analysis section using Revman Web to align with the published results (using log of the published HRs). Note that we were unable to copy the footnote in the Analysis 1.3.1 for neonatal mortality "Please note that these are all Hazard Ratios rather than risk ratios" to Analysis 1.3.2 Infant mortality or Analysis 1.3.3 Under-five mortality. We have added a comment in Revman Web to this effect. We would be grateful if

the editors/copy editors could ensure this footnote is added for infant and under-five mortality.

- Please check if this issue also applies to other analyses. Nick: Ok have done so.

4. Comparison 1, outcome 4: reporting of explanations of the results
   - The explanations in the paragraphs starting 'Regarding differences in components and input…' and 'Bhandari estimate infant mortality may be…' are very detailed, and the length of these makes the results section difficult to read and 'obscures' the main findings. I think it would be best to move these explanations, some of which are hypotheses, to an appendix. You can then refer to this appendix in these sections of the results. Nick: Yes we agree. We have moved this information to Appendix 2.
   - Please also see my comments below under point 7. Nick: Ok

5. Cluster CBAs:
   - Ideally, these should also have been adjusted for clustering. However, given that most of the findings from these are of low or very low certainty, it is unlikely that re-analysing to account for clustering would be worthwhile now. Please note in the methods section under 'Unit of analysis issues' that the cluster CBAs have not been adjusted for clustering, if that is indeed the case. Nick: Ok have done so.
   - I'm afraid that I don't understand the following sentence under 'Unit of analysis issues', *'For area level analysis (e.g. CBAs that used districts as the unit of analysis), we did not make inferences about the individuals based on the area to which they belonged, to avoid ecological fallacy (Morgenstern 1982).'* Could you let me know what you were thinking in relation to this? Nick: Ok we have deleted this.
6. Using raw count data from the trials:
   - Where trials have reported adjusted RRs or HRs, and the adjustments made seem sensible, it may be good to use these rather than calculating unadjusted effects from the raw data reported in the papers. Nick: Ok we have done this for the trials.

7. Additional comments in the review text:
   - Please see some additional comments below (next page), excerpted from the review text. These comments are not in the version that is currently being copy edited, and you will need to make changes in that version, once it comes back from copy editing. Ok have done.

Comparison 1: iCCM versus usual facility services

Outcome 4: Measures of mortality

Neonatal mortality

Two cRCTs (Bhandari 2012 and Boone 2016) reported effects of iCCM on neonatal mortality. These studies suggest that iCCM may have little or no effect on neonatal mortality, compared to usual facility services (HR 1.01, 95% 0.73 to 1.28; two trials; 65209 children; *low-certainty evidence (downgraded due to indirectness and serious imprecision of one of the studies* (Boone 2016)) *[SIMON: I think it is not appropriate to downgrade due to imprecision in one study when you have a pooled estimate. I think that the pooled estimate shows serious imprecision, in that it includes both benefit and harm and that you should therefore downgrade on this basis];* Summary of findings table 1, Analysis 1.3, Figure 6, Table 4 and Table 8). Nick: Ok I have changed to ("downgraded due to indirectness and serious imprecision") so that we are not referring the one study.

Bhandari 2012 reported neonatal mortality may be 9% lower in the intervention group (cluster-adjusted HR 0.91, 95% CI 0.80 to 1.03)[SIMON: This HR and the one below for Boone seems to be different to that in Analysis 1.3? Why is that? I think it is not necessary to report the individual results from each trial, as these are captured in the pooled effect above. You could just report the relevant subgroup analyses here] Nick: I have removed the individual study results and just reported the subgroup analysis. with confidence intervals that included no effect; and a sub-group analysis found that neonatal mortality may be 20% lower in the intervention subgroup that delivered at home compared to usual facility services (cluster-adjusted HR 0.80, 95% CI 0.68 to 0.93) but may be 6% higher in the intervention subgroup that delivered at a health facility compared to usual facility services (cluster-adjusted HR 1.06, 95% CI 0.91 to 1.23) with confidence intervals that included no effect for the latter. Boone 2016 reported a small negative effect (HR 1.21, 0.89 to 1.63) with confidence intervals that included no effect. The reasons for the heterogeneity are unclear but may be due to differences in intervention components and inputs (see table Table 1 and Table 2) and differences in contextual setting between Bhandari 2012 and Boone 2016.

