Individual and environmental factors associated with overweight among children in primary schools in Ghana

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ABSTRACT

Background

Overweight/obesity is a risk factor for non-communicable diseases such as cardiovascular diseases, diabetes, and some cancers. Obesity in childhood is known to predict later obesity in adolescence and adulthood. Understanding the factors associated with overweight/obesity among children may present an opportunity for timely and appropriate interventions in the African setting.

Aims

1. To describe the prevalence of overweight and obesity and associated factors among school children aged 8 - 11 years in primary schools in Adentan Municipality, Ghana.
2. To review the available literature on childhood obesity in the African context to provide evidence to support the design and improvement of appropriate school-based interventions for the prevention and control of overweight/obesity among African learners.

Methodology

This was a cross-sectional study design which was conducted in two phases. In ***Phase I***, the available literature on the prevalence of overweight and obesity among learners, school-based interventions to promote healthy nutrition and physical activity (PA), and weight status, and key policy interventions at the national levels to provide supportive environments in the African context was reviewed and synthesised. In ***Phase II,*** interviews were conducted to collect individual and family data from 543 learners in 14 schools to assess family socio-demographics characteristics, dietary, PA, and sedentary behaviours, and sleep duration. Body weight, height, and waist circumference were measured. Data on perceived school

neighbourhood/ community, school food, and PA environments were collected from school heads/administrators. A sub-sample of 183 children participated in the assessment of body fat using the deuterium dilution method. Multivariable and logistic regressions, multilevel logistic regressions, and multilevel linear regression models were used to examine the associations among child, family, and school level explanatory variables, and overweight/obesity, abdominal obesity and body mass index (BMI).

Results

The reviews revealed the following: (i) The pooled overweight and obesity estimates across Africa were: (10.5% 95% CI: 7.1-14.3) and 6.1% (3.4-9.7) by World Health Organization; 9.5% (6.5-13.0) and 4.0% (2.5-5.9) by International Obesity Task Force; and 11.5% (9.6-13.4) and 6.9% (5.0-9.0) by Centers for Disease Control and Prevention, respectively and differed for overweight ($p=0.0027$) and obesity ($p<0.0001$) by the criteria. The estimates were mostly higher in urban, and private schools, but generally similar by gender, major geographic regions, publication year, and sample size; (ii) Although inconsistent, school-based interventions broadly improved weight status and some energy-balance related health behaviours of African learners; (iii) On applying the Analysis Grid for Environments Linked to Obesity (ANGELO) framework, key interventions on unhealthy diets and physical inactivity targeted the school, family and community settings, and macro environments, and broadly aligned with global recommendations.

In the school-based study, 16.4% of Ghanaian learners were overweight (9.2%) or obese (7.2%), with the prevalence being significantly higher in children from middle- to high socio-economic status (SES) households, and private schools. In multivariable regression models, attending private school (AOR = 2.44, 1.39–4.29) and excessive television viewing (AOR = 1.72, 1.05–2.82) significantly increased the likelihood of overweight/obesity, whereas adequate sleep (AOR = 0.53, 0.31–0.88), and active transport to and from school (AOR = 0.51, 0.31 – 0.82) decreased the odds. Using deuterium-derived percent body fat as criterion method, the published BMI criteria was found to be highly specific but with moderate sensitivity for diagnosing obesity among Ghanaian children. Moreover, the BMI-for-age z-scores that optimise sensitivity, specificity, and predictive values for obesity were lower than the published cut-off points.

Multilevel logistic and linear regression analyses revealed that the school contextual level contributed 30.0%, 20.6% and 19.7% of the total variance observed in overweight (including obesity), abdominal obesity, and BMI respectively. Availability of school cafeteria ($\beta = 1.83$, $p = 0.017$) and shops ($\beta = 2.34$, $p = 0.001$), healthy foods ($\beta = 0.77$, $p = 0.046$), less healthy foods ($\beta = 0.38$, $p = 0.048$), child age ($\beta = 0.40$, $p = 0.008$), school-level SES ($\beta = 1.02$, $p < 0.0001$), private school attendance ($\beta = -1.80$, $p = 0.006$), and after-school recreational facilities ($\beta = 0.89$, $p < 0.0001$) were all associated with BMI. In the mutually adjusted models for all significant predictors, school-level SES, healthy foods, after-school recreational facilities, and PA facility index remained significant predictors of overweight and or abdominal obesity.

Conclusions

The prevalence of overweight/obesity is significantly higher in urban children attending private or high SES schools, regardless of criteria used to define obesity. A number of individual, family, and school-level factors significantly predicted weight status of school children in Ghana. Given that many African governments have initiated policy interventions aiming to provide supportive environments for healthy choices, it is recommended that resources are made readily available for the implementation of these interventions across the home, school and community.

KEYWORDS

Overweight

Obesity

Learners

School children

Meta-analysis

Systematic review

Scoping review

Logistic regression

Multivariable regression

Multilevel modelling

Africa

Ghana

Body mass index

Deuterium oxide

Deuterium dilution method

Percent body fat

Sensitivity

Specificity

Positive predictive value

Negative predictive value

Receiver operating curves

ANGELO framework

Non-communicable diseases

Area under the curve

DEDICATION

This thesis is dedicated to the children who participated in the study.

DECLARATION

I, THEODOSIA ADOM, declare that "**Individual and Environmental Factors Associated with Overweight among Children in Primary Schools in Ghana**" is my own work, and that all the sources I have used or cited have been indicated and acknowledged as complete references. The thesis is being submitted for examination, through the School of Public Health at the University of Western Cape, South Africa. This work has not been submitted for any other degree in this or another university.

Signed   Date: 5th August 2019

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ABBREVIATIONS AND ACRONYMS

AOR	Adjusted odds ratio
ANGELO	Analysis Grid for Environments Linked to Obesity
ANOVA	Analysis of variance
β	Beta
BMI	Body mass index
BMI-for-age	Body mass index for age
BAZ	Body mass index for age z-score
CERSGIS	Centre for Remote Sensing and Geographic Information Services
CDC	Centers for Disease Control and Prevention
D2O	Deuterium oxide
FFM	Fat free mass
FTIR	Fourier transform infrared spectrometry
GDHS	Ghana Demographic and Health Survey
GHS	Ghana Health Service
IAEA	International Atomic Energy Agency
ICC	Intraclass correlation coefficient
IOTF	International Obesity Task Force
IPAQ-C	International Physical Activity Questionnaire for Children
MVPA	Moderate-to-vigorous Physical Activity
OR	Odds ratio
PA	Physical Activity
PBF	Percent body fat
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
ρ	rho

SD	Standard deviation
SE	Standard error
SES	Socioeconomic status
TBW	Total body water
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
WHtR	Waist-to-height ratio

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PREFACE

This thesis is written in publication format. The role of the PhD candidate in the study is outlined below:

Phase I

In this phase, systematic reviews, meta-analysis, and scoping review of the literature were conducted. The candidate designed the studies, developed the protocols, conducted the literature searches, data collection, data analysis, and interpretation, and wrote Chapters 2 - 4.

Phase II

This phase involves the school-based survey. The candidate conceptualised the study, collected data, assembled and cleaned data, did literature searches, conducted the data analysis and interpretation and wrote Chapters 5 - 7.

The candidate received academic guidance, financial support (through article processing fees) and moral support from the supervisory team throughout the study.

LIST OF PAPERS PUBLISHED DURING PHD CANDIDATURE

1. Theodosia Adom, Thandi Puoane, Anniza De Villiers, André Pascal Kengne. Prevalence of Obesity and Overweight in African Learners – A Protocol for Systematic Review and Meta-analysis. *BMJ Open* **2017**; 7: e013538. doi:10.1136/bmjopen-2016-013538.
2. Theodosia Adom, Thandi Puoane, Anniza De Villiers, André Pascal Kengne. Protocol for a scoping review of existing policies on the prevention and control of obesity across countries in Africa. *BMJ Open* **2017**; 7: e013541. doi:10.1136/bmjopen-2016-013541.
3. Theodosia Adom, Thandi Puoane, Anniza De Villiers, André Pascal Kengne. Protocol for systematic review of school-based interventions to prevent and control obesity in African learners. *BMJ Open* **2017**; 7: e013540. doi:10.1136/bmjopen-2016-013540.
4. Theodosia Adom, André Pascal Kengne, Anniza De Villiers, Thandi Puoane. Prevalence of overweight and obesity among African primary school learners: a systematic review and meta-analysis. *Obesity Science & Practice* **2019**; 5(5):487-502. doi:10.1002/osp4.355.
5. Theodosia Adom, Anniza De Villiers, Thandi Puoane and André Pascal Kengne. Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana. *BMC Obesity* **2019**; 6:14. https://doi.org/10.1186/s40608-019-0234-8.
6. Theodosia Adom, André Pascal Kengne, Anniza De Villiers, Thandi Puoane. Association between school-level attributes and weight status of Ghanaian primary school children. *BMC Public Health* **2019**; 19:577. https://doi.org/10.1186/s12889-019-6937-4.
7. Theodosia Adom, André Pascal Kengne, Anniza De Villiers, Rose Boatin, Thandi Puoane. Diagnostic accuracy of body mass index in defining obesity: analysis of cross-sectional data from Ghanaian children. *Int. J. Environ. Res. Public Health* **2019**, 17, 36; doi:10.3390/ijerph17010036.
8. Theodosia Adom, Anniza De Villiers, Thandi Puoane and André Pascal Kengne. School-Based Interventions Targeting Nutrition and Physical Activity, and Body Weight Status of African Children: A Systematic Review. *Nutrients* **2019**, 12, 95; doi:10.3390/nu12010095.

CHAPTER 1

General Introduction

1.1 Background information

Childhood obesity continues to be of major public health concerns globally [1–4]. In the past two decades, overweight and obesity in children under 5 years increased from 4.2% to 6.7% worldwide [2]. By regional distribution, the estimates increased from 3.2% to 4.9% in Asia and 4.0% to 8.5% in Africa from 1990 to 2010, with the estimates in Africa expected to increase to 12.7% in 2020 [2]. According to the 2014 estimates by the Global Burden of Disease, the combined prevalence of overweight and obesity in children and adolescents during 1980-2013 was 23.8% in boys and 22.6% in girls in developed countries and 12.9% in boys and 13.4% in girls in developing countries [3]. The prevalence appears to have stabilised in most developed countries, contrary to developing countries where the trends seem to be on the increase [3].

Estimates from sub-Saharan Africa suggest evidence of overweight/obesity transition among children and adolescents [2,5,6]. For instance, a systematic review of the literature estimated overweight and obesity prevalence to be 10.6% and 2.5% respectively in school children and youth in 2014. The weighted averages of overweight/obesity prevalence in boys and girls were 7.6% and 15.4%, and 2.0% and 3.9% for obesity.

In Ghana, nationally representative estimates from the Demographic and Health Survey showed that prevalence of overweight and obesity in children under 5 years increased from less than 1% in 1988 to 5% in 2008 [7]. School-going children in the pre-adolescence age group are largely under-represented in national nutrition and health surveys and hence national-level estimates of overweight/obesity for this age group are lacking. However, a few studies have reported increasing overweight and obesity rates particularly among urban children attending private schools [8–11]. Combined prevalence of overweight and obesity of 26.7% was reported in a study in Accra [8] and in about 17% of basic school children in Tamale Metropolis. Among adolescents, 5% were either overweight or at risk of overweight [12].

Childhood obesity presents major health issues as it is associated with early onset of cardiovascular risk factors (including elevated blood pressure), and impaired fasting glucose [4,13,14]. Children who are overweight or obese may experience other health and psychosocial problems including depression, low self-esteem, bullying and teasing, musculoskeletal problems, eating disorders among others [15,16]. Moreover, there is considerable wealth of evidence that overweight and obesity in childhood predict adult obesity. For instance findings from systematic reviews show that children who are overweight or obese are at increased risk of becoming obese adults [13] with increased morbidity and mortality [4].

Ghana experienced considerable economic growth during the last decades since the launch of the structural adjustment programme in the early 1980s [17,18]. Like most developing economies, this rapid growth resulted in increased urbanisation and higher disposable incomes [19]. The increasing trends of overweight and obesity in developing countries including Ghana, have been attributed to unhealthy lifestyles associated with the nutrition transition, globalisation, increased urbanisation, and improvement in human and social development [20,21]. The aetiology of overweight and obesity is complex and multifactorial [22], however, the immediate cause is energy imbalance resulting from increased energy intake and lower energy expenditure. Thus, the increasing trends of overweight and obesity are predominantly driven by physical inactivity and unhealthy dietary patterns.

Despite the well-documented benefits of physical activity (PA) [23], a general decline in overall PA levels and increasing sedentary behaviours has been reported among Ghanaian youth [24]. Evidence from the nationally representative 2016 Report Card on Physical Activity levels among children and youth showed that less than 40% were physically active by the World Health Organization (WHO) guidelines [24], an improvement of earlier observations from the 2012 Global Physical Activity Surveillance where only 20% of 13-15 years old were getting at least 60 minutes of daily moderate-to-vigorous PA (MVPA) [25]. In children who were overweight or obese, MVPA levels were even lower than the recommended guidelines [10,26]. Also, PA tended to be related to age and gender: older children, and boys engaged in MVPA during leisure time [10]. Active transport (including walking and cycling) ranged from 36% to 87% among school children, and this varied by distance to school, regions, as well as rural-urban divide [24]. Among school-aged children in sub-Saharan Africa, higher levels of PA were linked to active transport and spending more time in activities of daily living [27]. Moreover, between 20% and 70% of Ghanaian children and youth were sedentary [12,24,25].

In Ghana, there is a rapid expansion of international fast food chains and supermarkets in recent times in major cities and towns, and they are mainly patronised by middle-to-high income earners [28]. These provide varieties of foods including fresh fruits and vegetables, and also high-energy foods and drinks. As food choices and eating behaviours are largely determined by accessibility and availability, these may lead to reduced consumption of healthy foods such as whole grains, and fruits and vegetables and increased consumption of energy-dense foods. For example, results from a few studies suggest that the dietary patterns of Ghanaian children are mainly characterised by low intake of fruits and vegetables, and high consumption of energy-dense snacks [26,29,30].

1.2 Social determinants of obesity

Social determinants of health can be defined as the conditions in which people are born, grow, live, play, work, and age [31]. Poor health and disease burden including obesity are disproportionately distributed within and across countries and are influenced by factors outside the health domain which are described as upstream and downstream. These factors are multiple, complex, integrated and interact at different levels to influence population health outcomes by increasing the risks for certain groups of the population thereby creating inequalities in obesity rates [31,32]. To achieve health equity therefore, it is needful to eliminate these disparities by addressing not only the immediate risk factors, but also by targeting the upstream determinants that make these risk factors and subsequent development of diseases possible.

Upstream determinants

These are those overarching underlying determinants which are largely beyond the control of the individual and shape the food and built or natural environments thereby having indirect significant influence on health [32]. They occur at the macro level and include global forces and government policies.

Food environment

Among the factors that influence the food environments are: trade agreements, advertising, price, and school environment [32,33]. Multilateral trade agreements open up the domestic markets to international food trade resulting in significant changes to the food environment through tariff and non-tariff barriers to trade, domestic industry supports, foreign direct investment and trade in services. These in turn influence imports and exports, agricultural production, food processing, and food retail, leading to increased access to and availability of ultra-processed foods high in energy, salt and sugar but of low nutritional quality and at relatively low cost [34]. For instance, specific trade agreements between Central America-Dominican Republic and North America resulted in increased availability of animal products and ultra-processed food products and soft drinks [34]. Similar findings were reported in Fiji where trade liberalisation contributed to increased availability of both healthy and less healthy imported foods [35].

Considerable wealth of evidence suggest that food advertising (through multiple media such as children programming on television, internet, popular celebrities, and social media) has an influence on the food environment through product branding and is one of the key strategies of the food industry to influence food preferences and choices especially among children who are not able to differentiate programming and reality [36]. Most of the products advertised are generally high in fat, sugar and salt, and of low nutritional quality, and continued exposure might influence product request by these children and ultimately affect the purchasing decisions by parents [36]. Indeed, the WHO identifies regulation of marketing of unhealthy foods to children as one strategy of creating less obesogenic food environment [37].

Price of foods is another component that impacts the food environment. The price of healthier foods are relatively higher than the less healthy options. At the population level, food taxes and subsidies have been proposed to promote healthy dietary behaviours [38,39]. Introduction of taxes on unhealthy foods such as excise sugar tax on sugar sweetened beverages can increase the consumer prices of these products thereby discouraging purchase and consumption, and subsequently obesity [38,40]. On the other hand, subsidising healthy foods like fruits and vegetables might lead to increased production and accessibility, a key strategy to incentivizing fruits and vegetable consumption and lower obesity [38].

Built and natural environment

Impact of the built environment on obesity with regard to food and PA has been extensively studied [41–45]. Multiple features of the built and natural environments such as urban design, land-mix use, transport mode, and public facilities can serve as facilitators or barriers to healthy behaviours. Access to supermarkets and proliferation of fast food outlets particularly near schools and in socially disadvantaged neighbourhoods have been linked to high obesity rates with the causal pathway identified as unhealthy dietary habits [42]. Furthermore, urban design planning to improve neighbourhood walkability, aesthetics, maintaining, and lighting of parks or playgrounds, recreational areas, walking paths or trails, cycling lanes, and living in close proximity to parks, green/open spaces, public transport, crime and safety concerns have been associated with BMI or obesity through active transport and active play [34,35,41,45–47].

There is an extensive body of literature on the influence of the school environment on development of childhood obesity. Nutrition education on healthy diets, restrictions on marketing of especially junk food and sugar sweetened beverages at school canteens, shops and cafeterias, regulation of the nutrition standards of school meals, and school vegetable gardens, integration of physical education in the school curriculum, and provision of PA and recreational facilities [46,50–52] are some school policies and practices to improve dietary behaviours and PA. A study conducted in Canada to investigate the association of the school food environment, consumption and BMI of adolescents found that the availability and consumption of sugar sweetened beverages at school was positively associated with obesity, but not overweight [53]. Similarly, provision of a variety of sports equipment and recreational facilities have been linked to increased overall MVPA and lower rates of obesity [54].

Accordingly, the National Strategy for the Management, Prevention and Control of Chronic Non-Communicable Diseases by the Government of Ghana outlined a number of policies relating to diet aimed at primary prevention. Among children and youth, regulation of advertising of unhealthy foods and non-alcoholic beverages, mandatory inclusion of fruits and vegetables in school menus, and limiting intake of energy dense foods, salt, trans fatty acids, and sugar were highlighted [39]. To promote PA participation, provision of adequate play spaces for children and young people, PA involving indoor and outdoor games as specified by the School Education Policy of the Ghana Education Service, and monitoring of physical education programmes in schools by the Ministries of Education, Youth and Sports, and Health were outlined [39].

Downstream determinants

These occur at the micro level or social environment and include: education, occupation, income, health-related knowledge, beliefs, attitudes, health behaviours, genetics, sex, and race/ethnicity. Education provides increased access to information on health-related knowledge and behaviours in addition to increasing the occupational and earning potentials. Considerable evidence [31] suggests that life-expectancy is generally higher in high-income countries relative to low-to-middle-income countries. Even within the same country, wealthier individuals have lower odds of poor health outcomes and are less likely to die young relative to poor individuals and this disparity is even apparent in countries where there is quality health care [31].

Having a secured high-paying occupation with higher incomes makes it easier to provide better and affordable health care, nutritious foods and recreational facilities, better education, and live in healthier neighbourhoods with better amenities, among others [31]. On the contrary, families with lower incomes are more likely to have poor education, and live in poor conditions resulting from limited amenities, and unsafe neighbourhood and may not allow their children to engage in active transport or in outdoor activities even in areas where recreational facilities are within easy access [48]. These social gradients lead to the health inequalities.

Age, gender and ethnicity are other elements in the social environment that drive the obesity epidemic. Obesity disproportionately affects some racial and ethnic groups relative to others. For example, in the US, African American and Hispanics are more likely to be overweight or obese compared to non-Hispanic whites or Asians [21]. Among the risk factors are culture and social norms which may differ significantly across racial and ethnic groups. Ethnicity is associated with food-related beliefs, preferences, and behaviours, and perception of ideal body size. African-Americans and Hispanic women for example, perceive large body size as ideal, similar to Africans who perceive larger body size as a sign of wealth and good health [55]. While overweight/ obesity is higher in adult females relative to males [3], in children and adolescents, the evidence is mixed [56,57].

1.3 Statement of the problem

In Ghana, increasing prevalence of chronic non-communicable diseases (NCDs) such as hypertension, cardiovascular diseases, diabetes, and some cancers in the general populace has been reported [58–61]. According to the 2014 WHO estimates, 39% deaths and 31% disease burden in Ghana are attributable to NCDs [62]. Over the past two decades, newly reported cases of hypertension increased more than ten-folds in outpatients at health facilities, excluding the teaching hospitals [60,61]. Cardiovascular diseases are among the leading causes of admissions, and in 2008 accounted for 14.5% of all institutional deaths [63]. From the early to the late 1990s, diabetes prevalence increased from 2-3% to 6.4% in urban communities in Accra [58], while medical admissions at Korle-Bu Teaching Hospital increased from 3.5% to 6.4% from the mid-1970s to mid-1980s. Stroke, hypertension, diabetes and cancer were among the top 10 causes of death in at least each regional health facility by 2003 [64].

Among the major risk factors of NCDs are overweight and obesity [65]. From the review of available evidence, childhood obesity is an emerging public health issue in Ghana. As indicated, childhood overweight tracks into adulthood once it is established. Prevention of unhealthy weight gain at a young age is therefore an important approach to reduce the burden of NCDs. For effective interventions, the risk factors in the local context should be targeted. Given the multifactorial nature of obesity, there is the need to consider the multiple environments in which children live. Furthermore, the adverse health consequences associated with obesity are related to excess body fat, calling for more accurate methods of diagnosis, particularly among children.

The correlates of overweight and obesity have not been extensively studied in the Ghanaian context. In addition, BMI has been the most widely used indicator of obesity among Ghanaian children. The findings of this study would thus provide evidence to healthcare providers, nutritionists, policymakers, and medical professionals working in the field of childhood overweight and obesity that could lead to improvements in the prevention, management and control of chronic NCDs in Africa in general, and Ghana in particular. This would consequently contribute to achieving the United Nations Sustainable Development Goal 3, good health for all ages. Moreover, the utility of the socioecological framework would make it possible to examine the contributions of individual as well as environmental factors to the overweight and obesity epidemic. Subsequent dissemination of study findings in peer-reviewed journals would contribute new knowledge to the evidence base.