Regarding differences in components and inputs, iCCM providers in Bhandari 2012 were trained to treat newborn local infection and identify and refer newborns with danger signs, whereas iCCM providers in Boone 2016 were not trained to manage ill children below 2 months of age. Although both studies included perinatal home visits (day 1, day 3 and day 7 in Bhandari 2012 and during the first 10 days after birth in Boone 2016) by lay health workers and convening of health groups (women's health groups in Bhandari 2012 and health clubs for caregivers in Boone 2016) by lay health workers, the lay health workers in Bhandari 2012 were trained on iCCM for newborns (as noted above) whereas lay health workers that conducted home visits and convened health clubs for caregivers in Boone 2016 were not trained on iCCM for newborns. Lay health workers in Bhandari 2012 were paid incentives for perinatal home visits, treatment of sick newborns and convening of women's groups, whereas Boone 2016 did not report that lay health workers were paid (it may be fair to assume they were not paid). In addition, Bhandari 2012 included training of facility-based providers on IMNCI to improve facility-based case management. Boone 2016 included training of registered nurses to provide mobile health services, including vaccinations, supplementation,

deparasitisation, and growth monitoring for children, as well as basic antenatal and postnatal consultations for pregnant women, but training on case management was not reported and the intervention did not include important enhancements for facility-based IMNCI/IMCI. The authors of Bhandari 2012 attributed the effect to substantial improvements in careseeking to an appropriate provider for newborn illness (and timeliness thereof), improvements in other newborn care practices (early breast feeding, exclusive breast feeding, delayed bathing, appropriate cord care) and reductions in hospital admissions and reporting of morbidities such as neonatal illness associated with danger signs and diarrhoea and pneumonia during infancy. The authors in Boone 2016 indicated the following factors may have dampened the effect: the short timeframe of the study; possible issues with therapeutic effectiveness of malaria treatment (chloroquine per national protocol) early in the trial and possible earlier population access to ACTs in control clusters, once the national protocol changed to ACTs from chloroquine; and lack of broader health system strengthening, including lack of interventions at health facility level to improve availability and quality of care for severe illness and lack of interventions to improve successful referral from community to health facilities for children with serious illness. Differences in context may have also contributed to the heterogeneity. Bhandari 2012 was conducted in a mixed rural/urban area of northern India whereas Boone 2016 was conducted in rural Guinea-Bissau. However the lack of important differences in effect for careseeking to an appropriate provider between the two studies supports the argument that the above differences in inputs related to newborn health explain more of the differences in effect for neonatal mortality [SIMON: But you have said above that there was little or no effect on neonatal mortality? Are you referring to subgroup analysis here? Please clarify] Nick: You are right. There are no differences in effect. I have changed this to read "explain more of the heterogeneity" (I2 is 64%). than do differences in contextual setting.[SIMON: This paragraph (started 'Regarding differences...') is very long and really breaks up the results section. I would suggest that you move this to an appendix and then refer the reader to that appendix here] Nick: Agreed. I have moved it to Appendix 2.

Bhandari 2012 (linked paper Taneja 2015) reported no effect of iCCM on inequity in neonatal mortality by wealth quintile compared to usual facility services (Difference in equity gradient 0.5, 95% CI -2.0 to 2.9) and no effect on inequity in neonatal mortality by gender compared to usual facility services (Difference in equity gradient -0.1, 95% CI -8.7 to 8.4), Table 9.

Infant mortality

Two cRCTs (Bhandari 2012 and Boone 2016) reported effects of iCCM on infant mortality. Due to inconsistent effects (large effect in favour of the intervention to no effect), indirectness and serious imprecision in one of the studies (Boone 2016),[SIMON: See my comment above on grading - you need to grade based on the overall pooled result rather than one of the studies. I think you could downgrade once and possible twice for imprecision and then also consider indirectness] Nick: Ok we have adjusted accordingly. we concluded that we are uncertain of the effect of iCCM on infant mortality compared to usual facility services (HR 1.02, 95% CI 0.83 to 1.26; two trials; 60480 children; *very low-certainty evidence;* Summary of findings table 1, Analysis 1.3, Figure 6, Table 4 and Table 8).

Bhandari 2012 estimated infant mortality may be 15% lower in the iCCM group (HR 0.85, 95% CI 0.77 to 0.94). The subgroup effect noted above for neonatal mortality Bhandari 2012 persisted for infant mortality (lower infant mortality among home deliveries, cluster-adjusted HR 0.77, 95% CI 0.69 to 0.87; modestly lower infant mortality for facility-based deliveries,cluster-adjusted HR 0.98, 95% CI 0.87 to 1.10, with confidence intervals that

included no effect for the latter). Boone 2016 estimated infant mortality may be 17% higher in the iCCM group (HR 1.17, 95% CI 0.93 to 1.47) with confidence intervals that include no effect. The reasons for the heterogeneity may include the factors noted above for newborn mortality. [SIMON: see my comment above on reporting individual trial results] Nick: Ok have only reported the pooled estimate and the sub-group analysis for Bhandari. The authors of Bhandari 2012 noted that the persistent effect into infancy was likely the result of mother's retention of disease prevention messages communicated through the women's group meetings, with a reported 45% participation, rather than the postnatal visits by lay health workers, since the latter were restricted to days 1, 3 and 7 following birth. Boone 2016 noted a similar level of participation (36%-38%) for the caregiver's health clubs but did not achieve an effect on infant mortality similar to Bhandari 2012. Differences in intervention inputs included, incentives for lay health workers and breadth of the iCCM package -- and possibly quality of the care and messages delivered -- as well as training of facility-based providers on IMNCI and, as noted above for neonatal mortality, these differences may have played a role in the differences in the effect of iCCM on infant mortality. Also as noted above for neonatal mortality, differences in contextual setting may have contributed to differences in the effect of iCCM on infant mortality but the lack of important differences in the effect of iCCM on careseeking to an appropriate provider between the two studies supports the argument that the differences in inputs related to newborn and infant health better explain the differences in effect for infant mortality than do differences in contextual setting.[SIMON: Suggest also moving these explanations to an appendix] Nick: Agreed. I have moved this to Appendix 2.

Bhandari 2012 (linked paper Taneja 2015) reported an important effect of iCCM on inequity in infant mortality by wealth quintile compared to usual facility services, favouring the very poor (Difference in equity gradient 2.2, 95% CI 0 to 4.4) but no effect on inequity in infant mortality by gender compared to usual facility services (Difference in equity gradient 1.7, 95% CI -3.2 to 6.6), Table 9.

Outcome 6: Coverage of careseeking

To an iCCM provider

For diarrhoea

Two CBA studies (White 2018 and Yansaneh 2014) reported on the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhoea compared to usual facility services. No cRCTs reported on this outcome for this comparison. Certainty of the evidence was *very low*, precluding meta-analysis [SIMON: This is confusing as you appear to present a meta-analysis in the next sentence? Please check]. Nick: We have adjusted the text to just state that we are uncertain of the effect and provided the number of studies, number of children, and certainty of evidence, but we removed the pooled estimate from the text and deleted the part that says "Certainty of the evidence was *very low*, precluding meta-analysis". Due to risk of bias and serious imprecision, we are uncertain of the effect of iCCM on coverage of careseeking to an iCCM provider for diarrhea compared to usual facility services (RR 140.28, 95% CI 19.66 to 1000.95; 1654 children; two CBA studies; *very low-certainty evidence*; Analysis 1.6, Figure 9, Table 4 and Table 12). We recalculated unadjusted results for White 2018 and Yansaneh 2014 (see Data extraction and management).

Comparison 2: iCCM versus usual facility services plus CCM for malaria

Outcome 1: Coverage of appropriate treatment

From an appropriate provider

For any iCCM illness

For the effect of iCCM on coverage of appropriate treatment from an appropriate provider for any iCCM illness compared to usual facility services plus CCM for malaria, one CBA study (Munos 2016) reported results for diarrhoea and malaria, totaling two results for the outcome "any illness" (see disease-specific results below). We are uncertain of the effect of iCCM on coverage of appropriate treatment by an appropriate provider for any iCCM illness (ORS and zinc for diarrhoea and ACTs for malaria) compared to usual facility services plus CCM for malaria (RR 1.59, 95% CI 0.66 to 3.87; 7876 children; one CBA study; *very low-certainty of evidence)*. We report results from the study in Summary of findings table 2, Analysis 2.1, Figure 10 and Table 13.