1.4 Research Questions

1. What is the prevalence of overweight and obesity among children in primary schools in the Adentan Municipal District of Ghana?

2. What individual, family and school (including school neighbourhood) factors influence child weight?
3. What is the accuracy of the published BMI criteria in defining childhood obesity in a sample of Ghanaian primary school children?
4. What is the contribution of each of the different context to childhood obesity and the associations among these contexts?

1.5 Aims and Objectives

1.5.1 Aims

The aim of the thesis was to describe the prevalence of overweight and obesity and associated factors among school children aged 8 - 11 years in primary schools in Adentan Municipality, Ghana. The study further sought to review the available literature on childhood obesity in the African context to provide evidence to support the design and improvement of appropriate school-based interventions for the prevention and control of obesity among African learners.

1.5.2 Specific objectives

Phase I: Reviews

1. To describe the magnitude and distribution of overweight and obesity among learners aged 6–12 years of both genders within countries in Africa, using any of the internationally accepted BMI cut-offs.
2. To summarise the available evidence on school-based interventions that focused on promoting healthy eating and PA among learners aged 9 – 15 years in Africa to prevent childhood obesity; and to identify factors that lead to successful interventions or

potential barriers to success of these programmes within the African context to identify research gaps in the literature for further studies.

3. To identify and synthesise the evidence on existing national policies on the prevention and control of obesity in Africa.

Phase II: School-based survey

4. To determine the prevalence of overweight and obesity among Ghanaian school children, describe energy-related behaviours; and to examine associated individual and family correlates of childhood overweight/obesity.
5. To evaluate the diagnostic accuracy of the Centers for Disease Control and Prevention (CDC), International Obesity Task Force (IOTF) and WHO based BMI criteria in defining childhood obesity compared to the percentage body fat as assessed by the deuterium dilution method in a sample of Ghanaian primary school children.
6. Investigate the association of the schools' contextual factors with BMI, abdominal obesity and overweight (including obesity) in urban Ghana.

1.6 Study setting

The study was conducted in Adentan Municipality (with Adentan as the central business district) in the Greater Accra Region of Ghana. It is located on latitude 5′ 43″ north and longitude 0′ 09″ West and lies 10 kilometres to the north-east of Accra (**Figure 1.1**). The district is one of the 16 districts in the Greater Accra Region and shares boundaries with Ashaiman Municipal Assembly and Kpong Akatamanso District Assembly in the east and north, La Nkwantanang Municipal Assembly in the west and south, and Tema Metropolitan Assembly in the north [66].

The Adentan Municipality was chosen because of its proximity to the capital Accra, where high prevalence of overweight and obesity have been consistently reported in children under 5 years and adult populations [7,67]. It is one of the fastest growing municipalities in the Greater Accra Region of Ghana. Adentan is mainly urban with about 62.5% of the population residing in urban areas. Adentan serves as a town for most people who have migrated from other parts of the country to seek employment in government institutions, industries and the service sector within the Tema-Accra Metropolitan areas.

According to the 2010 Population and Housing Census, the population of Adentan Municipality is 78,215. Slightly more than half of the population are males (50.3%). About two-thirds (66.2%) of the total population falls within the working population, 2.4% are within the aged population while 31.4% are children aged 0 – 14 years [66]. At the household level, children constitute more than one-third (35.1%) of the members. The district has 13 public basic schools and 135 private basic schools [66]. Of those aged 3 years and older, 24,740 are currently attending school. Approximately 71.0% are attending basic education from kindergarten (13.8%), primary (40.7%), and Junior Secondary School/Junior High School (16.9%). Of the total number of children attending basic school, about 70.0% are males (13.7% in nursery kindergarten, 40.1% in primary and 16.4% in Junior Secondary School/Junior High School) and 72.5% are females (13.8% in nursery kindergarten, 41.4% in primary and 17.3% in Junior Secondary School/Junior High School).

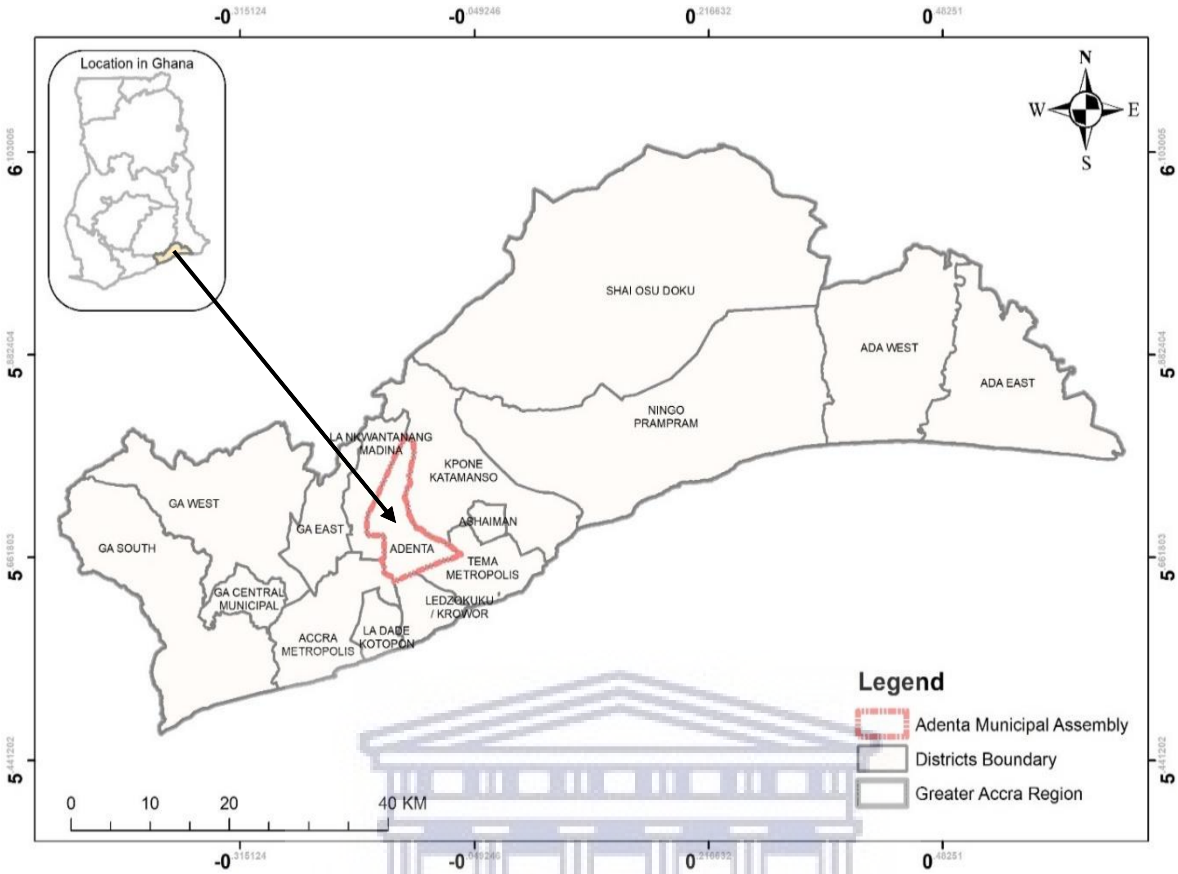

Figure 1.1: District map of the Adentan Municipality, showing its location within the Greater Accra Region of Ghana

Source: Centre for Remote Sensing and Geographic Information Services (CERSGIS), University of Ghana, Legon

1.7 Conceptual framework for the thesis

The conceptual framework for the present study (**Figure 1.2**) was adapted from the socioecological model [68] and integrates concepts based on the literature reviewed. The socioecological theory conceptualises human development from an interactive contextual perspective. It describes layers of contextual systems that influence a child, and these systems are in turn influenced by the child's actions. The model articulates the complexity and interactions of the contextual systems that the child is embedded in, as well as acknowledging the reciprocal nature of the relationships.

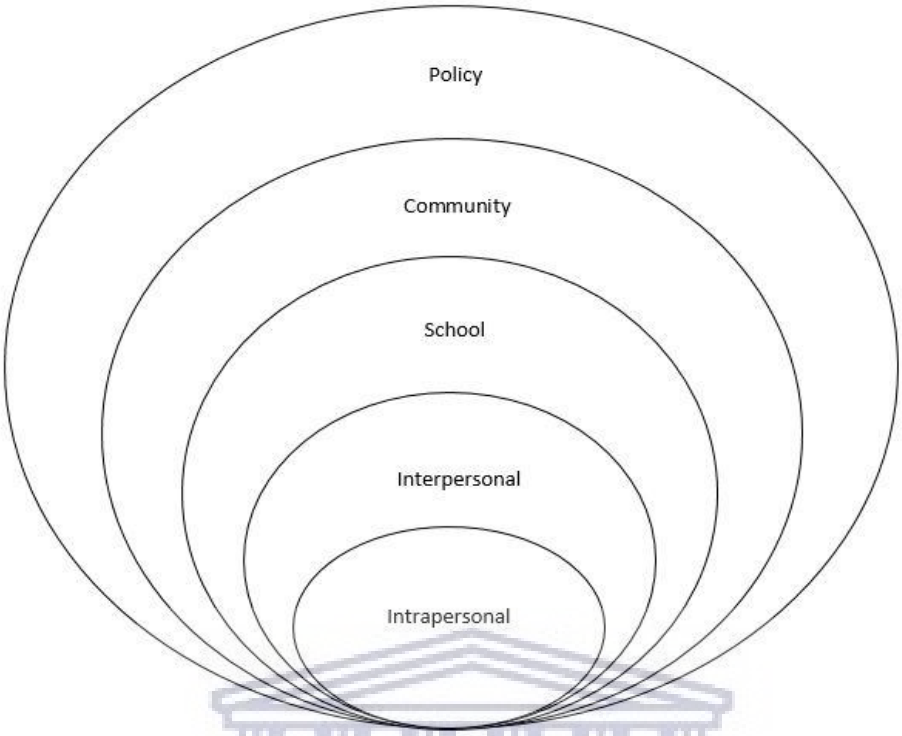

Figure 1.2: Conceptual framework for the thesis

Adapted from McLeroy et al, 1988 [68].

Socioecological models have been widely used in health promotion and health behaviour [69,70]. While some of these studies acknowledge the different contexts that influence individual behaviours and health outcomes, they may not readily suggest relationships between the myriad of factors and testable hypotheses. For example, some researchers examined simple relationships between childhood obesity and predictors and could not show the significance of the multiple ecological contexts of the child and the interactions expected from an ecological perspective. In some other studies, the different contexts were examined separately without determining any association. In their review, Larson and colleagues [71] found that majority of existing studies did not report on the association between child behaviours and environments, and findings were reported as either child behaviours or environments (home, school or community).

In the present study, child weight is conceptualised as being influenced by factors across multiple levels: intrapersonal, interpersonal, school, community, and policy, represented by five concentric layers. The components of the conceptual framework are:

Intrapersonal: In the inner layer are child characteristics and target behaviours such as PA, dietary behaviours, sedentary behaviours and sleep that directly impact child weight status and may be moderated by child's age, gender and genetics.

Interpersonal: These include employment/occupation status of parent(s)/guardians, family size, number of sleeping rooms (a measure of crowding), water, sanitation and hygiene, and household ownership of assets.

School: These refer to the characteristics of the school PA and food environment such as structured periods for activity, time allocated to weekly PA, support for active transport, open space for play during recess, PA facilities during and after school hours, presence of school cafeteria, school shops, foods and drinks available.

Community: Include foods outlets/fast food restaurants around schools, low cost recreational facilities around schools, crime rates and violence, traffic, road connectivity, land-mixed uses.

Policy: This includes organisational and national policies on diet and nutrition, and provision of PA and recreational facilities.

Influences from the other four layers may interact with each other to impact child weight. The application of this model would provide a better understanding of the interactions among the individual and the different levels of the environments in which these behaviours are performed by the child.

1.8 Overview of methodology

This section discusses a summary of methodologies used to achieve the objectives such as the study setting and design, reliability and validity of study instruments. Additional details of study design, sample size calculation, sampling procedures, data collection procedures, study permit, ethics statements and confidentiality, and data analyses are described in the subsequent chapters.

Study design

This study was a cross-sectional design employing quantitative techniques: anthropometry, laboratory analysis, and questionnaires, and was conducted in two phases, that is, review and cross-sectional. The cross-sectional data was obtained from 14 primary schools (six public and eight private). This study was nested in an African Regional Project entitled "Applying Nuclear Techniques to Design and Evaluate Interventions to Reduce Obesity and Related Health Risks"- RAF 6042 supported by the International Atomic Energy Agency (IAEA). The overall objective of RAF 6042 was "to use stable isotope techniques to assess body fat, total energy expenditure and PA among children aged 8 – 11 years from urban primary schools, to inform the design and improvement of interventions aimed at prevention and control of obesity and related health risks such as diabetes among children in Africa".

Modification to the original protocol

The original protocol was modified due to the failure to secure funds for the study and the challenges encountered regarding the collection of the family and home level data. Most parents, after consenting to participate in the study could not make time for interviews in their homes, at the schools, or by telephone. As a result of the limited number of respondents, data on family and home environments could not be included in the analysis. The meta-analysis and systematic reviews were added and written in three chapters on prevalence, school-based interventions and national policies on obesity prevention across Africa.

Reliability and validity

Several steps were taken to ensure reliability and validity of the study. Firstly, research assistants were trained on the study protocol and standard operating procedures (SOPs), which were developed for the data collection process and included participants' enrolment, questionnaire administration, anthropometry, and deuterium oxide method to ensure consistency of procedures. The training emphasised the importance of proper coding of questionnaires and samples, how to complete the questionnaire, measure body weight, height, and waist circumference. The technical error of measurements for both inter- and intra-observer readings were within the acceptable limits - 5% or less [72]. Laboratory technologists were trained on how to prepare deuterium doses, deuterium dosing, samples collection and sample analysis. Secondly, the student researcher was on the field to supervise data collection procedures and to ensure that there was no deviation from the SOPs by reviewing data collection procedures directly, and randomly reviewing questionnaires that have been administered. Data entry forms were checked for completeness and any incomplete or missing information were corrected.

Furthermore, questions were adapted from validated instruments in related studies: dietary patterns [73], PA [74], and school environment [75], and an expert with background in public health nutrition reviewed the developed instruments for face and content validity. Also, the methods used in the selection process of study participants reduced selection bias. Before the commencement of the main survey, pre-testing of the study instruments was conducted in two randomly selected schools (one private and one public) which were outside the study area but with similar characteristics as those in the study area. The pre-testing aimed to standardise the data collection tools to increase validity of the instruments. It also provided field and laboratory training, and experience to research assistants in data collection procedures. Any discrepancies and misunderstanding observed during the pre-testing were noted and corrected. The revised versions of the tools were used in the main survey.

1.9 Outline of Thesis and description of chapters

This thesis is written in manuscript format with a general introduction in chapter 1, six manuscripts forming the subsequent chapters, and a concluding chapter. **Figure 1.3** is a schematic presentation of the study showing temporal linkages among the different studies.

Chapter 1: General introduction

In chapter 1, a summary of the prevalence of overweight or obesity at the global, African and national contexts, and general lifestyle behaviours including dietary patterns, PA and sedentary behaviours of Ghanaian children are described. Additionally, the social determinants of obesity, statement of the problem, research questions, aim and objectives are presented. The chapter also describes the study setting, conceptual framework adapted, and a brief overview of methodology including study design.

Chapter 2: Prevalence of overweight and obesity among African primary school learners: a systematic review and meta-analysis

In this study, we aimed to estimate the prevalence of overweight and obesity among primary school learners residing in Africa according to different diagnostic criteria, namely the WHO, the CDC, and the IOTF references; and population level characteristics. The results highlight overweight and obesity as emerging public health issues in Africa, where the focus hitherto had been on undernutrition. It was noted that the prevalence of both overweight and obesity differed by BMI-for-age criteria used. Estimates were mostly higher in urban, and private schools, but generally similar by gender, major geographic regions, publication year, and sample size.

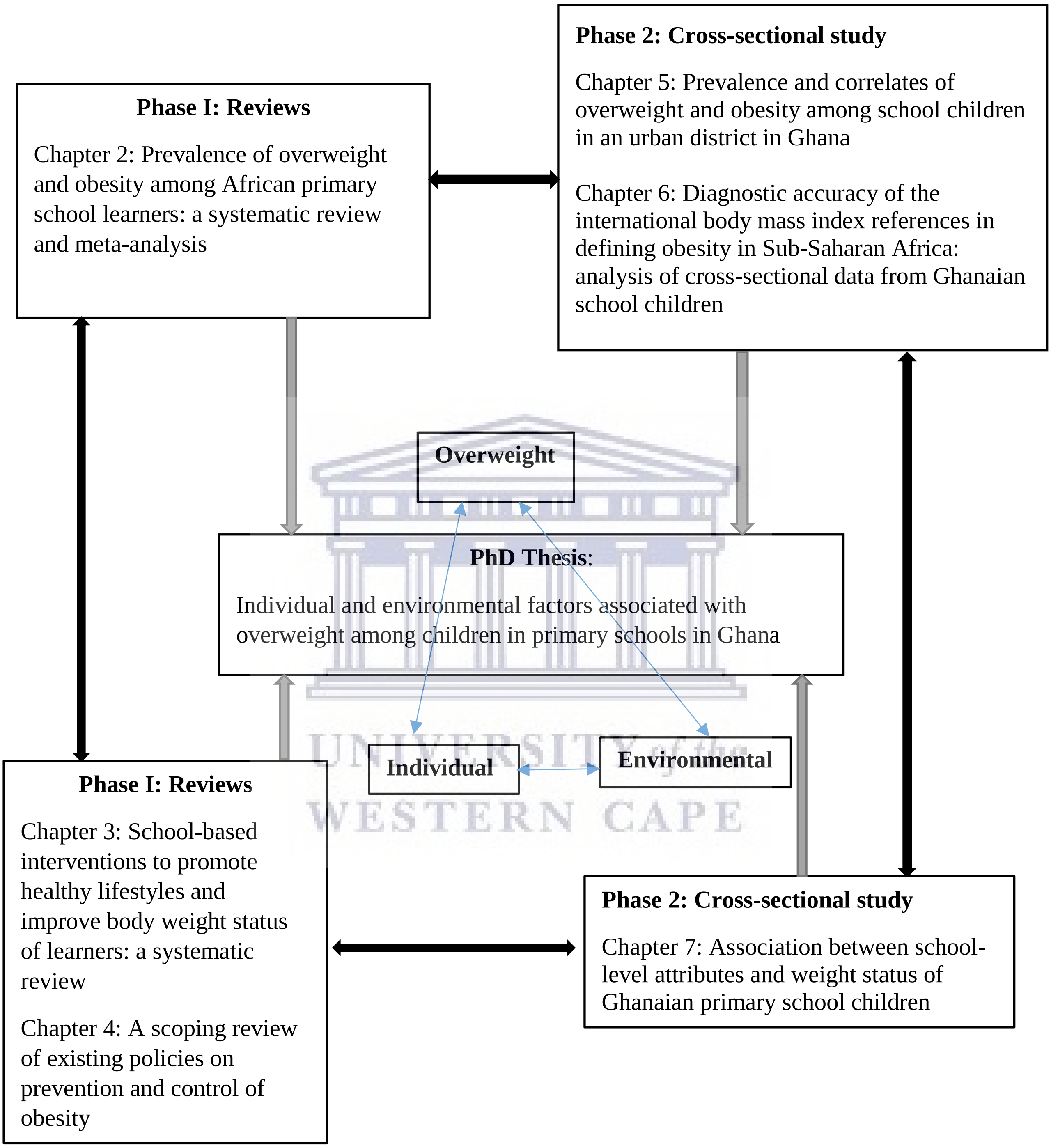

Figure 1.3: Schematic presentation of the thesis showing temporary linkages among the different studies

Chapter 3: School-based interventions targeting nutrition and physical activity behaviours, and body weight status of African learners: a systematic review

This study was conducted to characterise and summarise available evidence from school-based interventions that focused on improving nutrition and PA knowledge, attitude, and behaviours, and weight status of learners aged 9 – 15 years within the African context. Ten studies, mostly low quality and conducted in two countries, were included in this review. The results revealed that on the continent, limited studies were available and these mostly focused on weight-related behaviours rather than weight status (overweight, obesity, excess body fat). The results of the effectiveness of these interventions were inconsistent. The interventions were however, generally promising in improving some energy-balance related behaviours and also weight status of learners.

Chapter 4: A scoping review of existing national policies on prevention and control of overweight/obesity in African countries

In this chapter, a scoping review was conducted to examine the nature, extent and range of national policies on obesity prevention in Africa in order to assess how they align with international efforts. The study found only two documents on obesity; the majority were on NCD, and detailed key interventions to address unhealthy diets and physical inactivity. Using the ANGELO framework, key policy initiatives targeted the school, family, community settings, and macro environments. Additionally, the physical, legislative, and sociocultural domains were largely featured with less emphasis on the economic domain. The available national policies and programmes on prevention of obesity in Africa broadly focused on nutrition and diet, and PA interventions in alignment with global recommendations to provide supportive environments for healthy behaviours.

Chapter 5: Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana

There is dearth of studies on the independent associations of the determinants of overweight and obesity among learners in urban Ghana. This school-based survey, involving 543 learners aged 8 – 11 years, was conducted to describe the prevalence of overweight and obesity in Ghanaian learners, and to investigate the associated individual characteristics and behaviours, and family risk factors. The overall prevalence of overweight or obesity was 16.4%. In the adjusted models, middle- and high- SES households, private school attendance, and excessive television viewing increased the odds of being overweight or obese, while active commuting to and from school and sufficient sleep decreased the odds. The associations were similar for all variables except for household SES which was not longer associated with the likelihood of overweight or obesity in the fully adjusted multivariable model. The results suggest that public health interventions to address childhood overweight and obesity should target the homes, and also schools. Television viewing may represent one important area of obesity prevention intervention in children. Schools and families should also consider the promotion and support of regular active transport.