Diarrhoea was diagnosed symptomatically and treated with ORS and zinc. Coverage of appropriate treatment by an appropriate provider for diarrhoea was measured differently by Munos 2016 compared to Mubiru 2015 and Yansaneh 2014. Munos 2016 considered receipt of ORS regardless of receipt of zinc as appropriate treatment, whereas the other two CBAs considered appropriate treatment as the receipt of both ORS and zinc. This may have inflated the effect of iCCM on coverage of appropriate treatment by an appropriate provider for diarrhoea in Munos 2016. In Munos 2016 and Mubiru 2015, iCCM providers diagnosed malaria with an RDT and treated with ACT, whereas in Yansaneh 2014, iCCM providers diagnosed malaria symptomatically (i.e. RDTs were not used) and treated with ACT. This may have inflated the effect of iCCM on coverage of appropriate treatment by an appropriate provider for malaria in Yansaneh 2014. [SIMON: it is unclear why this text is included since you only report results from Munos 2016 above?] Nick: True. We have deleted this. I think it was copied from the comparison 1 results.

We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

For diarrhoea

For coverage of appropriate treatment from an appropriate provider for diarrhoea compared to usual facility services plus CCM for malaria, one CBA study (Munos 2016) reported. We are uncertain of the effect of iCCM on coverage of appropriate treatment by an appropriate provider for diarrhoea (ORS and zinc) compared to usual facility services plus CCM for malaria (RR 2.51, 95% CI 2.05 to 3.07; one CBA study; 2641 children; *very low-certainty evidence*). We reported results in Table 5, Analysis 2.1, Figure 10 and Table 13.

As noted above, this outcome was measured differently by Munos 2016 compared to Mubiru 2015 and Yansaneh 2014, which may have inflated the estimated effect of iCCM on this outcome in Munos 2016.[SIMON: see my comment above] Nick: Agreed. We have deleted this. We were unable to conduct our planned subgroup analyses due to insufficient information for this outcome.

Outcome 6: Coverage of careseeking

To an appropriate provider

For any iCCM illness

One cRCT (Kalyango 2012) reported on the effect of iCCM on coverage of careseeking to an appropriate provider of treatment services for any iCCM illness compared to usual facility services plus CCM for malaria. Based on the cRCT, iCCM may have little or no effect on careseeking to an appropriate provider of treatment services for any iCCM illness compared to usual facility services plus CCM for malaria (RR 1.06, 95% CI 0.97 to 1.17; one trial; 811 children; *low-certainty evidence;* Summary of findings table 2, Analysis 2.3, Figure 12 and Table 15). The effect based on the CBA (RR 1.24, 95% CI 1.01 to 1.53) is consistent
[SIMON: It doesn't seem to be consistent with the cRCT that showed little or no effect?]
Nick: True. It indicates a moderate/large effect. We have adjusted the text to highlight this inconsistency. with an effect in favour of the intervention; Analysis 2.4, Figure 13 and Table 15.

Appendix 3: Link to systematic review protocol. (Oliphant *et al*., 2022)
https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD012882/full

Appendix 4: EPOC systematic review summary video. Cochrane EPOC. (2021, July 12). *Integrated community case management of childhood illness in low- and middle-income countries* [Video]. YouTube.
https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD012882.pub2/full

Appendix 5: Link to EPOC narrative summary of the systematic review. Glenton C and Cooper C. (2021) Integrated community case management of childhood illness in low and middle-income countries. Briefly Summarised.
https://epoc.cochrane.org/sites/epoc.cochrane.org/files/public/uploads/PDF_summaries/iccm_childhood-illness_lmic.pdf

Appendix 6: Reflexivity statement for Study 2

Reflexivity Statement

1. How does this study address local research and policy priorities?

Our analysis addressed national research and policy priorities identified by the Ministry of Health and Sanitation (MOHS) related to the scale and deployment of CHWs in Sierra Leone. An earlier iteration of our analysis, which was included in an assessment of the National CHW Program and broader CHW policy discussions, informed the development of a new MOHS CHW policy for the period 2021-2025. The new policy included three key shifts: harmonisation and integration of all CHW cadres into the national CHW program, rightsizing the scale of the CHW network, and retargeting CHW deployment to areas of greatest need. Our current analysis further explored optimisation of the scale and deployment of CHWs and concluded by supporting the MOHS policy shifts noted above. Our analysis also aimed to inform the operationalisation of the new CHW policy (underway at the time of writing) and contribute to future MOHS planning.