Chapter 6: Diagnostic accuracy of body mass index in defining obesity: analysis of cross-sectional data from Ghanaian school children

This chapter focused on the methodological issues associated with the assessment of childhood obesity. Given that unhealthy weight (and excess body fat) particularly in children is associated with cardiovascular implications even at young age, the study assessed the diagnostic accuracy of the international BMI-for-age criteria to identify and classify children as obese using deuterium oxide, a stable isotope as the reference method in 183 learners. The overall highest prevalence of obesity was diagnosed by deuterium derived percent body fat (PBF). Significant positive correlations were observed between the BMI z-scores and PBF. The study found that BMI as an indicator of obesity had high specificity with mostly high predictive values across diagnostic criteria, but of moderate sensitivity in identifying Ghanaian children with excess body fat. None of the published criteria achieved optimal rates of sensitivity. It is recommended that the assessment of body fat and or other health risk factors should be considered in addition to BMI-based definition to improve the diagnostic accuracy and minimise misclassification.

Chapter 7: Association between school-level attributes and weight status of Ghanaian primary school children

There is limited research on the contributions of the school environments to childhood obesity using multilevel analysis. This study investigated the school contextual factors influencing child weight status. In the univariable analyses, controlling for the school effects, it was noted that individual and school level factors were independently and jointly related to weight status. Nonetheless, these relationships depended on the outcome measure. The school context explained between 19.7% and 30.0% of the school level variability in weight status. Child weight status was significantly associated with school type, school-level SES, availability of school cafeterias (providing school meals) and school shops (sale of competitive foods and beverages), healthy foods, less healthy foods, PA facility index, and availability and accessibility of after-school recreational facilities. For example, after controlling for individual and school-level variables, it was observed that the school type continued to be related to only BMI, but in the opposite direction. The association with school-level SES was seen with BMI and overweight, but not abdominal obesity. At the individual and school levels, child age, school-level SES, private school and after-school recreational facilities made significant contributions to BMI.

Chapter 8: Summary of findings, discussion, conclusions, implications for public health, and recommendations

In this chapter a summary of the findings of the thesis from the individual papers are integrated and presented. The findings are discussed in relation to what is already known in the study area and the contribution of this thesis to the body of literature. Additionally, some limitations and strengths which were not addressed in the individual studies of the thesis are outlined. The chapter concludes with recommendations targeted at future research directions, government, the home, school, and health care practitioners.

1.10 References

1. Lobstein T, Baur L, Uauy R. Obesity in children and young people: A crisis in public health. *Obes Rev*. 2004;5 Suppl 1:4–85.

2. de Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr*. 2010;92(5):1257–64.

3. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014/06/02. 2014;384(9945):766–81.

4. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. *Int J Obes*. 2011;35(7):891–8.

5. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3):e92846. DOI: 10.1371/journal.pone.0092846.

6. Gebremedhin S. Prevalence and differentials of overweight and obesity in preschool children in Sub-Saharan Africa. *BMJ Open*. 2015/12/25. 2015;5(12):e009005. DOI: 10.1136/bmjopen-2015-009005.

7. Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF Macro. 2009. Ghana Demographic and Health Survey 2008. Accra, Ghana: GSS, GHS, and ICF Macro.

8. Mohammed H, Vuvor F. Prevalence of childhood overweight/obesity in basic school in Accra. *Ghana Med J*. 2013/05/11. 2012;46(3):124–7.

9. Amidu N, Owiredu WKBA, Saaka M, Quaye L, Wanwan M, Kumibea PD, et al. Determinants of childhood obesity among basic school children aged 6 – 12 years in Tamale Metropolis. *J Med Biomed Sci*. 2013;2(3):26–34.

10. Mogre V, Gaa PK, Nagumsi R, Abukari S. Overweight, Obesity and Thinness and

Associated Factors Among School- Aged Children (5-14 Years) in Tamale. *Eur Sci J*. 2013;9(20):160–75.

11. Agbozo F, Atito P, Abubakari A. Malnutrition and associated factors in children: a comparative study between public and private schools in Hohoe Municipality, Ghana. *BMC Nutr*. 2016;2(1):32. DOI:10.1186/s40795-016-0073-7

12. Peltzer K, Pengpid S. Overweight and obesity and associated factors among school-aged adolescents in Ghana and Uganda. *Int J Env Res Public Heal*. 2011/11/11. 2011;8(10):3859–70.

13. Singh AS, Mulder C, Twisk JWR, Van Mechelen W, Chinapaw MJM. Tracking of childhood overweight into adulthood: A systematic review of the literature. *Obes Rev*. 2008;9(5):474–88.

14. Mirza NM, Palmer MG, Sinclair KB, Mccarter R, He J, Ebbeling CB, et al. Effects of a low glycemic load or a low-fat dietary intervention on body weight in obese Hispanic American children and adolescents: a randomized controlled trial. *Am J Clin Nutr*. 2013;97(4):276–85.

15. Reilly JJ. Health consequences of obesity. *Arch Dis Child*. 2003;88(9):748–52.

16. Kelly AS, Barlow SE, Rao G, Inge TH, Hayman LL, Steinberger J, et al. Severe obesity in children and adolescents: Identification, associated health risks, and treatment approaches: A scientific statement from the American Heart Association. *Circulation*. 2013;128(15):1689–712.

17. Ghana Statistical Service (GSS), Ghana Living Standard Survey Round 6 (GLSS 6). Main Report. 2014;223 p.

18. Ecker O, Fang P. Economic development and nutrition transition in Ghana: Taking stock of food consumption patterns and trends. International Food Policy Research Institute (IFPRI). 2016:28-50.

19. Ghana Statistical Service (GSS). Urbanisation in Ghana. 2014. 2010 Population and housing census.

20. Wang Y, Liang H, Tussing L, Braunschweig C, Caballero B, Flay B. Obesity and related

risk factors among low socio-economic status minority students in Chicago. *Public Heal Nutr*. 2007/03/27. 2007;10(9):927–38.

21. Newby PK. Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence. *J Law Med Ethics*. 2007;35(1):35–60.

22. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocr Rev*. 2012;33(1):48–70.

23. Hills AP, Andersen LB, Byrne NM. Physical activity and obesity in children. *Br J Sport Med*. 2011;45:866–70.

24. Ocansey R, Aryeetey R, Sofo S, Nazzar A, Delali M, Pambo P, et al. Results From Ghana's 2016 Report Card on Physical Activity for Children and Youth. *J Phys Act Health*. 2016;13(11 Suppl 2):S165-S168.

25. Ghana School Survey. Nutrition and obesity report of the Ghana school survey results dissemination workshop. Accra. Department of Nutrition and Food Science, University of Ghana and School of Human Nutrition and Dietetics, McGill University, Montreal; 2012.

26. Steiner-Asiedu M, Addo P, Bediako-Amoa B, Fiadjoe FYM, Anderson AK. Lifestyle and Nutrition Profile of Overweight and Obese School Children in the Ga-East District of Ghana. *Asian J Med Sci*. 2012;4(3):99–104.

27. Muthuri SK, Wachira LJ, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. *BMC Public Health*. 2014/06/03. 2014;14(9):436. http://www.biomedcentral.com/1471-2458/14/436.

28. Meng T, Florkowski WJ, Sarpong DB, Chinnan MS, Resurreccion AVA. Consumer's food shopping choice in Ghana: Supermarket or traditional outlets? *Int Food Agribus Manag Rev*. 2014;17(Special IssueA):107–29.

29. Aryeetey R, Lartey A, Marquis GS, Nti H, Colecraft E, Brown P. Prevalence and predictors of overweight and obesity among school-aged children in urban Ghana. *BMC Obes*. 2017;4(1):38. DOI:10.1186/s40608-017-0174-0.

30. Doku D, Koivusilta L, Raisamo S, Rimpela A. Socio-economic differences in adolescents' breakfast eating, fruit and vegetable consumption and physical activity in Ghana. *Public Health Nutr*. 2011;16(5):864–72.

31. CSDH. Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission on Social Determinants of Health. Geneva, World Health Organization. 2008

32. Friel S, Chopra M, Satcher D. Unequal weight: equity oriented policy responses to the global obesity epidemic. *BMJ*. 2007;335(7632):1241–3.

33. Vargas CM, Stines EM, Granado HS. Health-equity issues related to childhood obesity: a scoping review. *J Public Health Dent*. 2017;77(5):S32–42.

34. Friel S, Hattersley L, Snowdon W, Thow AM, Lobstein T, Sanders D, et al. Monitoring the impacts of trade agreements on food environments. *Obes Rev*. 2013;14(S1):120–34.

35. Ravuvu A, Friel S, Thow A, Snowdon W, Wate J. Monitoring the impact of trade agreements on national food environments: trade imports and population nutrition risks in Fiji. *Global Health*. 2017;13:33. DOI: 10.1186/s12992-017-0257-1.

36. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: Part of a bigger picture. *Lancet*. 2015;385(9986):2510–20.

37. WHO. Report of the Commission on Ending Childhood Obesity. World Health Organization. 2016. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

38. Thow AM, Downs S, Jan S. A systematic review of the effectiveness of food taxes and subsidies to improve diets: Understanding the recent evidence. *Nutr Rev*. 2014;72(9):551–65.

39. Ghana. Strategy for the Management, Prevention and Control of Chronic Non-Communicable Diseases in Ghana. Ministry of Health; 2016.

40. Cabrera Escobar MA, Veerman JL, Tollman SM, Bertram MY, Hofman KJ. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. *BMC*

Public Health. 2013;13(1072). DOI: 10.1186/1471-2458-13-1072

41. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC. The built environment and obesity. *Epidemiol Rev*. 2007;29(1):129–43.

42. Cummins S, Macintyre S. Food environments and obesity - Neighbourhood or nation? *Int J Epidemiol*. 2006;35(1):100–4.

43. Mayne SL, Auchincloss AH, Michael YL. Impact of policy and built environment changes on obesity-related outcomes: A systematic review of naturally occurring experiments. *Obes Rev*. 2015;16(5):362–75.

44. Neumann CG, Harrison GG. Onset and evolution of stunting in infants and children. Examples from the Human Nutrition Collaborative Research Support Program. Kenya and Egypt studies. *Eur J Clin Nutr*. 1994/02/01. 1994;48 Suppl 1:S90-102.

45. Potwarka LR, Kaczynski AT, Flack AL. Places to play: Association of park space and facilities with healthy weight status among children. *J Community Health*. 2008;33(5):344–50.

46. Williams A, Henley WE, Williams C, Hurst A, Logan S, Wyatt K. Systematic review and meta-analysis of the association between childhood overweight and obesity and primary school diet and physical activity policies. *Int J Behav Nutr Phys Act*. 2013;10(1):101. DOI:10.1186/1479-5868-10-101.

47. Sallis JF, Floyd MF, Rodríguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. 2012;125(5):729–37.

48. Galvez MP, Pearl M, Yen IH. Childhood Obesity and the Built Environment: A review of the Literature from 2008-2009. *Curr Opin Pediatr*. 2010;22(2):202–7.

49. Edwards N, Hooper P, Knuiman M, Foster S, Giles-Corti B. Associations between park features and adolescent park use for physical activity. *Int J Behav Nutr Phys Act*. 2015;12(1):1–10.

50. Story M, Kaphingst KM, Brien RR, Glanz K. Creating Healthy Food and Eating Environments: Policy and Environmental Approaches. *Annu Rev Public Heal* 2008. 2008;29:253–72.

51. Welker E, Lott M, Story M. The School Food Environment and Obesity Prevention: Progress Over the Last Decade. *Curr Obes Rep*. 2016;5(2):145–55. doi.org/10.1007/s13679-016-0204-0.

52. Terry-McElrath YM, O'Malley PM, Johnston LD. Potential Impact of National School Nutritional Environment Policies. *JAMA Pediatr*. 2014;169(1):78.

53. Mâsse LC, de Niet-Fitzgerald J, Watts AW, Naylor P-J, Saewyc EM. Associations between the school food environment, student consumption and body mass index of Canadian adolescents. *Int J Behav Nutr Phys Act*. 2014;11(1):29. DOI:10.1186/1479-5868-11-29.

54. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EMF. The school environment and adolescent physical activity and sedentary behaviour: A mixed-studies systematic review. *Obes Rev*. 2016;17(2):142–58.

55. Puoane T, Tsolekile L, Steyn N. Perceptions about body image and sizes among Black African girls living in Cape Town. *Ethn Dis*. 2010/02/25. 2010;20(1):29–34.

56. Ogden CL, Fryar CD, Hales CM, Carroll MD, Aoki Y, Freedman DS. Differences in Obesity Prevalence by Demographics and Urbanization in US Children and Adolescents, 2013-2016. JAMA. 2018;20782(23):2410–8.

57. O'Dea JA. Gender, ethnicity, culture and social class influences on childhood obesity among Australian schoolchildren: Implications for treatment, prevention and community education. *Heal Soc Care Community*. 2008;16(3):282–90.

58. de-Graft Aikins A. Ghana's neglected chronic disease epidemic: a developmental challenge. *Ghana Med J*. 2007;41(4):154–9.

59. Bosu WK. A comprehensive review of the policy and programmatic response to chronic non-communicable disease in Ghana. *Ghana Med J*. 2012;46(2 Suppl):69–78.

60. Bosu WK. Epidemic of hypertension in Ghana: a systematic review. *BMC Public Health*. 2010;10(1):418. DOI:10.1186/1471-2458-10-418

61. Ministry of Health. National Policy for the Prevention and Control of Chronic Non-Communicable Diseases in Ghana. 2011;(October):1-23.

62. WHO Non-communicable Diseases Country Profiles. 2014; World Health Organization. 20 Avenue Appia, 1211 Geneva 27, Switzerland. 207 p

63. Bosu W. Accelerating the control and prevention of non-communicable diseases in Ghana: the key issues. *Postgrad Med J*. 2013;2(1):32–40.

64. Agyei-Mensah S, De-Graft Aikins A. Epidemiological transition and the double burden of disease in Accra, Ghana. *J Urban Heal*. 2010;87(5):879–97.

65. WHO. Global Strategy on Diet, Physical Activity and Health. Vol. 8. 2004. p. 1–21.

66. Ghana Statistical Service. Adentan Municipality: Population and housing census. Vol. 2, District Analytical Report. 2014.

67. Biritwum RB, Gyapong J, Mensah G. The epidemiology of obesity in Ghana. *Ghana Med J*. 2005;39(3):82–85.

68. McLeroy K, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Heal Educ Q*. 1988;15(4):351–77.

69. Townsend N, Foster C. Developing and applying a socio-ecological model to the promotion of healthy eating in the school. *Public Health Nutr*. 2013;16(6):1101–8.

70. Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ, Public Health Approaches to the Prevention of Obesity (PHAPO) Working Group of the International Obesity Task Force (IOTF). Obesity prevention: the case for action. *Int J Obes*. 2002;26(3):425–36.

71. Larson N, Ward DS, Neelon SB, Story M. What Role Can Child-Care Settings Play in Obesity Prevention? A Review of the Evidence and Call for Research Efforts. *J Am Diet Assoc*. 2011;111(9):1343–62.

72. WHO Multicentre Reference Group. Reliability of anthropometric measurements in the WHO Multicentre Growth Reference Study. *Acta Paediatrica.* 2006;450(Suppl):38–46.

73. Wilson AM, Magarey AM, Mastersson N. Reliability and relative validity of a child nutrition questionnaire to simultaneously assess dietary patterns associated with positive energy balance and food behaviours, attitudes, knowledge and environments associated

with healthy eating. *Int J Behav Nutr Phys Act*. 2008;5(5). DOI: 10.1186/1479-5868-5-5.

74. Kowalski KC, Crocker PRE, Donen RM. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. Coll Kinesiol Univ Saskatchewan. 2004;(August):1–37.

75. Katzmarzyk PT, Barreira T V, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE): design and methods. *BMC Public Health*. 2013/10/02. 2013;13:900. https://doi.org/10.1186/1471-2458-13-900.

CHAPTER 2

Prevalence of overweight and obesity among African primary school learners: a systematic review and meta-analysis

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Abstract

Introduction: The increasing trend in the global prevalence of childhood overweight and obesity presents a major public health challenge. This study reports the results of a systematic review and meta-analysis to estimate the prevalence of overweight and obesity among primary school learners residing in Africa according to the different body mass index (BMI) criteria and population level characteristics.

Methods: A search of multiple databases was conducted to identify relevant research articles published between January 1980 and Feb 2017. Random effects models were used to pool prevalence data within and across population level characteristics after variance stabilisation through arcsine transformation. PROSPERO registration number CRD42016035248.

Results: Data from 45 studies across 15 African countries, and comprising 92,379 and 89,468 participants for overweight and obesity estimates were included. Estimated overweight and obesity prevalence differed significantly across criteria: 10.5% (95% CI: 7.1-14.3) and 6.1% (3.4-9.7) by WHO; 9.5% (6.5-13.0) and 4.0% (2.5-5.9) by IOTF; and 11.5% (9.6-13.4) and 6.9% (5.0-9.0) by CDC, respectively ($p=0.0027$ for overweight; $p<0.0001$ for obesity). Estimates were mostly higher in urban, and private schools, but generally similar by gender, major geographic regions, publication year, and sample size. Substantial heterogeneity in the estimates across and within criteria were not always explained by major study characteristics.

Conclusion: Overweight and obesity are prevalent among African primary school learners, particularly those attending urban, and private schools. The results from this meta-analysis could be helpful in making informed decisions on childhood obesity prevention efforts in African countries.

2.1 Introduction

Globally, the prevalence of childhood overweight/obesity is increasing [1–3], with public health implications in both developed and developing countries. Energy imbalance resulting from increased caloric intake and physical inactivity are the main drivers of obesity; however, biological, genetics, social and environmental factors also play crucial roles [4]. Some documented risk factors for childhood obesity include: family socioeconomic status [5,6], maternal employment [7], parental obesity [8], school food and PA environments [9,10], and community and neighbouring factors such as density of fast food restaurants, and living in close proximity to parks and playgrounds [11,12].

There is a growing interest in the epidemic of obesity across Africa, resulting in several in-country studies to determine the prevalence [13]. In a systematic review to investigate the trends of overweight and obesity among school-aged children and youth in sub-Saharan Africa, the body mass index (BMI) cut-off points used in each study were not taken into consideration in estimating the prevalence rates [13]. Using different BMI cut-off references to estimate overweight and obesity prevalence in children poses a challenge in defining the extent of the problem at the population level. Although substantial heterogeneity was observed in the study methodology, this was not accounted for in the estimates.

To date no comprehensive study has been conducted to examine the extent of the overweight and obesity problem among primary school learners overall and by region across Africa. It is important to assess and monitor the prevalence from a young age to provide relevant data that could inform decisions on appropriate interventions. Therefore the objective of this meta-analysis was to estimate the prevalence of overweight and obesity among primary school learners residing in Africa according to different diagnostic criteria, the WHO [14], the CDC [15], and the IOTF [16] criteria; and population level characteristics.

2.2 Methods

The methods for this systematic review and meta-analysis have been previously described [17], Appendix X, and registered with PROSPERO, number CRD42016035248. Included studies had to be school-based surveys involving children aged between 6 and 12 years. Where the age covers a wider range but prevalence was reported by age categories to include the specified age range, the studies were retained. Studies had to be cross-sectional or cross-sectional evaluations in longitudinal surveys. Studies that used objective measures of body weight and height and were published between 1 January 1980 and February 2017 were included. No language restrictions were applied, however included studies were published in either English or French. For articles reporting more than one study or defining overweight and obesity using different BMI criteria, each was considered as a separate study. Studies were excluded if they were conducted on school learners suffering from critical illness or known chronic health conditions such as diabetes; were conducted in African populations residing outside the continent; and were not school-based.

Identification and selection of relevant studies

A comprehensive search of the following electronic databases was conducted to identify eligible studies: MEDLINE (PubMed), MEDLINE (EBSCOHost), CINAHL (EBSCOHost), Academic Search Complete (EBSCOHost) and African Journal Online (AJOL). The complete search strategy comprised combinations of relevant Medical Subject Headings (MeSH) and keywords relating to obesity, overweight, body mass index, school children, learners, the names of the 54 African countries, and the five African sub-regions (Appendix I, Table S1). The searches were independently conducted by one reviewer and a research assistant. References were exported, duplicates removed and reviewed using Endnote software. The titles, abstracts and full text copies of potentially relevant articles were independently screened by the same reviewer and research assistant for eligibility. Any disagreement about the eligibility was resolved through a consensus and discussion with a third reviewer. The last search date was 20 February 2017. This review is reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (checklist available in Appendix I, Table S2).

Data extraction and quality assessment of included studies

The methodological quality of included studies was assessed using a modified version of Downs and Black checklist [18]. Ten questions from the checklist were used to provide scores for the quality of reporting, internal validity (bias) and external validity. The following data were extracted: study details (author, year of publication, year of beginning of study, country of study), study characteristics (study design, mean/median age and range, sample size, diagnostic criteria), study setting/location (urban and rural, private and public school), type of sample (national and subnational), gender distribution, African region where the study country was located, and prevalence of overweight and obesity (overall and by subgroups).

Data synthesis and analysis

Data analyses used the *'meta'* package of the statistical software R (version 3.3.3 (2017-03-06), the R Foundation for statistical computing, Vienna, Austria). To minimise the influence from studies with extremely small or extremely large prevalence estimates on the overall estimate, the variance of the study-specific prevalence was first stabilized using the Freeman-Tukey double arcsine transformation [19] before pooling using the random-effects meta-analysis model [20]. Heterogeneity between studies was assessed using the Cochran's Q and I^2 statistics [27]. The I^2 statistic estimates the percentage of total variation across studies due to true between-study differences rather than chance. In general, I^2 values greater than 60-70% indicate the presence of substantial heterogeneity. The sources of heterogeneity were explored by comparing overweight/obesity prevalence between subgroups defined by several pre-specified study-level characteristics like gender for naturally occurring categories and median values across studies for publication year and sample size. Subgroups comparisons were done using the Q-test based on ANOVA. The presence of publication bias was assessed using funnel plots and the Egger test of bias [22]. Potential outliers were investigated in sensitivity analyses by dropping one study at a time. The Duval and Tweedie trim-and-fill method was used to adjust estimates for the effects of publication bias.

2.3 Results

Figure 2.1 shows the PRISMA flow chart of the study selection process. A total of 1518 records were identified from the searches. After removing duplicates, the titles and abstracts of 729 articles were screened for eligibility out of which 65 full text articles were accessed. A total of 40 articles comprising 45 studies met the inclusion criteria and were retained in the meta-analysis.

Characteristics of included studies

Table 2.1 summarises the characteristics of studies included in the meta-analysis. The forty-five included studies originated from fifteen countries. With regard to regional representation, twenty-two studies were conducted in Southern Africa, six in Western, eight in Eastern, nine in Northern, and one in Central Africa. Thirty-seven studies presented data on both boys and girls, three and five exclusively reported on boys and girls respectively. Of the studies that reported study settings, eighteen were conducted exclusively in urban areas, six in rural areas and eleven in urban/rural areas. Out of the twenty-six studies that reported on school type, sixteen were conducted in private/public schools, nine in public schools and one in exclusively private school. Year of beginning of study, reported in twenty-six studies ranged from 1994 to

2013. Majority of the included studies were conducted at the sub-national level while only two were national in coverage. The mean/median age was 10.1 years, reported in 25 studies. All of the studies except two used the international BMI criteria to define overweight/obesity: WHO (22 studies, n=36981), IOTF (18 studies, n=51604) and the CDC (4 studies, n=2433). The publication years varied from 2003 to 2016; twenty-six studies were published after year 2012.

Quality scores of included studies

Majority of the included studies scored seven or higher with a median of 7.4 (**Table 2.1**). Scores for reporting were moderate to adequate, and these ranged from 51.2% to 97.6%. However, the scores for external validity were low. Less than half of the studies (46.3%) reported that participants were representatives of the population from which they were recruited, and even fewer (14.6%) reported their recruited samples were representative of the population (Appendix I, Table S3).

Overall prevalence of overweight and obesity

The overall prevalence estimates were 9.4% (95% confidence interval (CI): 7.5-11.4)) and 5.0% (3.7-6.4) for overweight and obesity. Overweight prevalence estimates for WHO (21 studies, n = 36981), IOTF (18 studies, n = 51604), CDC (4 studies, n = 2433), and unspecified criteria were: 10.5% (7.1-14.3), 9.5% (6.5-13.0), 11.5% (9.6-13.4), and 0.5% (0.0-4.5) respectively and these differed significantly across the various criteria a ($p = 0.0027$); **Figure 2.2**. Similarly, obesity prevalence for WHO (18 studies, n = 34895), IOTF (16 studies, n = 50779) CDC (4 studies, n = 2433) and unspecified criteria were 6.1% (3.4-9.7), 4.0% (2.5-5.9), 6.9% (5.0-9.0) and 0.5% (0.0-1.7) with significance difference among the criteria ($p < 0.0001$); **Figure 2.3**, Appendix I, Table S4 & Table S5.

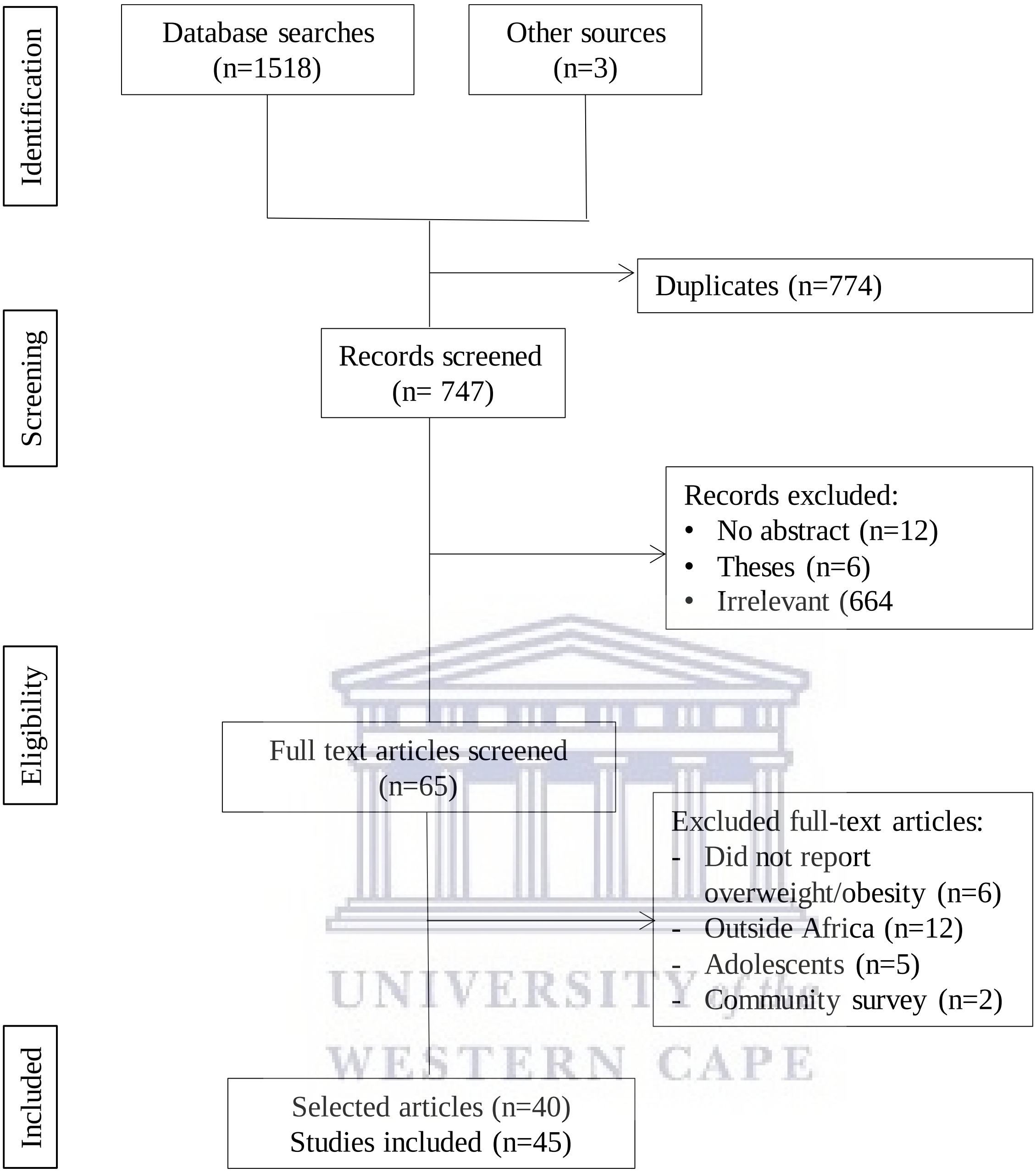

Figure 2.1: PRISMA flowchart for the study selection process

Table 2.1: Summary characteristics of included studies on overweight/obesity prevalence

Reference	Publication year	Start Year	Country	Region location	Data type	Study Site	School type	Study design	Diagnostic criteria	Sample size				Quality score
										Overall	Boys/ Girls	Urban/ Rural	Private/ public	
Abrahams et al. [23]	2011		South Africa	Southern	Sub-national	Urban-Rural			WHO	643	NS	-	NS	7
Amidu et al. [24]	2013	2012	Ghana	Western	Sub-national	Urban	Private-Public	Cross-sectional	CDC	400	200 B 200 G	400 U	200 PR 200 PU	8
Armstrong et al. [25]	2006	2001	South Africa	Southern	National	Urban-Rural	Private-Public	Cross-sectional	IOTF	10195	5611 B 4584 G	-	NS	10
Boukthir et al. [26]	2011	2007	Tunisia	Northern	sub-National	Urban	Public	Cross-sectional	IOTF	1335	637 B 698 G	1335 U	1335 PU	8
Caleyachetty et al. [27]	2012	2006	Mauritius	Southern	Sub-national	Urban-Rural		Cross-sectional	IOTF	841	412 B 429 G	298 U 543 R	NS	9
Chebet et al. [28]	2014		Uganda	Eastern	Sub-national		Private-Public	Cross-sectional	WHO	958	435 B 523 G	NS	456 PR 502 PU	5
Daboné et al. [29]	2011	2008	Burkina Faso	Western	Sub-national	Urban-Rural	Private-Public	Cross-sectional	WHO	649	309 B 340 G	543 U 106 R	192 PR 457 PU	8
Dekkaki et al. [30]	2011	2010	Morocco	Northern	Sub-national	Urban	public	Cross-sectional	WHO	1570	768 B 802 G	1570 U	1570 PU	8
El-Sabely et al, [31]	2013		Egypt	Northern	Sub-national		Private-Public	Cross-sectional	WHO	288	288 G	-	182 PR 106 PU	7
Fetuga et al. [32]	2011		Nigeria	Western	Sub-national	Urban	Public	Cross-sectional	WHO	1016	479 B 537 G	1016 U	574 PU	8
Hassan et al. [33]	2008	2002	Egypt	Northern	Sub-national	NS	Public	Cross-sectional	CDC	1283	681 B 602 G	-	1283 PU	6
Jinabhai et al. [34]	2005	1995	South Africa	Southern	Sub-national	Rural	NS	Cross-sectional	IOTF	643	292 B 351 G	643 R	-	9
Jinabhai et al. [35]	2003	1994	South Africa	Southern	National	Urban-Rural		Secondary analysis	IOTF/ WHO	24391	14503 B 9888 G	-	-	9
Kirsten et al. [36]	2013		South Africa	Southern	Sub-national	Urban		Cross-sectional	IOTF	638	NS	638 U	NS	8
Kyallo et al. [37]	2013	2008	Kenya	Eastern	Sub-national	Urban	Private-Public	Cross-sectional	WHO	321	153 B 168 G	321 U	138 PR 183 PU	7
Maruf et al.[38]	2013	2009	Nigeria	Western			Private-Public		IOTF	1775	873 B 902 G	NS	NS	9
McKersie et al. [39]	2014		South Africa	Southern	Sub-national	Urban		Cross-sectional	IOTF	713	372 B 341 G	713 U	NS	7
Mogre et al. [40]	2013	2010	Ghana	Western	Sub-national	Urban		Cross-sectional	WHO	218	91 B 127 G	218 U	NS	7
Mohammed et al. [41]	2012		Ghana	Western	Sub-National	Urban	Private	Cross-sectional	WHO	270	141 B 129 G	270 U	270 PR	6
Moselakgomo et al. [42]	2015		South Africa	Southern	Sub-national			Cross-sectional	NS	1361	678 B 683 G	NS	NS	8

Mosha et al. [43]	2010	2008	Tanzania	Eastern	Sub-national		Private-Public	Cross-sectional	WHO	428	150 B 278 G	NS	NS	6
Mpembeni et al. [44]	2014		Tanzania	Eastern	Sub-national	Urban-Rural	Private-Public	Cross-sectional	CDC	446	209 B 237 G	NS	NS	9
Muhihi et al. [45]	2013	2011	Tanzania	Eastern	Sub-national	Urban-Rural	Private-Public	Cross-sectional	IOTF	446	209 B 237 G	249 U 197 R	NS	9
Muthuri et al. [46]	2014		Kenya	Eastern	Sub-national	Urban	Private-Public		WHO	563	262 B 301 G	563 U	268 PR 295 PU	9
Mwaikambo et al. [47]	2015		Tanzania	Eastern	Sub-national		Private-Public	Cross-sectional	IOTF	1722	779 B 943 G	NS	692 PR 1030 PU	7
Navti et al. [48]	2014		Cameroon	Central	Sub-national	Urban-Rural	Private-Public	Cross-sectional	WHO	557	287 B 270 G	384 U 173 R	NS	7
Oldewage-Theron et al. [49]	2010		South Africa	Southern	Sub-national	Rural	public		WHO	142	72 B 70 G	142 R	NS	6
Pangani et al. [50]	2016		Tanzania	Eastern	Sub-national	Urban	Private-Public	Cross-sectional	WHO	1781	753 B 1028 G	1781 U	678 PR 1103 PU	8
Pedro et al. [51]	2014	2009	South Africa	Southern	Sub-national	Rural		Cross-sectional	WHO	588	292 B 296 F	588 R	NS	8
Pienaar 2015 [52]	2015	2013	South Africa	Southern	Sub-national			Longitudinal	IOTF	574	282 B 292 G	NS	NS	7
Prista et al. [53]	2003	1999	Mozambique	Southern	Sub-national	Urban-Rural	Private-Public		WHO	1070	475 B 595 G	NS	-	7
Puckree et al. [54]	2011	2006	South Africa	Southern	Sub-national	Urban	Public	Cross-sectional	WHO	120	48 B 72 G	120 U	120 PU	7
Regaieg et al. [55]	2014	2010	Tunisia	Northern	Sub-national	Urban	Public	Cross-sectional	IOTF	1529	782 B 747 G	1529 U	1529 PU	7
Salman et al. [56]	2010		Sudan	Northern	Sub-national	Urban		Cross-sectional	CDC	304	68 B 236 G	304 U	NS	6
Sebbani et al. [57]	2013	2011	Morocco	Northern	National	Urban	Public	Cross-sectional	IOTF/ WHO	1418	709 B 709 G	1418 U	1418 PU	6
Taleb et al. [58]	2010	1998	Algeria	Northern	Sub-national	Urban		NS	IOTF	3396	1819 B 1577 G	3396 U		6
Tathiah et al. [59]	2013	2011	South Africa	Southern	Sub-national	Rural		Secondary analysis	IOTF	952	952 G	952 R	NS	7
Truter et al. [60]	2010		South Africa	Southern	Sub-National			One-way	IOTF	280	128 B 152 G	NS	NS	7
Van Den Ende et al. [61]	2014	1999	South Africa	Southern	Sub-national	Rural		Cross-sectional	IOTF	825	421 B 404 G	825 R	NS	7
Wiles et al [62]	2013		South Africa	Southern	Sub-national	Urban		Cross-sectional	WHO	311	138 B 173 G	311 U	311 PU	6

NS: not specified; B: boys; G: girls; U: urban; R: rural; PU: public; PR: private; CDC: Centers for Disease Control and Prevention; IOTF: International Obesity Task Force; WHO: World Health Organization

Heterogeneity

There was substantial heterogeneity in estimates across included studies by diagnostic criteria for obesity prevalence (all heterogeneity $p \leq 0.019$), and for overweight prevalence (all $p<0.0001$) except across studies that used the CDC criteria to diagnose overweight (heterogeneity $p=0.124$); see Appendix I, Table S4 & Table S5 for more heterogeneity statistics. In sensitivity analyses using the leave-one-out approach, none of the studies had significant impact on the pooled estimates and measures of heterogeneity within diagnostic criteria; Appendix I, Figure S1 & Figure S2.

Publication bias

Figure 2.4 shows the funnel plots for publication bias across the different criteria. These plots were asymmetric for WHO (Egger test $p=0.0029$ for overweight; $p=0.0019$ for obesity) and IOTF ($p=0.020$ for overweight; $p=0.003$ for obesity), but not for CDC (both $p \geq 0.320$); Appendix I, Table S4 & Table S5. The small number of studies available precluded similar analyses across studies that applied unspecified criteria to diagnose overweight or obesity.

For the CDC as expected, no study was imputed through the trim-and-fill approach and pooled estimates remained unchanged for overweight and obesity. For the WHO, nine studies were imputed for obesity and ten for overweight while equivalents for IOTF were eight and nine studies. Funnel plots became symmetrical and Egger test non-significant when imputed studies were accounted for (Appendix I, Figure S3). However, for both criteria and outcomes, imputed studies had to be of large sample size, with a null prevalence of overweight or obesity (Appendix I, Figure S4 & Figure S5). This is unrealistic in the context of the current epidemiology of overweight and obesity in children and adolescents. Therefore, the publication bias found in the main analysis was likely artefactual.

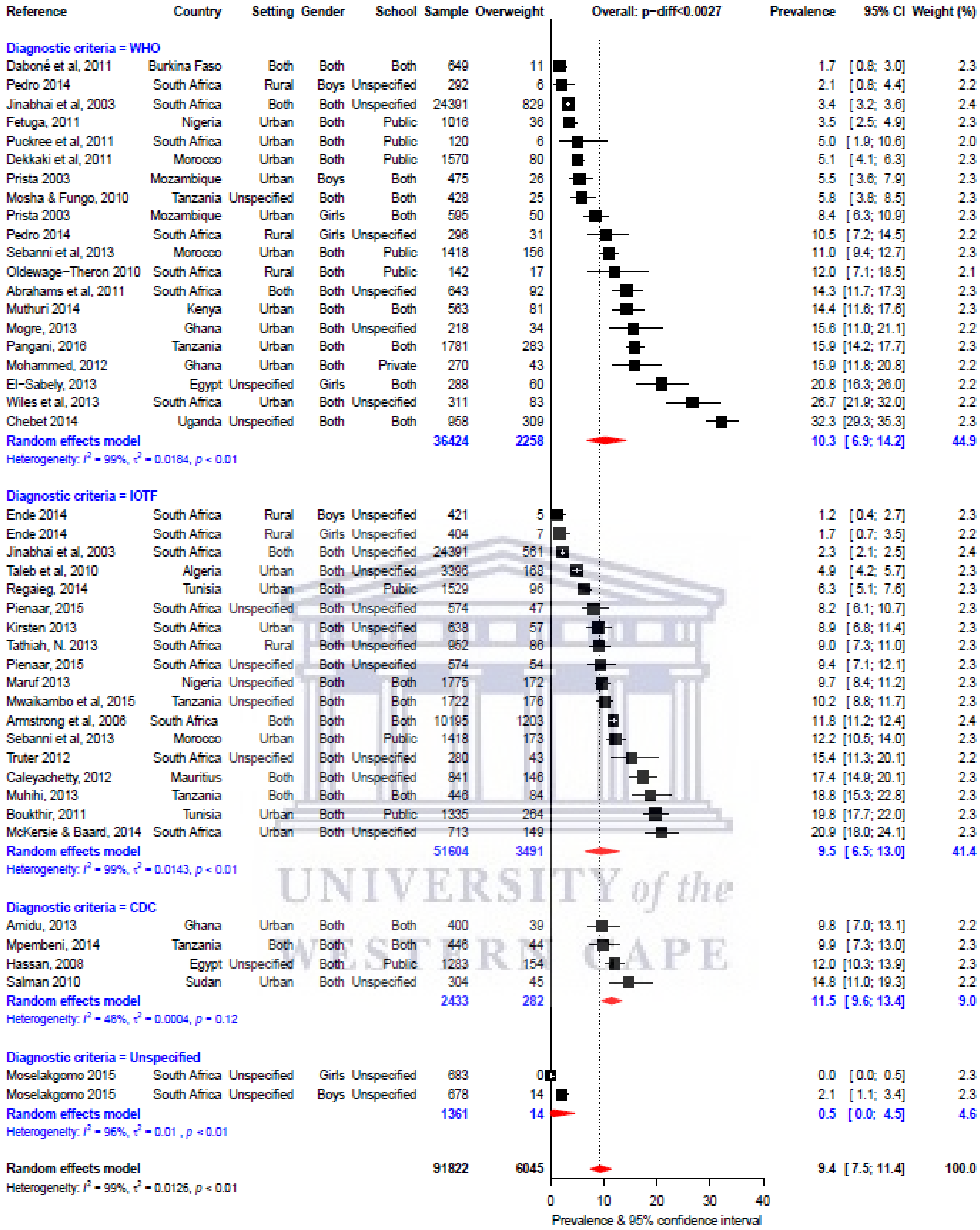

Figure 2.2: Forest plot of the prevalence of overweight by major diagnostic criteria

Legend: Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the *pooled* effect estimate and 95% CI.