2. How were local researchers involved in study design?

The study grew organically out of policy and operational discussions between the MOHS and partners (technical and financial) on the CHW program, rather than as a research project. The analysis was based on existing datasets. People from Sierra Leone or based in Sierra Leone who led the data collection of the main datasets used (e.g., the CHW master list, master facility list) were included as authors (EM, MS, JK, AK from the MOHS and KH and SO from UNICEF Sierra Leone), and others were acknowledged in the Acknowledgement section of the manuscript. There was no dedicated budget for the study. All authors devoted time to the work as part of their routine work coordinated through the CHW Hub, led by the MOHS. NPO, who was working at UNICEF at that time and providing technical assistance to the MOHS on the CHW program, conceptualised and designed the work with substantial contributions from all authors based on the discussions noted above and feedback on iterations of the analysis.

While our study includes authors from the MOHS, we recognise the privileged position that the lead author and some authors from high-income country (HIC) institutions, as well as partner (technical and financial) institutions, have (e.g., time to devote to conceptualising and conducting the analysis, positions of power as they relate to financial resources and providers of technical assistance). While this analysis was not conceptualised within the context of a research project, we recognize that we could have done better in terms of enabling a more equitable partnership and authorship. For example, authors from the MOHS are "sandwiched" in the middle of the author line-up. We could have done better to build the capacity of the MOHS earlier in the process, enabling them to conduct the analysis themselves. We could have engaged local researchers at local research institutions to lead and conduct the analysis and/or we could have built their capacity (if needed) to do so. In addition, we should have ensured that a representative of CHWs in Sierra Leone participated as an author throughout the process to ensure a voice for CHWs in the spirit of "nothing about us without us". We recognize these shortcomings and we have started to address them in meaningful ways. For example, discussions have started between the MOHS and partners on developing a multi-year program for strengthening the capacity of the MOHS, other parts

of the Government of Sierra Leone, and other local institutions (including research institutions) on data analysis and use for decision making including geospatial analysis. This would strengthen the capacity of the MOHS and other local institutions to undertake geospatial analysis, use it in their work, and lead future publications. We have also promoted the integration and involvement of CHW representation in future policy, programmatic, and research discussions relevant to CHWs through the MOHS-led CHW Hub. We recognize these efforts on their own will not resolve the above issues, however, we hope they will contribute to a more equitable partnership and more equitable authorship in the future.

3. How has funding been used to support the local research team?

As noted above, the analysis did not have a dedicated budget. The lack of a budget limited our ability to involve local researchers. That said, we anticipate that the efforts noted in our response to question #2 will contribute to meaningful support to local researchers within the MOHS and other local institutions.

4. How are research staff who conducted data collection acknowledged?

As noted above, the analysis was based on existing datasets. People who led or provided technical assistance to and oversight of data collection for the main datasets used (e.g., the national georeferenced CHW master list, master facility list) were included as authors (i.e., EM, MS, JK, AK, KH, SO, and NPO), and others were acknowledged in the Acknowledgements section of the manuscript.

5. Do all members of the research partnership have access to study data?

Yes.

6. How was data used to develop analytical skills within the partnership?

In our response to question #2 we outline the shortcomings regarding capacity building on geospatial analysis within the partnership and ongoing efforts to address them.

7. How have research partners collaborated in interpreting study data?

Authors NPO, EM, MS, JK, AK, KH, and SO collaborated in earlier iterations of the analysis in 2016 as part of workshops for the interpretation of results from the 2015-2016 national georeferenced census of CHWs (the national georeferenced CHW master list). Insight from that workshop informed the main shifts in the MOHS CHW policy noted above. NPO, AC, and NR conducted the geospatial analysis. EM, MS, JK, AK, KH, SO, NPO, AC, and NR provided feedback on data and data visualisation. NPO, AC, NR, and TD verified the underlying data. All authors reviewed and interpreted the results of the analysis presented in the manuscript and contributed to editing the manuscript. We acknowledge as a shortcoming that the geospatial analysis was not conducted by the authors from the MOHS or other local institutions and we aim to do better in this respect in future endeavours as noted in our response to question #2.