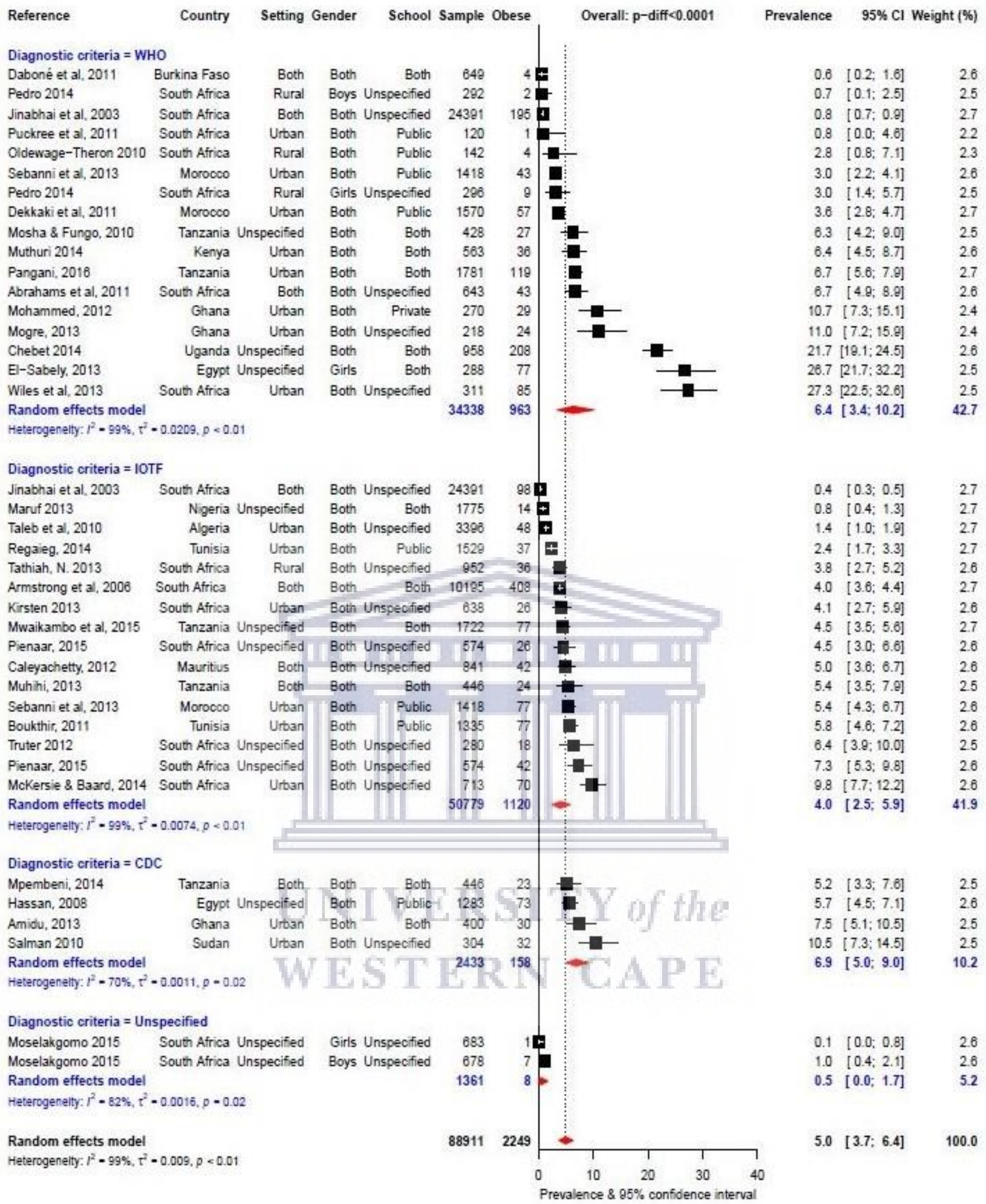

Figure 2.3: Forest plot of the prevalence of obesity by major diagnostic criteria

Legend: Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI

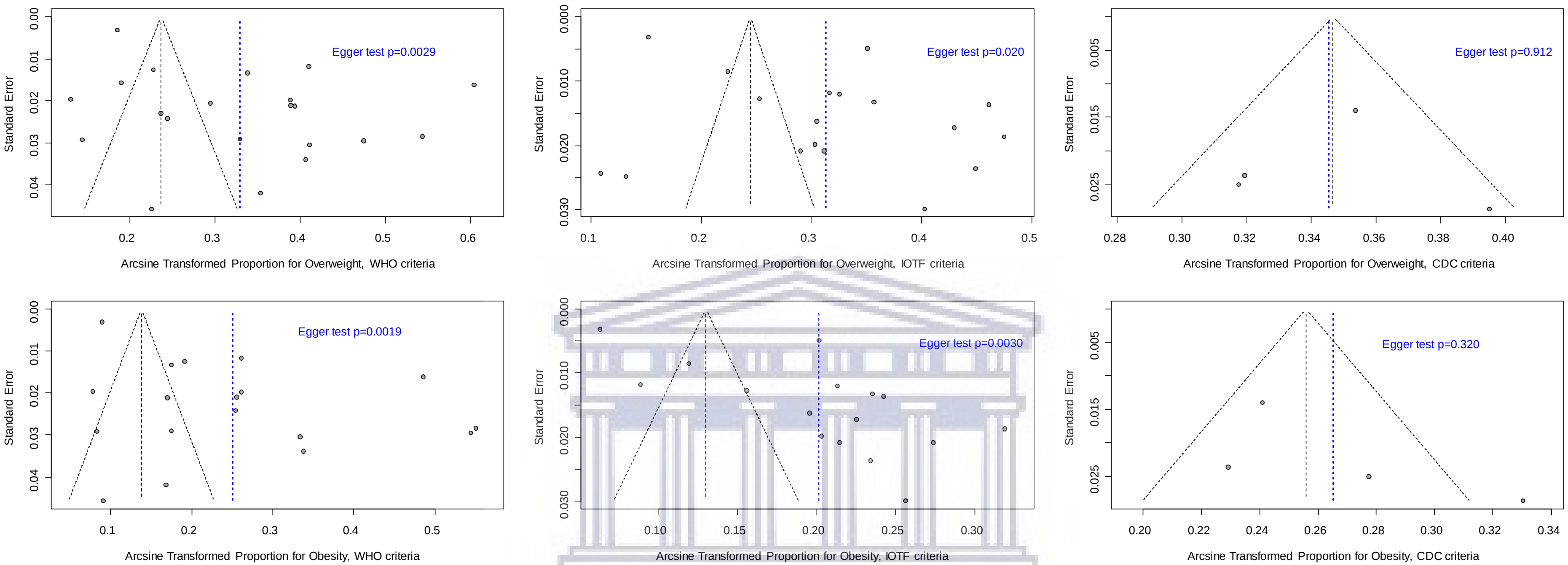

Figure 2.4: Funnel plots for the assessment of publication bias: overweight (upper panels) and obesity (lower panels) by the WHO (left column), IOTF (middle column) and CDC (right column) criteria, in African learners

Legend: For each figure panel, the dots are the arcsine transformed prevalence estimates of individual studies (horizontal axis) plotted against their standard error (vertical exist). The dotted vertical blue line is for the observed pooled prevalence estimates, while the dotted vertical black line bisector of the angle formed by the two upward converging lines, indicated where the pooled estimates should have been in the absence of publication bias. The p-value from the egger test of bias is also shown.

Prevalence of overweight and obesity within and across subgroups

Gender

In all, 29 studies (WHO), 28 studies (IOTF), 6 studies (CDC), 2 studies (unspecified criteria); and 18 studies (WHO), 16 studies (IOTF), 4 studies (CDC) and 2 studies (unspecified criteria) respectively provided overweight and obesity prevalence data by gender. The overall prevalence of overweight and obesity across these studies were 11.4% (8.4-14.9) and 7.0% (4.5-10.1) respectively based on WHO criteria; 10.3% (8.4-12.3) and 4.3% (3.4-5.3) based on IOTF criteria and, 11.5% (9.5-13.7) and 6.2% (4.7-8.0) based on CDC criteria, with always significant differences across criteria (overweight $p \leq 0.0028$; obesity $p < 0.0001$); Appendix I, Table S4 & Table S5.

By gender, point estimates of the pooled prevalence of overweight and obesity were always higher in girls compared to boys, but these did not result in significant gender differences within the major diagnostic criteria (all $p \geq 0.128$ for gender comparisons). Within genders, pooled prevalence estimates always significantly differed across diagnostic criteria (all $p < 0.0001$); Figures S6 – S9. There was substantial heterogeneity for WHO- and IOTF- based studies (all p-heterogeneity $p < 0.0001$) and for CDC-based overweight prevalence in boys only ($p = 0.029$). Publication bias was apparent only for IOTF-based obesity prevalence in boys (Egger $p=0.034$); (Appendix I, Table S4 & Table S5).

Urban-rural settings

The estimates for overweight and obesity were 12.8% (8.7-17.5) and 9.8% (6.0-14.6) among children in urban compared to 6.9% (3.3-11.6) and 1.5% (0.6-2.9) in children in rural settings by WHO criterion. The respective estimates by the IOTF criteria were 9.4% (5.2-14.7) and 4.9% (3.0-7.2)] among urban areas compared to 4.0% (1.3-8.2) and 1.8% (0.6-7.2) in rural areas. By CDC criterion, the prevalence were 12.0% (9.8-14.4) and 7.5% (5.1-10.5) overweight and obesity in only urban school children. The point estimates were consistently higher in children in urban, compared to those in rural schools, and significant with obesity estimates only within the major criteria (all $p<0.0001$ for urban-rural comparison; Appendix I, Table S4 & Table S5). Within urban-rural settings, the pooled estimates did not differ across diagnostic criteria ($p \geq 0.076$); Appendix I, Figures S10 – S14. There was substantial heterogeneity for WHO- and IOTF- based prevalence (all p-heterogeneity ≤ 0.035) and for CDC-based obesity prevalence estimate in urban areas ($p=0.015$). Further, there was publication bias in IOTF-based obesity prevalence in urban areas only (Egger $p<0.035$); Appendix I, Table S4 & Table S5.

Private-public schools

Across all criteria, the pooled overweight and obesity estimates were higher in private, compared to public schools. Overweight prevalence were 22.6% (16.0-30.0) and 11.2% (7.4-15.7) by WHO, 18.2% (15.4-21.2) and 7.6% (3.7-12.9) by IOTF, and 15.0% (10.4-20.3) and 8.0% (2.2-17.0) by CDC in private and public schools respectively. The corresponding estimates for obesity in private and public schools were 16.6% (10.4-23.8) and 6.2% (3.1-10.3) for WHO; 1.2% (0.5-2.1) and 4.9% (2.5-8.1) for IOTF and 12.5% (8.3-17.4) and 4.2% (1.6-7.9) for CDC. With the exception of overweight prevalence by CDC, the pooled estimates differed by school type within the major criteria ($p \leq 0.018$ for private-public comparisons). Within private-public schools, the point estimates did not differ significantly across the criteria (all $p \geq 0.209$) except for obesity prevalence in private schools ($p<0.0001$); Appendix I, Figures. S15 – S18. Heterogeneity was apparent across studies irrespective of criteria used (all p-heterogeneity ≤ 0.031). There was no evidence of publication bias for type of school (Egger $p \geq 0.241$); Appendix I, Table S4 & Table S5.

Regional distribution

The pooled overweight prevalence ranged from 7.7% (2.4-15.7) in Western Africa to 16.1% (6.1-26.8) in Eastern Africa by WHO (p = 0.155); 8.5% (4.6-13.5) in Southern Africa to 14.1% (6.8-23.5) in Eastern Africa by IOTF (p = 0.684); and 9.7% (7.0-12.8) in Western Africa to 12.1% (7.7-17.3) in Eastern Africa by CDC (p = 0.434). Obesity estimates ranged from 4.1% (0.7-9.9) in Southern Africa to 9.6% (3.8-17.6) in Eastern Africa by WHO (p < 0.0001); 0.8% (0.4-1.2) in Western Africa to 4.6% (2.2-7.8) in Southern Africa by IOTF (p < 0.0001); and 5.7% (4.5-7.0) in Northern Africa to 7.6% (3.2-13.6)] in Eastern Africa by CDC (p=0.019). The point estimates across the regional subgroups were comparable within the major criteria and differed only for obesity prevalence by IOTF-based criterion (p<0.0001).

Within regional subgroups, the point estimates did not differ across the major criteria (all p ≥ 0.125) except for studies conducted in Southern Africa (p≤0.014) and obesity for Western Africa (p<0.0001). Substantial heterogeneity was observed in estimates across diagnostic criteria with regional subgroups (all p ≥0.042), with the exception of IOTF-based obesity prevalence in Eastern Africa (p=0.428). Publication bias was apparent in Southern African studies reporting overweight by WHO-based criterion (Egger p = 0.032) and obesity by IOTF-based criterion (Egger p = 0.043); (Appendix I, Table S4 & Table S5).

Publication year

By diagnostic criteria, the pooled estimates of overweight and obesity were always higher in recent studies (published in 2013 or after) compared to studies published earlier (published before 2013) by WHO criteria (p=0.0007). Among studies that applied the IOTF and CDC criteria, overweight estimates were lower in recent compared to earlier studies, whereas obesity prevalence were higher in recent compared to earlier studies. Within publication year, pooled estimates of both overweight and obesity differed across all criteria except for studies published earlier ($p=0.154$). Heterogeneity was observed for WHO and IOTF criteria (all $p < 0.0001$) and for CDC-based obesity prevalence in studies published earlier only ($p<0.005$). Publication bias was apparent in earlier studies (Egger $p \leq 0.028$) using WHO criteria (Appendix I, Table S4 & Table S5).

Sample size

Pooled estimates of overweight and obesity were not appreciably different between small (less than 638 participants) and large studies (638 or more participants), and regardless of criteria (all $p \geq 0.05$). Pooled prevalence estimates of overweight and obesity were similar across criteria within small studies (both $p \geq 0.532$), but differed significantly within large studies (both $p<0.0016$), primarily driven by very low prevalence in studies based on unspecified diagnostic criteria. With the exception of small studies using CDC criterion for overweight ($p=0.074$) and IOTF criterion for obesity ($p=0.221$), there was substantial heterogeneity by diagnostic criteria within small and large studies (all $p<0.019$). Publication bias was apparent only in large studies using IOTF-based criterion (Egger $p = 0.017$); (Appendix I, Table S4 & Table S5).

2.4 Discussion

This study provides the first detailed contemporary meta-analysis of overweight and obesity prevalence in African primary school learners. The results showed that nearly one in ten African primary school learners is overweight while about one in twenty is obese. By criteria, overall estimates ranged from 9.5% to 11.5% for overweight, and 4.0% to 6.9% for obesity by IOTF and CDC respectively, with significant variations across major diagnostic criteria. Prevalence estimates were mostly higher in urban compared with rural schools, and in private compared with public schools, but mostly similar by gender, major geographic region, publication period, and study size. There were substantial heterogeneities in the estimates across studies, which were not always explained by major study characteristics. Sensitivity analyses proved the few apparent publication biases to be artefactual.

These results highlight the increasing burden of overweight and obesity and are largely consistent with previous estimates suggesting an increasing overweight and obesity prevalence among children and adolescents globally [2]. The present estimates are notably higher than those reported among children and adolescents in previous reviews [2,13]. In the review by Muthuri et al. [13], the focus was on studies conducted in sub-Saharan Africa, included adolescents, in addition to synthesising studies that used both subjective and objective methods to assess body composition. The current study assessed only studies that utilised objective methods and accounted for the diagnostic criteria used to define obesity unlike the aforementioned review.

By the major diagnostic criteria used, the highest overall estimated overweight and obesity prevalence was by the CDC-based criterion and the lowest by IOTF definition. Notably, the CDC definition was used in four studies whereas 18 studies employed the IOTF definition. Together, CDC and IOTF criteria were used in over half of the studies. Given that the CDC and IOTF criteria underestimate the prevalence of overweight/obesity in children and adolescents compared with the WHO criterion [13], it is plausible that the overall prevalence reported in the present meta-analysis had been underestimated. The lack of consensus on the BMI cut-off references to use across studies presents a challenge for results comparability. The observed variations in the overall prevalence estimates by the major criteria thus underscores the relevance of the stratified meta-analysis based on diagnostic criteria as done in the present study.

Unlike other studies, gender differences were not observed in the prevalence estimates of overweight and obesity in the present meta-analysis. The association between gender and overweight/obesity is inconsistent in the literature. A number of studies reported higher prevalence in girls [13,63], some found higher estimates in boys [64–67], and others showed similar prevalence estimates [68]. In a study involving Australian children, obesity prevalence did not differ between boys and girls in government and private, primary schools; however substantial gender differences were observed among adolescents in high school [68], suggesting age-gender interactions [64,67]. While the prevalence tended to be similar in boys and girls in the present study, among adults it is consistently higher in women compared to men [2,69].

In addition to biology, this could be partially due to certain socio-cultural practices that influence food choices and dietary intakes, overall energy expenditure and PA, and perception of overweight/obesity. In some cultures in Africa for instance, overweight/obesity is perceived as an indicator of beauty, good health and wealth particularly among females [70,71]. Additionally, females tend to be more sedentary compared to males [46]. Besides, adverse early life experiences such as abuse (physical, sexual, emotional) and child neglect have been linked with higher BMI, and development of overweight, or obesity in adulthood, especially among females, but not in childhood and adolescence [72–74]. While some showed abuse-specific effects, others reported more general effects across the spectrum of abuse.

Substantial variations in prevalence of overweight and obesity were observed across the rural-urban divide, and also across private-public schools in the present study, broadly in line with previous studies [13,66,75,76] that suggest significantly higher estimates in urban children attending private schools, compared to children living in rural areas, and in public schools. The results showed that studies conducted in private schools were mainly in urban areas as opposed to most of those studies in public schools which were a mix of urban and rural.

African countries are undergoing increasingly rapid urbanisation, globalisation of the food markets, and economic and human development. These are associated with lifestyle changes such as increased sedentary behaviours, physical inactivity and increased consumption of the "Westernised diets" [77]. Economic and human development may be linked to increased SES which could reflect in higher disposable incomes for high-calorie and ultra-processed convenient foods, with low nutritional value. Working parents especially mothers who work longer hours may have limited time to prepare fresh nutritious meals and may depend on convenient foods for the family. For example in the Millennium Cohort Study in the UK, a significant relationship of maternal employment and obesity was found only for children from households with higher annual incomes [7].

Access to technology like motorised transportation and varieties of gaming consoles for the children may be increased in the higher SES households. For instance, results from a study in Africa showed that increasing total annual income was inversely associated with meeting PA guidelines of children [78]. Additionally, rapid urbanisation may result in overcrowding and congestion, increased crime rates, limited space for neighbourhood playgrounds and parks for children, which may invariably lead to decreased PA. On the other hand, undernutrition [79] and PA like active transport and active play [13,80] generally tend to be higher in rural children in sub-Saharan Africa.

Preventing excess weight gain in childhood is a major preventive strategy with lasting benefits and the school provides opportunities as well as challenges for implementation of behavioural change programmes in children and adolescents. Restricting or limiting of marketing of unhealthy foods and beverages to children and provision of PA facilities are some of the recommended strategies [81] and the schools could provide children with the supportive environments to improve the PA and healthy eating habits by strengthening the school health promotion programmes.

2.5 Strengths and limitations

A strength of this study is the stratified meta-analysis based on the diagnostic criteria used. The PRISMA checklist guided the study from selection of studies to synthesis. This meta-analysis pooled and compared results from different studies that employed various diagnostic criteria to define overweight and obesity. Although there were substantial heterogeneity across studies, the sources of heterogeneity were thoroughly investigated on pre-specified population level characteristics. Likewise, an exhaustive search of multiple databases was conducted to identify relevant studies originating from Africa. Results from the present meta-analysis has highlighted the extent of the problem of overweight/obesity and provided valuable data for consideration by policy makers and public health practitioners on the prevention and control strategies among primary school learners in Africa.

There are a number of limitations which might influence the interpretation of the results. Some of the studies were not originally designed to assess prevalence of overweight and obesity. Results were pooled from studies conducted at different geographical locations, among different ethnic groups and with methodological differences but attempts were made to adjust for these differences through robust methodology. It is possible that some studies which were published in local and unindexed journals were missed. Also, all the geographical locations were not evenly represented. Data from national Demographic and Health Surveys were not considered given the time and resources available to complete the study. Finally, the predictors of childhood overweight and obesity were not explored in this study since this was an aggregated data meta-analysis.

2.6 Conclusions

The high prevalence of overweight and obesity reported in this review is of great concern considering the negative health impact across the life cycle. Results from the present study demonstrate that while overweight and obesity are more prevalent in urban children, rural residence does not protect against the epidemic. The similar prevalence estimates observed between genders in this study suggests that among African learners, boys and girls are equally affected. Private school attendance, an indicator of SES of families, and urban residence are thus major driving forces of overweight and obesity among African school children. If this prevalence persists, it may lead to increased healthcare cost and burden on healthcare facilities. Results from this meta-analysis could be helpful in making informed decisions on childhood obesity prevention efforts in African countries.

2.7 References

1. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014/06/02. 2014;384(9945):766–81.

2. de Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr*. 2010;92(5):1257–64.

3. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry*. 2012/06/26. 2012;24(3):176–88.

4. McLeroy K, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Heal Educ Q*. 1988;15(4):351–77.

5. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief*. 2010;127(51):1–8.

6. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocr Rev*. 2012;33(1):48–70.

7. Hawkins S, Cole TJ, Law C, The Millennium Cohort Study Child Health Group. Maternal employment and early childhood overweight: findings from the UK Millennium Cohort Study. *Int J Obes*. 2008;32(1):30–8.

8. Keane E, Layte R, Harrington J, Kearney PM, Perry IJ. Measured parental weight status and familial socio-economic status correlates with childhood overweight and obesity at age 9. *PLoS One*. 2012;7(8):e43503. DOI:10.1371/journal.pone.0043503.

9. Mâsse LC, de Niet-Fitzgerald J, Watts AW, Naylor P-J, Saewyc EM. Associations between the school food environment, student consumption and body mass index of Canadian adolescents. *Int J Behav Nutr Phys Act*. 2014;11(1):29. http://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-11-29.

10. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EMF. The school environment

and adolescent physical activity and sedentary behaviour: A mixed-studies systematic review. *Obes Rev*. 2016;17(2):142–58.

11. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC. The built environment and obesity. *Epidemiol Rev*. 2007;29(1):129–43.

12. Cummins S, Macintyre S. Food environments and obesity - Neighbourhood or nation? *Int J Epidemiol*. 2006;35(1):100–4.

13. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3):e92846. DOI: 10.1371/journal.pone.0092846.

14. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Heal Organ*. 2007;85(10):812–9.

15. Kuczmarski R, Ogden CL, Guo S, Grummer-Strawn L, Flegal K, Al. E. CDC Growth Charts for the United States: methods and development. Vital Health Stat. 2000. p. 1–190. https://www.cdc.gov/growthcharts/2000growthchart-us.pdf

16. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1–6.

17. Adom T, Puoane T, De Villiers A, Kengne AP. Prevalence of obesity and overweight in African learners: a protocol for systematic review and meta-analysis. *BMJ Open*. 2017;7(1):e013538. DOI:/10.1136/bmjopen-2016-013538.

18. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomized and non-randomized studies of health care interventions. *J Epidemiol Community Heal*. 1998;52:377–84. http://dx.doi.org/10.1136/jech.52.6.377.

19. Barendregt JJ, Doi SA, Lee YY, Norman RE, Vos T. Meta-analysis of prevalence. J *Epidemiol Community Health*. 2013;67(11):974–8.

20. Dersimonian R, Laird N. Meta-Analysis in Clinical Trials. *Stat Med*. 1986;188:177–88.

21. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ*. 2003;327(7414):557–60.

22. Egger M, Smith GD, Schneider M, Minder C. Bias in meta - analysis detected by a simple, graphical test. *BMJ*. 1997;14:1–16.

23. Abrahams Z, de Villiers A, Steyn NP, Fourie J, Dalais L, Hill J, et al. What's in the lunchbox? Dietary behaviour of learners from disadvantaged schools in the Western Cape, South Africa. *Public Heal Nutr*. 2011/07/07. 2011;14(10):1752–8.

24. Amidu N, Owiredu WKBA, Saaka M, Quaye L, Wanwan M, Kumibea PD, et al. Determinants of childhood obesity among basic school children aged 6 – 12 years in Tamale Metropolis. *J Med Biomed Sci.* 2013;2(3):26–34.

25. Armstrong ME, Lambert MI, Sharwood KA, Lambert E V. Obesity and overweight in South African primary school children -- the Health of the Nation Study. *S Afr Med J*. 2006/06/06. 2006;96(5):439–44.

26. Boukthir S, Essaddam L, Mazigh Mrad S, Ben Hassine L, Gannouni S, Nessib F, et al. Prevalence and risk factors of overweight and obesity in elementary schoolchildren in the metropolitan region of Tunis, Tunisia. *Tunis Med*. 2011/01/27. 2011;89(1):50–4.