8. How were research partners supported to develop writing skills?

All authors contributed to editing the manuscript. As noted in our response to question #2 discussions are underway between the MOHS and partners on developing a multi-year program of capacity building on geospatial analysis. We do not assume that the writing skills of the MOHS or other local institutions need to be developed. Indeed, based on feedback from the reviewers it is the authors' science popularization skills that need to be developed (there was a lot of feedback on being more concise, simple, and clear). However, this can be considered, as needed, as part of the above capacity-building effort of the partnership noted earlier.

9. How will research products be shared to address local needs?

Our analysis will be published as open access. The MOHS has access to all data inputs and outputs for their use to address local needs. Additionally, data are available in a public, open access repository under the Creative Commons Attribution 4.0 Unported (CC BY 4.0) licence, which permits others to copy, redistribute, remix, transform and build upon this work for any purpose, provided the original work is properly cited, a link to the licence is given, and indication of whether changes were made.
See: https://creativecommons.org/licenses/by/4.0/. Supplemental appendices 2-4, video 1, all model inputs (except existing service delivery locations) and all model outputs are available in supplemental appendix 1b at https://doi.org/10.5281/zenodo.5712134. Health service delivery location data are only available through data sharing agreements with the MOHS and UNICEF.

10. How is the leadership, contribution and ownership of this work by LMIC researchers recognised within the authorship?

We have recognised the important contributions of LMIC authors in the Contributorship Statement of the manuscript. Of the fourteen authors, four are from Sierra Leone and seven are from LMICs. As noted in our response to question #2, we recognise that although this analysis was not conceptualized within the context of a research project, we could have done better in terms of enabling a more equitable partnership and authorship. For example, authors from the MOHS are "sandwiched" in the middle of the author line-up. In our response to question #2 above, we outline steps we are taking currently to meaningfully address this shortcoming.

11. **How have early career researchers across the partnership been included within the authorship team?**

We have included early career researchers (NPO and AC) within the authorship team. NPO was the lead author, responsible for all aspects of the work. AC contributed to data analysis, feedback on data and data visualisation, verification of the underlying data, and reviewing and editing of the manuscript. We acknowledge that NPO and AC are from high-income countries and are based in institutions within high-income countries.

12. How has gender balance been addressed within the authorship?

Our analysis includes a strong gender equity lens (e.g., highlighting an important gender disparity in CHW employment and supporting the MOHS shift in the new CHW policy to shift the gender distribution to 60% female and 40% male). We should have brought an equally strong gender equity lens to how we operated as a partnership. Nine authors, including the lead author, are male (NPO, NR, AC, MS, JK, KH, SO, HL, and EFTC), and

five authors, including the last author, are female (EM, AK, YS, DJ, and TD). We recognize this gender imbalance as a shortcoming of our partnership and will strive to address this by embedding a gender equity lens within the future endeavours of the partnership.

13. How has the project contributed to training of LMIC researchers?

We acknowledge the lack of capacity building as a shortcoming and outline measures to address this in our response to question #2.

14. How has the project contributed to improvements in local infrastructure?

This project has not directly contributed to improvements in local infrastructure. This may be considered as part of the measures outlined in our response to question #2.

15. What safeguarding procedures were used to protect local study participants and researchers?

Since the analysis was based on secondary data, there were no study participants. Regarding the researchers, all authors had the capacity to refuse to collaborate and there were no restrictions on their influence on the design or conduct of the analysis. There were no indications of feelings of discomfort or compromise. That being said, we did not explicitly anticipate the need for safeguarding procedures when conceptualizing the analysis. In hindsight, we should have explicitly discussed the issue of safeguarding procedures and collectively decided on what measures (if any) were needed. While the content of our analysis is not particularly controversial, in hindsight we recognize that aspects (e.g., the "rightsizing" and "retargeting" of the CHW workforce) may be perceived negatively, particularly by the affected CHWs, their families, and the communities they serve. It is important to note that the policy revision which included the rightsizing and retargeting involved CHW representatives, local Paramount Chiefs, district council representatives, frontline health workers, District Health Management Teams (DHMTs), and CSOs, from all the 16 districts through consultative meetings. This is in addition to the national consultative and validation meetings with representation from districts. However, even with the above consultative process there may have been residual risk to the authors in Sierra Leone and we should have explicitly discussed whether any measures to protect the authors were needed. We fully support safeguarding procedures and commit to explicitly considering the need for them in any future work of the partnership.