27. Caleyachetty R, Rudnicka AR, Echouffo-Tcheugui JB, Siegel KR, Richards N, Whincup PH. Prevalence of overweight, obesity and thinness in 9-10 year old children in Mauritius. *Glob Heal.* 2012/07/25. 2012;8:28.

28. Chebet M, Goon DT, Nsibambi C, Otala J. Prevalence of overweight and obesity among primary school children in Kampala central, Uganda. *AJPHERD* 2014;20(December):1365–78.

29. Daboné C, Delisle HF, Receveur O. Poor nutritional status of schoolchildren in urban and peri-urban areas of Ouagadougou (Burkina Faso). *Nutr J*. 2011;10(1):34. http://nutritionj.biomedcentral.com/articles/10.1186/1475-2891-10-34.

30. Dekkaki IC, Mouane N, Ettair S, Meskini T, Bouklouze A, Barkat A. Prevalence of obesity and overweight in children: A study in government primary schools in rabat, Morocco. *Arch Med Res*. 2012/01/10. 2011;42(8):703–8.

http://dx.doi.org/10.1016/j.arcmed.2011.12.004

31. El-sabely AA, Tork HMM, Hussien YE. Comparative Study of Nutritional Status and Dietary Habits of Children from Public and Private Primary Schools in Zagazig City, Egypt. *IOSR J Nurs Heal Sci*. 2013;3(1):47–52.

32. Fetuga MB, Ogunlesi TA, Adekanmbi AF, Alabi AD. Nutritional Status of Semi-Urban Nigerian School Children using the 2007 WHO Reference Population. *West Afr J Med*. 2011;30(5):331–6.

33. Hassan NE, El-Masry SA, El-Sawaf AE. Waist circumference and central fatness of Egyptian primary-school children. *East Mediterr Heal J*. 2008;14(4):916–25.

34. Jinabhai CC, Taylor M, Sullivan KR. Changing patterns of under- and over-nutrition in South African children - future risks of non-communicable diseases. *Ann Trop Paediatr*. 2005;25(1):3–15.

35. Jinabhai CC, Taylor M, Sullivan KR. Implications of the prevalence of stunting, overweight and obesity amongst South African primary school children: a possible nutritional transition? *Eur J Clin Nutr*. 2003/02/07. 2003;57(2):358–65.

36. Kirsten AP, Marais D, Schübl C. The influence of socio-demographic factors on the nutritional status of children in the Stellenbosch area, Western Cape. *S Afr J Clin Nutr*. 2013;26(3):124–31.

37. Kyallo F, Makokha A, Mwangi AM. Overweight and obesity among public and private primary school children in Nairobi, Kenya. *Health*. 2013;5(8):85–90. http://dx.doi.org/10.4236/health.2013.58A3012.

38. Maruf FA, Aronu U, Chukwuegbu K, Aronu AE. Influence of gender on prevalence of overweight and obesity in Nigerian schoolchildren and adolescents. *Tanzan J Heal Res*. 2013/10/01. 2013;15(4):247–51.

39. McKersie JM, Baard ML. Body mass index and associated physical activity levels in 7 - 10-year-old children in primary schools in Port Elizabeth. *South African J Sport Med*. 2014;26(4):115–8.

40. Mogre V, Gaa PK, Nagumsi R, Abukari S. Overweight, Obesity and Thinness and

Associated Factors Among School- Aged Children (5-14 Years) in Tamale. *Eur Sci J*. 2013;9(20):160–75.

41. Mohammed H, Vuvor F. Prevalence of childhood overweight/obesity in basic school in Accra. *Ghana Med J*. 2013/05/11. 2012;46(3):124–7.

42. Moselakgomo VK, Monyeki MA, Toriola AL. Relationship between physical activity and risk factors of body weight disorders among south African primary school children. *Biomed Res*. 2015;26(4):730–8.

43. Mosha TC, Fungo S. Prevalence of overweight and obesity among children aged 6-12 years in Dodoma and Kinondoni municipalities, Tanzania. *Tanzan J Heal Res*. 2010/08/27. 2010;12(1):6–16.

44. Mpembeni RN, Muhihi AJ, Maghembe M, Ngarashi D, Lujani B, Chillo O, et al. Overweight, obesity and perceptions about body weight among primary schoolchildren in Dar es Salaam, Tanzania. *Tanzan J Heal Res*. 2014/10/01. 2014;16(4):304–11.

45. Muhihi AJ, Mpembeni RNM, Njelekela MA, Anaeli A, Chillo O, Kubhoja S, et al. Prevalence and determinants of obesity among primary school children in Dar es Salaam, Tanzania. *Arch Public Heal*. 2013;71(1):26. http://archpublichealth.biomedcentral.com/articles/10.1186/0778-7367-71-26

46. Muthuri SK, Wachira LJ, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. *BMC Public Health*. 2014/06/03. 2014;14(9):436. http://www.biomedcentral.com/1471-2458/14/436.

47. Mwaikambo SA, Leyna GH, Killewo J, Simba A, Puoane T. Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. *BMC Public Health*. 2015/12/23. 2015;15:1269. DOI: 10.1186/s12889-015-2598-0.

48. Navti LK, Ferrari U, Tange E, Bechtold-Dalla Pozza S, Parhofer KG. Contribution of socioeconomic status, stature and birth weight to obesity in Sub-Saharan Africa: cross-sectional data from primary school-age children in Cameroon. *BMC Public Health.* 2014;14(1):320. http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-

2458-14-320

49. Oldewage-Theron WH, Egal AA. Nutrition knowledge and nutritional status of primary school children in QwaQwa. *S Afr J Clin Nutr*. 2010;23(3):149–54.

50. Pangani IN, Kiplamai FK, Kamau JW, Onywera VO. Prevalence of Overweight and Obesity among Primary School Children Aged 8–13 Years in Dar es Salaam City, Tanzania. *Adv Prev Med*.; 2016:1–5. http://www.hindawi.com/journals/apm/2016/1345017/.

51. Pedro T, Kahn K. Under- and overnutrition and evidence of metabolic disease risk in rural black South African children and adolescents. *S Afr J Clin Nutr*. 2014;27(4):194–200.

52. Pienaar AE. Prevalence of overweight and obesity among primary school children in a developing country: NW-CHILD longitudinal data of 6–9-yr-old children in South Africa. *BMC Obes*. 2015;2(1):2. http://bmcobes.biomedcentral.com/articles/10.1186/s40608-014-0030-4.

53. Prista A, Maia JAR, Damasceno A and BG. Anthropometric indicators of nutritional status: implications for fitness, activity, and health in school-age children and adolescents. *Am J Clin Nutr*. 2003;77:952–9.

54. Puckree T, Naidoo P, Pillay P, Naidoo T. Underweight and overweight in primary school children in eThekwini district in kwazulu-Natal, South Africa. *African J Prim Heal Care Fam Med*. 2011;3(1):1–6.

55. Regaieg S, Charfi N, Trabelsi L, Kamoun M, Feki H, Yaich S, et al. [Prevalence and risk factors of overweight and obesity in a population of school children in urban areas Sfax, Tunisia]. *Pan Afr Med J*. 2014/07/16. 2014;17:57.

56. Salman Z, Kirk GD, DeBoer MD. High Rate of Obesity-Associated Hypertension among Primary Schoolchildren in Sudan. *Int J Hypertens*. 2011;2011:1–5. http://www.hindawi.com/journals/ijhy/2011/629492/.

57. Sebbani M, Elbouchti I, Adarmouch L, Amine M. [Prevalence of obesity and overweight among children in primary schools in Marrakech, Morocco]. *Rev Epidemiol Sante*

Publique. 2013/11/05. 2013;61(6):545–9.

58. Taleb S, Oulamara H, Agli AN. [Prevalence of overweight and obesity in schoolchildren in Tebessa (Algeria) between 1998 and 2005]. *East Mediterr Heal J*. 2010/08/31. 2010;16(7):746–51.

59. Tathiah N, Moodley I, Mubaiwa V, Denny L, Taylor M. South Africa's nutritional transition: overweight, obesity, underweight and stunting in female primary school learners in rural KwaZulu-Natal, South Africa. *S Afr Med J*. 2013/10/02. 2013;103(10):718–23.

60. Truter L, Pienaar AE, Du Toit D. The relationship of overweight and obesity to the motor performance of children living in South Africa. *South African Fam Pract*. 2012;54(5):429–35.

61. Van Den Ende C, Twisk JW, Monyeki KD. The relationship between BMI and dietary intake of primary school children from a rural area of South Africa: The Ellisras longitudinal study. *Am J Hum Biol*. 2014/07/22. 2014;26(5):701–6.

62. Wiles NL, Green JM VF. Tuck-shop purchasing practices of Grade 4 learners in Pietermaritzburg and childhood overweight and obesity. *S Afr J Clin Nutr*. 2013;26(1):37–42.

63. Negash S, Agyemang C, Matsha TE, Peer N, Erasmus RT, Kengne AP. Differential prevalence and associations of overweight and obesity by gender and population group among school learners in South Africa: a cross-sectional study. *BMC Obes*. 2017;4(1):29. http://bmcobes.biomedcentral.com/articles/10.1186/s40608-017-0165-1

64. Ogden CL, Fryar CD, Hales CM, Carroll MD, Aoki Y, Freedman DS. Differences in Obesity Prevalence by Demographics and Urbanization in US Children and Adolescents, 2013-2016. *JAMA*. 2018;20782(23):2410–8.

65. Song Y, Wang H-J, Dong B, Ma J, Wang Z, Agardh A. 25-year trends in gender disparity for obesity and overweight by using WHO and IOTF definitions among Chinese school-aged children: a multiple cross-sectional study. *BMJ Open*. 2016;6(9):e011904. http://bmjopen.bmj.com/lookup/doi/10.1136/bmjopen-2016-011904

66. Chirita-Emandi A, Barbu CG, Cinteza EE, Chesaru BI, Gafencu M, Mocanu V. Overweight and Underweight Prevalence Trends in Children from Romania – Pooled Analysis of Cross-Sectional Studies between 2006 and 2015. *Obes Facts*. 2016;(9):206–220.

67. Wang VH, Min J, Xue H, Du S, Xu F, Wang H, et al. What factors may contribute to sex differences in childhood obesity prevalence in China? *Public Health Nutrition*. 2018;21(11):2056-2064. DOI: 10.1017/S1368980018000290.

68. O'Dea JA. Gender, ethnicity, culture and social class influences on childhood obesity among Australian schoolchildren: Implications for treatment, prevention and community education. *Heal Soc Care Community*. 2008;16(3):282–90.

69. The GBD 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. *N Engl J Med*. 2017;377(1):13–27. DOI:10.1056/NEJMoa1614362.

70. Ziraba AK, Fotso JC, Ochako R. Overweight and obesity in urban Africa: A problem of the rich or the poor? *BMC Public Health*. 2009;9(1):465. http://doi.org/10.1186/1471-2458-9-465.

71. Mokhtar N, Elati J, Chabir R, Bour A, Elkari K, Schlossman NP, et al. Diet Culture and Obesity in Northern Africa. *J Nutr*. 2001;(131):S887–92.

72. Hemmingsson E, Johansson K, Reynisdottir S. Effects of childhood abuse on adult obesity: a systematic review and meta-analysis. *Obes Rev*. 15(11):882-93. DOI: 10.1111/obr.12216.

72 Danese A, Tan M. Childhood maltreatment and obesity: systematic review and meta-analysis. *Mol Psychiatry.* 2014;19(5):544–54. http://dx.doi.org/10.1038/mp.2013.54.

74. Hawton K, Norris T, Crawley E, Bch BM, Shield JPH, Chb MB. Is Child Abuse Associated with Adolescent Obesity? A Population Cohort Study. *Child Obes*. 2018;14(2):1–8.

75. Yu Z, Han S, Chu J, Xu Z, Zhu C, Guo X. Trends in Overweight and Obesity among Children and Adolescents in China from 1981 to 2010: A Meta-Analysis. *PLoS One*.

2012;7(12):e51949. DOI: 10.1371/journal.pone.0051949.

76. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. *Clin Obes*. 2016;6(1):19–32. DOI: 10.1111/cob.12130.

77. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev*. 2012;70(1):3–21.

78. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho AMN, Merom D. Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review. *Int J Environ Res Public Health*. 2017;14(8):1–18.

79. Johnson JA, Johnson AM. Urban-Rural Differences in Childhood and Adolescent Obesity in the United States: A Systematic Review and Meta-Analysis. *Child Obes*. 2015;11(3):233–41. http://doi.org/10.1089/chi.2014.0085.

80. WHO. Report of the Commission on Ending Childhood Obesity. World Health Organization. 2016. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

CHAPTER 3

School-based interventions targeting nutrition and physical activity, and body weight status of African learners: a systematic review

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Abstract

Introduction: Overweight/obesity is an emerging health concern among African children. The aim of this study was to summarise available evidence from school-based interventions that focused on improving nutrition and PA knowledge, attitude, and behaviours, and weight status of learners aged 9 – 15 years in the African context.

Methods: Multiple databases were searched for studies evaluating school-based interventions of African origin that involved diet alone, PA alone, or multicomponent, for at least 12 weeks duration, reporting changes in either diet, PA, or body composition, and published between 1 January 2000 and 31 December 2018. No language restrictions were applied. Relevant data from eligible studies were extracted. Narrative synthesis was used to analyse and describe the data.

Results: This systematic review included nine interventions comprising 10 studies. Studies were conducted among 9957 children and adolescents in two African countries, namely South Africa and Tunisia and generally of low methodological quality. The sample size at baseline ranged from 28 to 4003 participants. Participants were between the ages of 12.4 and 13.5 years. All but one intervention targeted learners of both sexes. Four studies were described as randomised control trials while five were pre- and post-test quasi-experiments. Except for one study that involved the community as a secondary setting, all studies were primarily school-based. The duration of the interventions ranged from four months to three years. The interventions focused largely on weight-related behaviours while a few targeted weight status. The results of the effectiveness of these interventions were inconsistent: three of five studies that evaluated weight status (BMI, BMI z-score, overweight/obesity prevalence), three of six studies that reported PA outcomes (number of sports activities, and PA duration ≥ 30 minutes for at least six days/week), and four of six reporting on nutrition-related outcomes (number meeting fruits and vegetable intake ≥ 5 times/day) found beneficial effects of the interventions.

Conclusion: Given the dearth of studies and the inconsistent results, definite conclusions about the overall effectiveness and evidence could not be made. Nonetheless, this study has identified research gaps in the childhood obesity literature in Africa and strengthened the need for further studies, the findings of which would contribute valuable data and inform policy.

3.1 Introduction

In **Chapter 2**, the prevalence of overweight and obesity in African schoolchildren were estimated as 9.4% and 5.0% respectively. Documented evidence from Africa suggests positive associations of markers of metabolic syndrome with increased body mass index, body fat, overweight or obesity [1–6]. For instance, in a systematic review and meta-analysis of studies involving children and adolescents in Africa, Noubiap and colleagues [1] reported that blood pressure was six times higher in children who were obese relative to normal weight children. Among Tunisian [4–6], and South African children [7,8], prevalence of metabolic syndrome was higher in children and adolescents who were overweight/obese.

Given the multifactorial nature of overweight and obesity, there is the need for a multi-disciplinary, multi-sectoral approach that focuses on the diverse environments in which children live for successful interventions. The school setting has been identified as ideal for health promotion interventions since children spend significant amount of time in schools and are exposed to supportive environments like school health policies, nutrition education and support, physical education, and PA during school hours. Despite these, the evidence from systematic reviews and meta-analyses on the effectiveness of school-based programmes have been mixed [9–14]. Moreover, these evidence are mostly from high-to-middle income countries.

In their systematic review which included studies from low-to-middle-income countries, Verstraeten and colleagues [11] concluded that overall, school-based programmes are promising in improving behavioural determinants of unhealthy body weight. Only one African study was included in their review, making the generalisation of their findings to African countries a challenge. The purpose of the current study was therefore to characterise and summarise available evidence from school-based interventions that focused on improving nutrition and PA knowledge, attitude, and behaviours, and weight status of African learners aged 6–15 years within the African context.

3.2 Methods

Inclusion criteria

The protocol for this systematic review has been previously described [15] and follows the PRISMA guidelines [16], Appendix II, with PROSPERO registration no. CRD42016041614. To be eligible for inclusion, studies had to be: conducted in learners aged 9 – 15 years, or presenting data specific for the subgroup of participants within the specified age range, of African origin and residing in African countries; primary research evaluating dietary interventions alone, PA interventions alone, combined dietary and PA interventions, and school environments of at least 12 weeks duration; reporting changes in diet and PA knowledge, attitude and self-efficacy, increased participation in PA, increased intake of fruits and vegetables, decreased consumption of high fat diets and sugar sweetened beverages, changes in body weight, BMI or BMI z-score and reporting a baseline and a post-intervention measurements; focused primarily on the school setting; prevention and treatment that used a controlled or no control study design, with or without randomisation; published and unpublished studies between 1 January 2000 and 31 December 2018. The post-2000 studies were selected because, hitherto the focus of research had been on undernutrition in African children; no language limitations were applied. For studies that evaluated multiple outcomes of the same intervention, the most comprehensive and recent report is included. Studies were excluded if they were clinic-based or have no school-based components; conducted among learners with eating disorders, critical illness or chronic conditions; in African populations residing outside the continent.

Data sources and selection of relevant studies

A comprehensive search of MEDLINE (PubMed), MEDLINE (EBSCOHost), CINAHL (EBSCOHost), Academic Search Complete (EBSCOHost) and African Journals Online (AJOL) was conducted to identify potentially eligible studies. Key search terms relating to population (learners, 'schoolchildren', 'school going children'); interventions (diet-related, PA-related, school environment-related); geographical settings (African search filter [17]) and outcomes (changes in dietary and PA knowledge, attitude, intention, self-efficacy, and behaviours, and changes in body weight, waist circumference, PBF, BMI or BMI z-score) were used. The search terms were modified for each database. Details of the search strategy for PubMed database can be found in Appendix II & Appendix X. The reference lists of identified studies were manually checked for other relevant studies and key specialists in the field were contacted for any unpublished study. References were exported and duplicates removed using Endnote citation management. The titles and abstracts of potentially relevant articles were independently screened by two reviewers for eligibility. Full-text copies of articles that met the eligibility criteria were obtained and assessed by two independent reviewers for inclusion in the review. Any disagreement about the eligibility was resolved through discussion.

Data extraction

This was performed by one reviewer using a piloted data sheet that was purposely designed for the study and discussed by two reviewers. The following were extracted: study details (author, year of publication, country of study); study design; study population (sample size, age, gender); intervention characteristics (type, content, duration of study, follow-up time points, drop-outs, mode of delivery, intervention provider); setting; outcome (primary outcomes: changes in body weight, waist circumference, percent body fat, BMI or BMI z-score; changes in intake of fruits and vegetables, consumption of high fat diets and sugar sweetened beverages, increased participation in PA and physical fitness; other relevant outcomes: changes in nutrition/dietary and PA knowledge, attitude, intention and self-efficacy); intervention effects (as reported by the authors) and theoretical basis of intervention. The corresponding author of one study was contacted for additional information but there was no response. The study was included in the review despite unavailability of complete data because of its relevance.

Quality assessment

The “Effective Public Health Practice Project quality assessment tool for quantitative studies” [18] was used to evaluate the methodological quality of included studies. The studies were rated on six components namely, selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop-outs. For each study, the six, the components were rated as weak (1), moderate (2) or strong (3). The ratings for each study were summed to obtain overall score. A study was rated strong when there was no weak ratings for any of the listed components. Overall, studies with one weak rating were classified as moderate while those with two or more weak ratings were rated as weak.

Data synthesis

Meta-analysis was initially planned for this study, however, it could not be done due to the heterogeneity of study designs, interventions, reporting, measures and outcomes. Hence narrative synthesis was used to analyse and describe the data. Each included study was summarised by variables such as study design, setting and population, intervention characteristics including duration, drop-outs and follow-up, intervention outcomes and measures, and theoretical basis of interventions. Where results were reported for multiple follow-up points during the intervention, only the final results are presented in this review. Intervention effects are presented as mean differences, Cohen’s d, adjusted beta-estimates, only for those primary studies that reported these. Where applicable, simple statistics were computed for changes in outcome variables from baseline to post intervention and follow-ups and presented as mean differences. The results are grouped and presented according to the outcome measures.

3.3 Results

Description of included studies

The flowchart for selection of studies is presented in **Figure 3.1**. The database and other searches identified 720 studies. After removal of duplicates, 311 titles and abstracts were screened for eligibility. Eighteen full text articles were reviewed and 10 studies that met the inclusion criteria were retained in this review. Two of these studies evaluated the same intervention [19,20].

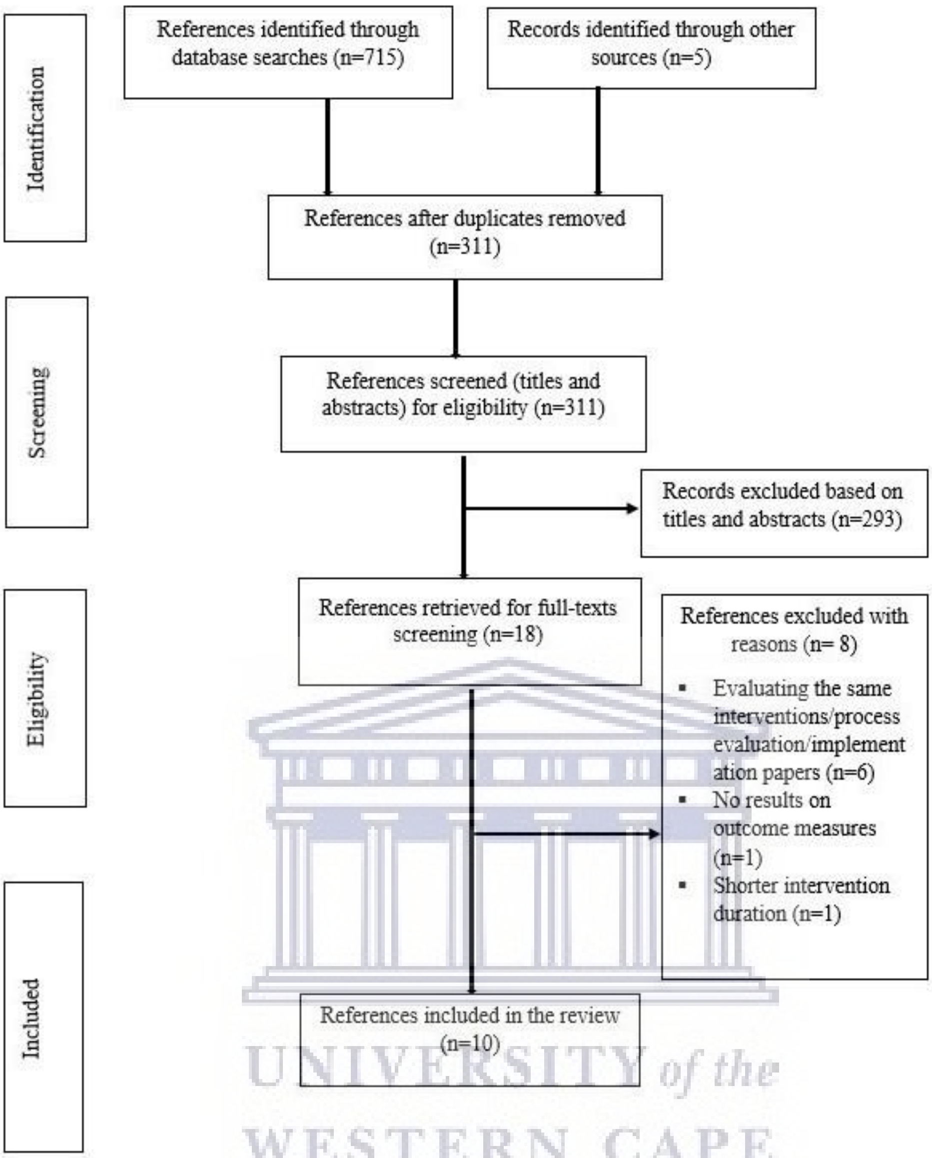

Figure 3.1: Flow chart for literature search for intervention studies

Study setting, design, and population

Table 3.1 shows the characteristics of the included studies. This systematic review included 10 studies conducted among 9957 children and adolescents in two African countries. Majority of the studies were conducted in South Africa [21,19,20,22–24] while the remaining were conducted in Tunisia [25–28]. Included studies were published between 2009 and 2017. Four studies were described as randomised control trials (RCTs) [19,20,24,28], five were pre- and post-test quasi-experiments [22,23,25–27], and one did not report the design [21]. Two of the studies were pilot studies to evaluate the feasibility of the interventions [22,23]. All the studies were primarily school-based with one [27] involving the community as a secondary setting. Three studies reported enrolling learners from both urban and rural schools [19,20,24]. Two studies [19,20] reported that participants were from low socioeconomic settings (defined as quintile 1 and 2 *vs* quintile 3 schools). Majority of the study participants were primary schoolchildren and adolescents in grades 4 to 6 [19,20,22–24], and grades 7, 8, and 9 [26,27]. One study [25] explicitly reported recruiting adolescents from public secondary schools while another [24] involved adolescents from urban and rural settings. The number of learners that participated at baseline ranged from 28 [28] to 4003 [27]. Except for one study that involved only boys [21], all the interventions targeted learners of both sexes. Of the studies that reported the mean age of learners, this ranged from 12.4 years [24] to 13.5 years [26].

Intervention characteristics

The duration of the interventions ranged from four months [23,28] to three years [19,20,27], with four lasting less than one year [21–23,28]. Post-intervention follow-ups, which were reported in three studies, ranged between 4 months [23,26] and 1 year [27]. The drop-out rates reported in five studies [22,24–26,28] ranged from 0.0% [28] (100.0% completed the intervention) to 30.8% [26]. Three of the ten studies were PA-based only interventions [21,23,28] and seven were multicomponent interventions involving both diet and PA only [19,20,26,27] or diet, PA and other health-promoting behaviours like tobacco use, and also the school environments [22,24,25].

Although the research teams comprised school personnel such as teachers, school doctors and nurses, medical personnel, and student leader groups, majority of the intervention activities were mainly facilitated by school teachers with additional training [21,19,20,22,23,25,26].

Programmes were presented as interactive sessions, games and sports, group discussions and exercise [21,23–26,28]. One study conducted delayed intervention for controls [27] while in another, the controls were exposed to a type of intervention, namely, prevention of sexually transmitted disease and HIV [24]. Furthermore, four studies integrated their additional sessions into the existing school curricula [20,22,23,25] while two others [24,28] were implemented as extracurricular activities. Additionally, two of the intervention studies targeted overweight and obese learners [26,28], one involved parents or caregivers [24] and two involved the school environments by promoting increased availability of healthy foods at school/tuck shops [22] and provision of PA equipment [26].

Intervention outcomes and measures

Two studies [19,23] evaluated PA-related outcomes only, three anthropometric outcomes only [21,26,28], two nutrition- and PA-related outcomes [24,25], one nutrition and anthropometric outcomes [20], one PA and anthropometric outcomes [22], and one nutrition, PA, and anthropometric outcomes [27].

Theoretical basis of intervention

The majority of the interventions were not theory-based except for three studies from South Africa. The socioecological theory guided the development of two [19,20] while one was based on the social cognitive and the theory of planned behaviour [24].

Methodological quality of included studies

The overall methodological quality of the included studies is presented in **Table 3.2** (details can be found in Appendix II). Nine out of the ten studies were categorised as weak and one of high quality [24]. The weak ratings were mainly due to missing information; the authors did not describe the components under consideration in most instances. For example, five studies each were rated either weak or moderate based on selection bias and only one of the four randomised controlled studies described method of randomisation [24]. The drop-out rates, reported by five studies [22,24–26,28] were between nil and 30.8%. Generally, information on blinding of assessors to the allocation of treatments in the RCTs, and confounding were mostly missing in the studies.

Table 3.1: Summary characteristics of included studies on school-based interventions targeting nutrition, physical activity, and weight status of children in African countries

Reference	Design, setting and population	Intervention characteristics		Intervention Outcomes			Measures	Theoretical basis	Overall quality
		Intervention components	**Duration, follow-up and drop-outs**	**Weight status**	**Nutrition**	**PA**			
Naidoo et al. 2009 [22]	Design: Cohort (one group pre- and post) Setting: Four primary schools in KwaZulu-Natal, South Africa Participants: 256 learners in grade 6 from low- to middle-income settings. Boys/girls: 81/104	Intervention: Diet, PA and school environment Concepts of PA and healthy eating habits were integrated with the existing curriculum. Programme was implemented by school personnel. Teachers were to advise and prompt learners to make healthy choices. Schools were to establish health promoting environments by increasing availability of healthy foods and decrease unhealthy foods at school/tuck shops.	Duration: 6 mo Drop-outs: 71 (27.7%)	√		√	BMI, Increased participation in sports and PA, availability of healthy food choices.	No	Weak
Draper et al. 2010 [23]	Design: Pre- and post-test study Setting: 5 elementary/primary schools in Alexandra Township, Gauteng Province, South Africa Participants: 508 grade 4-6 learners Age: NR Boys/girls: NR	Intervention: PA Teachers provided physical education as part of an integrated curriculum (Healthnutz project) to learners while situational analysis and focus group discussions were conducted for teachers and research team monitors.	Duration: 6 mo Follow-up: 4 mo	√		√	Physical fitness, knowledge, self-efficacy and attitudes, weight	No	Weak
Harrabi et al. 2010 [25]	Design: Pre- and post-test quasi experiment Setting: Seventy-six classes from four public secondary schools in Tunisia Participants: 2200 learners Age (range): 12-16y Boys/girls: 1026/1174	Intervention: Diet, PA and tobacco use This was delivered by project team, teachers and school doctors. Cognitive behavioural components of health knowledge and health promoting concepts such as tobacco use, PA, and healthy diet were integrated with the biological sciences and physical education curriculum.	Duration: 1 y Drop-outs 138 (5.9%)		√	√	Knowledge, intentions, behaviours of PA and nutrition	No	Weak
Jemmott et al. 2011 [24]	Design: RCT Setting: 18 schools (14 urban and 4 rural) in Eastern Cape Province, South Africa. Participants	Intervention Diet, PA and cognitive-behavioural health Consisted of 12 one-hour modules, with two modules delivered during each of six sessions on six consecutive school days; extracurricular held at the end of the school day and included	Duration: 13 mo Drop-outs: 35 (3.3%)		√	√	Nutrition and PA knowledge, attitudes, self-efficacy and behaviours	Social cognitive theory and the theory of planned behaviour	Strong

	1057 grade 6 learners Age (mean): 12.4 y; 9-17 y Boys/girls: 558/499	interactive exercises, games, brainstorming, role-playing and group discussions. Homework approach to involve parents or caregivers							
Monyeki et al. 2012 [21]	Design: NR Setting: Two primary schools in Gauteng Province, South Africa Participants 322 learners Age (range): 9-13 y Boys: 322	Intervention: PA Two 30 minutes exercise sessions per week during school hours. Lessons consisted of warm-up with stretching exercises, speed, strength, balance and cool down exercises. Intervention was provided by a trained physical education teacher.	Duration: 10 mo	√			BMI, body fat	No	Weak
Regaieg et al.2013 [28]	Design: RCT Setting: Elementary schools in Sfax, Tunisia. Participants 28 obese learners Age (range): 12-14 y Boys/girls:16/12	Intervention: PA Four extracurricular sessions (two sessions on weekdays and two on weekends) of 60 minutes per week aerobic exercises in addition to regular physical education that was provided by the schools. Exercises were performed under the supervision of a cardiologist.	Duration: 4 mo Drop-outs: 0%	√			BMI, weight, waist circumference, FFM	No	Weak
Maatoug et al.2015 [26]	Design: Quasi-experiment Settings: 6 schools in Sousse, Tunisia Participants 585 obese and overweight children in grades 7 & 8 Age: 13.1±0.9 y & 13.5±0.9 y in intervention and control groups Boys/girls: 236/349	Intervention: Diet and PA School personnel including PA teachers and parents were trained on the relevance of healthy behaviours in obesity management. Schools were provided with PA equipment. Learners were motivated to engage in regular PA and follow healthy diets in collective interactive sessions twice a week, each session lasting one hour as well as individual sessions for obese learners. Intervention was facilitated by dietician, psychologist, medical doctor and teachers (“Contrepoids” programme).	Duration: 1 y Follow-up: 4 mo Drop-outs: 180 (30.8%)	√			BMI, zBMI	No	Weak
De Villiers et al. 2016 [20]	Design: Cluster RCT Setting: 16 primary schools (8 urban and 8 rural) in low socioeconomic settings in Western Cape, South Africa Participants 998 grade 4 learners Boys/girls: 471/526	Intervention: Diet and PA HealthKick activities included the improvement of the school nutrition environment by developing healthy school nutrition policies, promoting the availability of healthier food options, initiation of vegetable gardens at schools and providing nutrition education support. Teachers were given training and resources; and were to organise additional 15 minutes of PA per day and at least one healthy eating activity per month to learners. Intervention was integrated with the existing nutrition curriculum	Duration: 3 y	√	√		Nutrition behaviour, self- efficacy, overweight, obesity	Socioecological theory	Weak
Uys et al. 2016 [19] [a]	Design: Cluster RCT Setting: 16 primary schools (8 urban and 8 rural) in low socioeconomic settings Participants	Intervention: Diet and PA This was implemented by the intervention schools that were also given toolkit containing teachers’ manual, curriculum manual, a resource box and PA resource bin (HealthKick).	Duration: 3 y			√	Physical fitness levels, and PA-related knowledge, attitudes and behaviours	Socioecological theory	Weak

	998 grade 4 learners Boys/girls: 471/526								
Ghammam et al. 2017 [27]	Design: Quasi-experiment Setting: 17 schools in Sousse, Tunisia Participants 4003 learners in grades 7 and 9 Age: 11-16 y Boys/girls: 1933/2070	Intervention: Diet and PA Educational events were organised at least three times in a school year for children, parents and teachers. Classroom sessions were organised by teachers and consisted of interactive lessons of healthy eating, the benefits of regular PA, and ways to incorporate PA into usual activities. After-school soccer games were organised both within and between the schools to encourage PA. Programmes were delivered by student leaders, project team and teachers ("Together in Health").	Duration: 3 y Follow-up: 1 y	√	√	√	Weight status, PA, screen time behaviours, fruits and vegetables intake, fast food intake	No	Weak

NR: not reported; RCT: randomised controlled trial; BMI: body mass index; BMI z-scores: body mass index z-scores; PA; physical activity; [a] these two studies evaluated the same intervention (HealthKick) with different outcomes measures; SES: socioeconomic status (defined as quintile 1 and 2 vs quintile 3 schools)

Main findings of interventions

Weight status

The main findings of the interventions are presented in **Table 3.2**. Six studies evaluated changes in body composition [21,20,25–28] and the results were mixed. Of these, three reported statistically significant effects in favour of the intervention groups [26–28] while observed changes were not significant in the other two studies [21,20]. It should be noted that two [26,28] of the studies targeted overweight/obese learners. Regaieg and co-workers [28] reported a statistically significantly decrease in BMI of learners in the intervention group (-0.6 kg/m^2, $p < 0.001$) compared to those in the control group. In addition to targeting obese learners, this was a small size. Maatoug and colleagues [26] reported a statistically significant decrease in BMI z-score in the post-intervention and follow-up (-0.13, $p < 0.001$ and -0.34, $p < 0.001$ respectively) in the overweight/obese children exposed to the intervention compared to those in the control group. In another study [27], overweight prevalence was significantly reduced in the intervention group (-2.0%, $p = 0.036$) but not the controls ($p = 0.602$). On the contrary, two studies did not observe beneficial effects of the intervention on weight status [21,20].

Physical fitness, and PA knowledge, attitudes, intentions and behaviours

Six studies evaluated physical fitness, PA knowledge, attitudes, and behaviours [19,22–24,27]. In one study, [22], PA and sports participation increased significantly. This study did not have a control group; however the number of sporting activities that learners participated in for at least five times per week increased from 35% to 55% after the intervention ($p < 0.05$). In other studies, more children met the recommended PA guidelines [24,27]. In the study by Jemmott and colleagues [24] for instance, the intervention resulted in significantly more learners meeting PA guidelines in the past seven days compared with controls (odds ratio = 1.56 ((95% CI: 1.29, 1.89)). Ghammam and colleagues [27] reported beneficial effects of the intervention in boys (p = 0.021) and older children (p = 0.004). For the studies that measured physical fitness, no overall effects were observed on the scores of learners [19,23]. PA self-efficacy [23], knowledge, attitudes and intention improved significantly in intervention learners but not in the controls [24].

Nutrition knowledge, attitudes, self-efficacy and behaviours

Five studies assessed changes in nutrition knowledge, attitudes, self-efficacy and intentions scores, and dietary behaviours including fruits and vegetable intake, fast foods intake, and consumption of carbonated drinks [20,22,24,25,27]. Two of these studies reported statistically significantly increase in the number of participants in the intervention group that met the recommended intake of fruits and vegetables compared with those in the controls. Jemmot et al. [24] reported that children in the intervention group were 1.30 times more likely to meet the recommended intake of fruits and vegetables compared to those in the controls (95% CI: 1.07, 1.58) that learners in the intervention group were. Likewise, Ghammam et al. [27] found that more learners in the in the intervention groups (+3.2%, p = 0.026) met the recommended intake of fruits and vegetables compared with the controls (-5.5%, p = 0.001). No significant effects were observed in one study [25]. Moreover, De Villiers [20] did not observe overall significant effect on dietary behaviour. Furthermore, significant improvements were reported in nutrition knowledge, self-efficacy, attitudes and intention of learners in other studies [20,24,25].

Table 3.2: Summary of the results of school-based interventions targeting nutrition and physical activity, and weight status of children in African countries

Reference and outcome	Change over time in I and C and I vs C					Intervention Effects as reported in primary studies	Main findings
	ΔI	ΔC	p-value	ΔI -ΔC	p-value		
Naidoo et al. 2009 [22] †							
Number of sports participated in (average)	10.0*						PA and sports participation increased significantly post intervention (*p*<0.05). Healthy food and drinks choices were available.
PA > 5 times/week after school (%)	20.0*						
Boys							
Sit ups	+2.0						
Sit and reach (cm)	+0.29						
Standing broad jump (m)	+1.0						
BMI (kg/m^2)	+0.8						
Girls							
Sit ups	+1.0						
Sit and reach (cm)	+0.89						
Standing broad jump (m)	+0.0						
BMI (kg/m^2)	+0.65						
Draper et al. 2010 [23]							
Sit and reach (cm)	+4.40	-10.50	<0.001				Intervention improved self-efficacy for PA in the experimental group but not the controls (*p*<0.05). PA knowledge improved in both the intervention and control groups. There was no effect on overall physical fitness scores. However, significant effects on sit and reach (*p*<0.001), sit ups (*p*<0.02), and -shuttle run (*p*<0.0001) between intervention and control groups were reported. Weight of learners in the intervention significantly decreased while change was reported for height.
Sit ups (in 30 seconds)	+1.80	+0.30	<0.02				
Shuttle run (seconds)	-2.30	+1.40	<0.0001				
Long jump (cm)	+9.70	+14.6	NS				
Ball throw (m)	-1.10	+0.10	NS				
PA self-efficacy	+0.30	-0.01	<0.05				
PA knowledge	+0.56	+0.47	NS				
Harrabi et al. 2010 [25]							
What to eat for breakfast (%)	+25.1	+1.2		+22.9	0.0001		Nutrition knowledge and intention improved significantly in the intervention compared to the control group. The percentage of learners with increased intake of fruits and vegetables increased in both groups, although significant in the controls. PA intention (p < 0.001) and behaviour (p < 0.001) improved in the intervention group. No significant differences in BMI in both groups.
Intention to eat breakfast (%)	+8.2	+2.9		+7.3	0.0001		
Fruit and vegetables intake ≥ 5 times/day (%)	+10.1	+9.6		-2.5	NS		
Intention to engage in PA daily (%)	+9.1	+1.7		+3.5			
PA duration ≥ 30 minutes for at least six days a week (%)	+18.4	+9.7		-1.0	0.0001		
Jemmott et al. 2011[a] [24]							
Fruit and vegetables intake ≥ 5 times/day in the past 30 days (5-a-Day) (%)	+2.83	-5.70			0.008	+0.16	More participants in health-promotion intervention than controls met 5-a-Day fruit (p =

Mean servings of fruit per day in the past 30 days	+0.49	+0.33		0.003	+0.19	0.003) and vegetable (p = 0.0001) intake, and PA guidelines (p = 0.0001). Health-promotion knowledge, attitude and intention increased (all p <0.0001) in the intervention group.
Mean servings of vegetables/day in the past 30 days	+0.98	+0.17		0.0001	+0.24	
Meeting PA guidelines in the past 7 days (%)	+7.10	+7.10		0.0001	+0.27	
Health knowledge	+3.48	+1.38		0.0001	+1.03	
Attitude toward health-promoting behaviour	+1.14	+0.69		0.0001	+0.89	
Intention for health-promoting behaviour	+1.02	+0.54		0.0001	+0.81	
Monyeki et al. 2012 [21]						
Body fat at age 12 y (%)	-0.32	+1.62	NS			Non-significant decreasing trends in BMI and percentage body fat (p = 0.32) in intervention group whereas BMI tended to be stable with an increasing percentage body fat by age in the control group,
Body fat at age 13 y (%)	-1.03	+2.31	NS			
Regaieg et al. 2013 [28]						
Weight (kg)	+0.70	+2.60	<0.001			Significant decreases in BMI, FM and waist circumference in intervention (p < 0.001). In the controls, a non-significant increase (p = 0.11) in waist circumference was observed. There were increases in FFM in both groups but this was higher in the intervention.
BMI (kg/m^2)	-0.60	+0.50	<0.01			
FM (%)	-4.30	-0.20	<0.01			
Waist circumference (cm)	-1.70	+0.70	<0.001			
Maatoug et al. 2015 [26]						
BMI (kg/m2)	+0.25	+0.49***				BMI z-score decreased significantly from pre-intervention to post intervention and from post-intervention to 4-mo follow-up in the intervention group. In the control group, BMI z-score decreased significantly from pre- to post-intervention but nor from post- to follow-up.
BMI z score	-0.13***	-0.18***				
De Villiers et al. 2016 [a] [20]						
Nutrition knowledge	+2.52	+0.60			+1.92**	Nutrition knowledge (p=0.011) and self-efficacy (p=0.039) significantly improved in the intervention group as compared with the controls. The intervention did not improve nutrition behaviour (p=0.743) nor weight status of the learners.
Nutrition behaviour	-0.52	-0.60		NS	+0.09	
Self-efficacy	+0.36	-0.35			+0.71*	
Overweight (%)	+1.00	+1.00				
Obesity (%)	-4.00	+7.00				
Uys et al. 2016 [a] [19]						
PA knowledge					-0.48*	Intervention did not improve overall physical fitness and determinants of PA behaviour. PA knowledge improved in both intervention (p < 0.005) and control ((p < 0.001) groups. Additionally, improvement was only observed in the sit-ups score of learners in the intervention group (p < 0.05)
PA behaviour					-0.44	
PA self-efficacy					-0.38	
Sit and reach (cm)					-1.29	
Sit ups (in 30 seconds)					+1.62*	
Shuttle run (seconds)					+3.32	
Long jump (cm)					-5.75	
Ghammam et al. 2017 [27]						
Fruit and vegetables intake ≥ 5 times/day (%)	+3.2*	-5.2**				Overall, higher proportion of learners (p =0.010), boys (p =0.021) and those ≥ 14 years (p =0.004) in the intervention group met the recommended daily PA post-intervention whereas in the
Fast food consumption ≥ 4 times/week (%)	-0.8	+5.1***				
Meeting recommended PA (%)	-3.6*	+0.1				
Week day screen time > 2hr/day (%)	+1.4	-2.1				

Weekend screen day > 2 hr/day	-0.1	-7.0***	controls, an increase was observed only at follow-up (p=0.023). Further, more learners in the intervention group reported eating 5 fruits and vegetables daily (p=0.02). Overweight prevalence reduced in the intervention group (p = 0.036).
Prevalence of overweight (%)	-2.6*	-1.0	

NS: not significant; ***p<0.001; **p<0.01; *p<0.05; [a]: adjusted beta estimates for baseline prevalence; FM: fat mass; FFM: fat free mass; PA: physical activity; BMI: body mass index; BMI z-score: body mass index z-score; I: intervention; C: control; IE: intervention effects; ΔI: change in intervention; ΔC: change in control; ΔI -ΔC: difference between change in intervention and controls; †: no controls, change in intervention are presented by gender

3.4 Discussion

The present systematic review aimed to summarise the available evidence on school-based interventions to prevent childhood overweight/obesity within the African context. A total of ten studies were evaluated. These studies were generally of low methodological quality. Majority of the studies focused on nutrition and PA while a few targeted body composition indices. Moreover, programme development of majority of these interventions were not theory-based. The results of the effectiveness of these interventions were inconsistent: three of five studies that evaluated weight status, three of six that reported PA outcomes, and four of six reporting on nutrition-related outcomes found beneficial effects of the interventions. Accordingly, we are unable to make definite statements about the overall effectiveness and quality of evidence due to the limited number and heterogeneous outcomes across studies.

These findings highlight the paucity of high quality, theory-based interventions to mitigate the effects of overweight and obesity, and energy-related behaviours among African learners. A considerable body of evidence suggests that multicomponent school-based interventions that target PA, dietary behaviours, sedentary behaviours, and the environments are more likely to be effective in children and adolescents compared with single component interventions [10–13,29]. Given the multi-faceted nature of overweight and obesity, it is not surprising that programmes that target individual behaviours and the obesogenic environments simultaneously are promising. Additionally, these behaviours tend to cluster so that any successful intervention should consider both ends of the energy balance equation. Contrary to the aforementioned studies, the present study found inconsistent results from the multicomponent programmes. It is worthy of note that of the single component interventions, positive effects were reported in a small sample of overweight and obese learners which may not have enough power.

The importance of theoretical frameworks in childhood obesity interventions have been highlighted [30]. In the present review, only three of the ten included studies were theory-based. While one reported beneficial effects in favour of the intervention groups in all the measured outcomes, results from the other two were inconsistent. Some beneficial effects were equally reported in the studies that did not apply theories. Documented evidence indicate that duration of interventions may have an impact on the overall effectiveness of adiposity measures, dietary and PA behaviours [12–14]. Kamath and others [14] showed that intervention trials with longer duration (> 6 months) and post-intervention outcomes tended to yield marginally larger effects. Results from another systematic review [13] showed that studies that reported significant effects were implemented over a longer period compared to those that did not report significant effects. Waters et al. [12] reported that interventions that lasted longer significantly decrease the prevalence of overweight/obesity in preschool children and children aged 6 – 12 years. The results from the present study are inconsistent; of the studies that lasted > 1 year, four yielded statistically significant intervention outcomes while two were not.

Majority of these interventions were designed to improve dietary and PA activity behaviours by targeting the children. The limited successes of many well-intended behavioural interventions have been attributed to changing behaviours without corresponding changes in the obesogenic environments such as the home, school policies and programmes, advertising, and the community. For schoolchildren, the family or home environment is one key setting to target for successful and sustainable interventions. Parents play influential role in promoting healthy dietary and PA behaviours of the children by not only parental practices and rules, but also by providing the supportive environment for these behaviours as well as serving as positive role models [31–33]. Parental involvement in school-based health interventions in developed countries is well documented [9,34–36]; however, in Africa, there is paucity of published studies. While there has been considerable interests for parental involvement in school-based obesity interventions, the evidence for programme effectiveness remains unclear. Results from one systematic review was inconclusive [34]; however other studies found positive effects [35,36]. In the present review, one study attempted to involve parents by organising meetings but this was not successful due to low turnout [20]. Another study reported parental involvement through homework approach [24]. Although this study was effective, no conclusions could be made based on the available evidence.

3.5 Strengths and limitations

The results of the present systematic review should be interpreted cautiously. The paucity of studies in Africa is a major limitation; all the studies included in this systematic review were conducted in two African countries hence the findings could not be generalised to the entire continent. It is possible some relevant studies that were not indexed in the targeted databases were missed in the review process. However, efforts were made to contact key experts in and across Africa for documents on school-based interventions among African learners. Also the school feeding scheme was not considered in the selected studies. Additionally, multiple reviewers were involved in the review and interpretation of the results. The methodological quality of the studies was low. Generally, important information such as selection bias, confounding, blinding, reliability, and validity of data collection tools were either missing or not clearly reported. Two of the included studies however made references to implementation details elsewhere [19,20]. It should be noted that none of the studies reported adverse effects of the interventions. Moreover, except for body composition and physical fitness, all outcomes relied on self-reports. Reliance on self-reports by children may be subject to recall bias and social desirability, thereby affecting the reliability and accuracy. Furthermore, given that most of the included studies were non-randomised, blinding of participants, data collectors and intervention assessors was not possible. Also, two studies reported high attrition rates. Those in the intervention have a high probability of completing the study and may have contributed to the reported effectiveness in the interventions. Meta-analysis was not possible given that the included studies were heterogeneous.

Despite these limitations, this is one of the first systematic reviews of the literature of school-based interventions in the African context. A further strength was the use of the “Effective Public Health Practice Project quality assessment tool for quantitative studies” to assess the quality. While the effectiveness and the evidence from this systematic review may be limited, these broadly agree with the available literature [9,13,14]. The result of this study has research and public health implications. Given the increasing trends of overweight/obesity in African learners and the limited studies on prevention efforts in the school settings, this study demonstrates the need for further intervention efforts across African countries. It is needful to explore the possibility of rigorous, large, multi-site, well-designed, and theory-driven interventions, with harmonised methodologies and parental involvement. Furthermore, researchers should consider incorporating formative research prior to implementation, as well as integrating interventions into already existing healthy lifestyle school programmes (regular school curricula) and structures to ensure maximum reach, sustainability and effectiveness.

Fortunately, in line with the recommendations by WHO [37], many African countries have detailed policy initiatives spanning across the family, school, the community, and the food and beverage industry. Some of the initiatives targeting educational settings include the creation of healthy food environments in schools and child-care settings by restricting marketing of unhealthy foods and beverages. Additionally, these settings are to provide adequate facilities on school premises and in public spaces for PA during recreational time for all children. It is expected that governments provide the needed resources for the implementation and evaluation of these interventions across Africa.

3.6 Conclusions

Overweight and obesity are emerging public health issues among African learners. Given the dearth of studies on school-based obesity interventions and the inconsistent results, definite conclusions about the overall effectiveness and quality of evidence could not be made. Nonetheless, this study has identified research gaps in the childhood obesity literature in Africa and strengthened the need for further studies. Future studies should focus on objective measures of body composition in addition to targeted energy-related behaviours. The findings of such interventions would contribute valuable data which will inform policy.

3.7 References

1. Noubiap JJ, Essouma M, Bigna JJ, Jingi AM, Aminde LN, Nansseu JR. Prevalence of elevated blood pressure in children and adolescents in Africa: a systematic review and meta-analysis. *Lancet Public Heal*. 2017;2(8):e375–86. http://dx.doi.org/10.1016/S2468-2667(17)30123-8.

2. Agyemang C, Redekop WK, Owusu-Dabo E, Bruijnzeels M a. Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. *BMC Public Health* 2005, **5**:114. doi:10.1186/1471-2458-5-114.

3. Salman Z, Kirk GD, DeBoer MD. High Rate of Obesity-Associated Hypertension among Primary Schoolchildren in Sudan. *Int J Hypertens*. 2011;2011:1–5. http://www.hindawi.com/journals/ijhy/2011/629492

4. Harrabi I, Bouaouina M, Maatoug J, Gaha R, Ghannem H. Prevalence of the metabolic syndrome among urban schoolchildren in Sousse, Tunisia. *Int J Cardiol*. 2009;135(1):130–1.

5. Jmal L, Jmal A, Abdennebi M, Feki M, Boukthir S. Prevalence of Metabolic Syndrome in Tunisian Overweight and Obese Children. *Tunis Med*. 2019;97(1):133–9.

6. Jamoussi H, Mahjoub F, Sallemi H, Berriche O, Ounaissa K, Amrouche C, et al. Metabolic Syndrome in Tunisian Obese Children and Adolescents. *Tunis Med*. 2012;90(1):36–40.

7. Zeelie A, Moss SJ, Kruger HS. The relationship between body composition and selected metabolic syndrome markers in black adolescents in South Africa: the PLAY study. *Nutrition*. 2010/06/15. 2010;26(11–12):1059–64.

8. Munthali RJ, Kagura J, Lombard Z, Norris SA. Childhood adiposity trajectories are associated with late adolescent blood pressure: birth to twenty cohort. *BMC Public Health*. 2016;1–10. http://dx.doi.org/10.1186/s12889-016-3337-x

9. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: An update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes Rev*. 2009;10(1):110–41.

10. Bleich SN, Vercammen KA, Zatz LY, Frelier JM, Ebbeling CB, Peeters A. Interventions to prevent global childhood overweight and obesity: a systematic review. *Lancet Diabetes Endocrinol*. 2018;6(4):332–46. DOI: http://dx.doi.org/10.1016/S2213-8587(17)30358-3

11. Verstraeten R, Roberfroid D, Lachat C, Leroy JL, Holdsworth M, Maes L, et al. Effectiveness of preventive school-based obesity interventions in low- and middle-income countries: a systematic review. *Am J Clin Nutr*. 2012;96(10):415–38.

12. Waters E, de Silva-Sanigorski A, Burford BJ, Brown T, Campbell KJ, Gao Y, et al. Interventions for preventing obesity in children. *Cochrane Database Syst Rev*. 2011(12). http://doi.wiley.com/10.1002/14651858.CD001871.pub3

13. Dobbins M, Husson H, Decorby K, LaRocca RL. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev*. 2013;(2):Art.No.:CD007651. DOI: 10.1002/14651858.CD007651.p.

14. Kamath CC, Vickers KS, Ehrlich A, Mcgovern L, Johnson J, Singhal V, et al. Behavioral Interventions to Prevent Childhood Obesity: A Systematic Review and Metaanalyses of Randomized Trials. *J Clin Endocrinol Metab*. 2008;93(12:4606–15. DOI: 10.1210/jc.2006-2411.

15. Adom T, Puoane T, De Villiers A, Kengne AP. Protocol for systematic review of school-based interventions to prevent and control obesity in African learners. *BMJ Open*. 2017;7(3):e013540. DOI: 10.1136/bmjopen-2016-013540.

16. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4(1):1.

17. Siegfried N, Clarke M, Volmink J. Randomised controlled trials in Africa of HIV and AIDS: descriptive study and spatial distribution. *BMJ*. 2005;331(7519):742.

18. Effective Public Health Practice Project. Quality assessment tool for quantitative studies. Hamilton (ON): Effective Public Health Practice Project, 1998. Date accessed Feb 13 2016.

19. Uys M, Draper CE, Hendricks S, De Villiers A, Fourie J, Steyn NP, et al. Impact of a South African school-based intervention, HealthKick, on fitness correlates. *Am J Health Behav*. 2016;40(1):55–66.

20. De Villiers A, Steyn NP, Draper CE, Hill J, Gwebushe N, Lambert E V, et al. Primary school children's nutrition knowledge, self-efficacy, and behavior, after a three-year healthy lifestyle intervention (HealthKick). *Ethn Dis*. 2016/04/23. 2016;26(2):171–80.

21. Monyeki MA, De Ridder JH, Du Preez SM, Toriola A, Malan DDJ. The effect of a ten month physical activity intervention programme on body composition of 9–13 year-old boys. *African J Phys Heal Educ Recreat Danc*. 2012;18(2):241–50.

22. Naidoo R, Coopoo Y, Lambert E, Draper C. Impact of a primary school-based nutrition and physical activity intervention on learners in KwaZulu-Natal, South Africa: A pilot study. *South African J Sport Med*. 2009;21(1):7–12.

23. Draper CE, De Kock L, Grimsrud AT, Rudolph M, Nemutandani S, Kolbe-Alexander T. Evaluation of a school-based physical activity intervention in Alexandra Township. *South African J Sport Med*. 2010;22(1):12–9.

24. Jemmott III JB, Jemmott LS, O'Leary A, Ngwane Z, Icard L, Bellamy S, et al. Cognitive-behavioural health-promotion intervention increases fruit and vegetable consumption and physical activity among South African adolescents: a cluster-randomised controlled trial. *Psychol Health*. 2011;26(2):167–85. DOI:10.1080/08870446.2011.531573.

25. Harrabi I, Maatoug J, Gaha M, Kebaili R, Gaha R, Ghannem H. School-based Intervention to Promote Healthy Lifestyles in Sousse, Tunisia. *Indian J Community Med*. 2010/07/08. 2010;35(1):94–9.

26. Maatoug J, Fredj SB, Msakni Z, Dendana E, Sahli J, Harrabi I, et al. Challenges and results of a school-based intervention to manage excess weight among school children in Tunisia 2012-2014. *Int J Adolesc Med Heal*. 2015/09/12. 2015;29(2).

27. Ghammam R, Maatoug J, Zammit N, Kebaili R, Boughammoura L, Al'Absi M, et al. Long term effect of a school based intervention to prevent chronic diseases in Tunisia, 2009-2015. *Afr Health Sci*. 2017;17(4):1137–48.

28. Regaieg S, Charfi N, Kamoun M, Ghroubi S, Rebai H, Elleuch H, et al. The effects of an exercise training program on body composition and aerobic capacity parameters in Tunisian obese children. *Indian J Endocrinol Metab*. 2014/01/02. 2013;17(6):1040–5.

29. Brown EC, Buchan DS, Baker JS, Wyatt FB, Bocalini DS, Kilgore L. A Systematised Review of Primary School Whole Class Child Obesity Interventions: Effectiveness, Characteristics, and Strategies. *Biomed Res Int*. 2016. http://dx.doi.org/10.1155/2016/4902714.

30. Sharma M. School-based interventions for childhood and adolescent obesity. *Obes Rev* 2006;(3):261–9.

31. Bauer KW, Neumark-Sztainer D, Fulkerson JA, Hannan PJ, Story M. Familial correlates of adolescent girls' physical activity, television use, dietary intake, weight, and body composition. *Int J Behav Nutr Phys*. 2011;8(1):25. http://ijbnpa. 10.1186/1479-5868-8-25.

32. McMinn AM, Griffin SJ, Jones AP, Van Sluijs EMF. Family and home influences on children's after-school and weekend physical activity. *Eur J Public Health*. 2013;23(5):805–10.

33. Zecevic CA, Tremblay L, Lovsin T, Michel L. Parental Influence on Young Children's Physical Activity. *Int J Pediatr*. 2010;2010:1–9.

34. Lippevelde W Van, Verloigne M, Bourdeaudhuij I De, Brug J, Bjelland M, Lien N, et al. Does parental involvement make a difference in school-based nutrition and physical activity interventions? A systematic review of randomized controlled trials. *Int J Public Heal*. 2012;57(4):673–8.

35. Golan M, Crow S. Targeting Parents Exclusively in the Treatment of Childhood Obesity: Long-Term Results. *Obes Res*. 2004;12(2):357–61.

36. Verjans-janssen SRB, Van De Kolk I, Van Kann DHH, Kremers PSPJ, Gerards SMPL. Effectiveness of school-based physical activity and nutrition interventions with direct parental involvement on children's BMI and energy balance-related behaviors – A systematic review. *PLoS One*. 2018;13(13(9)):e0204560. DOI: 10.1371/journal.pone.0204560.

37. WHO. Report of the Commission on Ending Childhood Obesity. World Health Organization. 2016. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

CHAPTER 4

A scoping review of policies on prevention and control of overweight and obesity in African countries

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Abstract

Introduction: To address the issue of childhood obesity, the WHO recommends a set of comprehensive programmes aimed at changing the obesogenic environments to improve the health of children by making healthier choices the default option available at the school, home and the community. The objective of this study was to examine the nature, extent and range of policies covering overweight/obesity prevention in Africa in order to assess how they align with international efforts in providing supportive environments.

Methods: The framework for scoping review by Arksey was adapted. A search of publicly available national documents on overweight/obesity, general health and NCDs was undertaken from relevant websites including WHO, ministries, and Google Scholar. Additional requests were sent to key contacts at relevant ministries about existing policy documents. Retrieved documents were reviewed and a standardised form used to extract data based on pre-determined criteria. The policies were categorised using the ANGELO framework.

Results: Policy initiatives to prevent overweight/obesity by many African countries targeted the school, family and community settings, and macro environments, and broadly aligned with global recommendations. The NCD documents were in the majority with only two on obesity. Majority of the documents detailed strategies and key interventions on unhealthy diets and physical inactivity. The physical, legislative, and sociocultural domains largely featured with less emphasis on the economic domain. Additionally, in all settings nutrition and diet-related policies were in the majority. Overlapping and interactions of policies were observed in the application of the ANGELO framework.

Conclusion: This study has provided data on national policies and programmes in Africa and can be useful as a first point of call for policymakers. The overlapping and interaction in the

initiatives demonstrate the importance of multi-sectoral partnerships in providing supportive environments for healthy behaviours.

4.1 Introduction

Globally, focus has been on individual lifestyles such as unhealthy diets and physical inactivity as the main determinants of the growing obesity crisis [1,2]. However, with the moderate success of individual lifestyle interventions to prevent and control overweight/obesity [3–7], recent attention has been shifted to the wider structural, global and national systems - upstream determinants - as significant drivers to the obesity crisis [8]. Among these are the food system, build and natural environments, and national policies. A considerable number of research has linked changes in the food system resulting from global and international food trade to the nutrition transition observed in low-to-middle income countries [9–11]. At the same time, structures and national policies on urban planning and design impact on neighbourhood walkability, public transport, and public amenities for recreation [8].

To address the issue of childhood obesity, the WHO [12–14] recommends a set of comprehensive programmes aimed at changing the obesogenic environments by providing the opportunities for healthy food options and increased PA in the school, home, healthcare facilities, and the community at large to improve the health of children. It is the responsibility of governments to provide political leadership and commitment by developing multi-sectoral policies and programmes given that no single intervention can be successful. This scoping review therefore aimed to examine the nature, extent and range of policies covering overweight/obesity prevention in Africa in order to assess how they align with international efforts in providing supportive environments towards the prevention of obesity.

4.2 Methods

The methodological framework for scoping review proposed by Arksey [15] was adapted to develop the protocol for this review, the details of which are provided elsewhere [16], (Appendix X).

Stage 1: Identifying the research questions

Based on the literature and the WHO documents, key research questions were derived. These covered the overweight/obesity prevention policies that were being addressed in the documents, the target population, and settings.

Stage 2: Identification and collection of policy documents

Briefly, a search of relevant, publicly available national documents on overweight/obesity, health, nutrition, and or NCDs was undertaken from Google Scholar, WHO websites, and relevant ministries in countries in Africa using the key words 'nutrition', 'food', 'physical activity' in combination with 'policy', guideline', 'action plan', 'programmes', 'strategy,' 'regulation', 'law', relating to 'overweight', 'obesity', and 'non-communicable diseases'. Additionally, requests were sent to key contacts at the health and education ministries of the countries about existing policy documents.

Stage 3: Screening and selection of policy documents

This was done following pre-determined inclusion and exclusion criteria. Documents were included if: they were national policies, either adopted and or at the draft stage, initiatives were being implemented or were proposed actions and strategies, targeted at unhealthy diets and physical inactivity, or that form part of a larger chronic disease prevention strategies, or to prevent and control overweight/obesity, and post-2000. No language restrictions were set.

Documents that were not national in coverage and reviews of policies were excluded. Where updated duplicate documents were found, the most recent in terms of year of production was included.

Stage 4: Charting the data

The documents were reviewed and a standardised form was used to extract data on the nature of policies e.g. title of document, type (policies, programmes, strategic plans or strategies, and action plans), year of publication or production and status (whether documents had official signatories, or at the draft stage), and coverage such as policies to increase fruits and vegetable intake, limit intake of fat and sugar, and promote PA.

Stage 5: Collating, summarising, and reporting the results

For the purposes of this review, policy refers to all documents regardless of the type, and includes policies, programmes, strategic plans or strategies, and action plans. The policies were categorised using the Analysis Grid for Environments Linked to Obesity **(**ANGELO) framework [17], commonly used for understanding the obesogenic environment. Based on the contents, these policies were assigned to one of the four environmental domains (physical, economic, legislative or regulatory, and socio-cultural), and settings (school, home and community), **Table 4.1**. Results are presented by the settings, key policy interventions, policy domains, and by country.

4.3 Results

Description of policy documents

The searches resulted in 87 documents from 54 African countries. Out of this, 64 documents were reviewed and 43 included in this study (**Figure 4.1**, Appendix III**)**. After initial searches, it became apparent that many African countries did not have standalone policies on obesity prevention, so the searches were modified to focus on NCDs prevention and control. Thirty (46.9%) of the retrieved documents were on NCDs [18–47], 19 (29.7%) on general health [48–66], 12 (18.8%) on nutrition [39,67–77], two (3.1%) on obesity [78,79], and one (1.5%) on PA [80]. In addition to the obesity and PA policies, 24 on NCDs, six on general health, and ten on food and nutrition were included in this review. Furthermore, these documents were described as policies, strategies, strategic plans or action plans. Of the documents reviewed, 13 countries namely: Burundi, Cape Verde, Comoros Island, Democratic Republic of Congo, Djibouti, Eritrea, Mali, Sao Tome et Principe, Senegal, Somali, South Sudan, Sudan, and Uganda [24,29,35,47,51,52,58–61,64,66,70] did not detail policy measures to address unhealthy diets and physical inactivity, although the policies underscored the importance of these risk factors. **Table 4.2** summarises the key policy actions identified in the reviewed documents and span the school, family, and the community settings.

Table 4.1: Analysis grid for environments linked to obesity (ANGELO)

	Macro-environment, diet-related and PA-related (national, regional, sectors, food industries, media, etc.)	**Micro-environment, diet-related and PA (**homes, schools, community groups, food retailers, etc.)
Physical	What is available? Example facilities, built environment, training opportunities, nutrition and exercise expertise, information	
Economic	What are the monetary cost/factors influences and consequences? Examples taxes and subsidies	
Legislative	What are the statutory provisions, rules and legal guidance, policy messages?	
Socio-cultural	What are the attitudes, beliefs, perceptions and values?	

Adapted from Swinburn et al. 1999 [17]

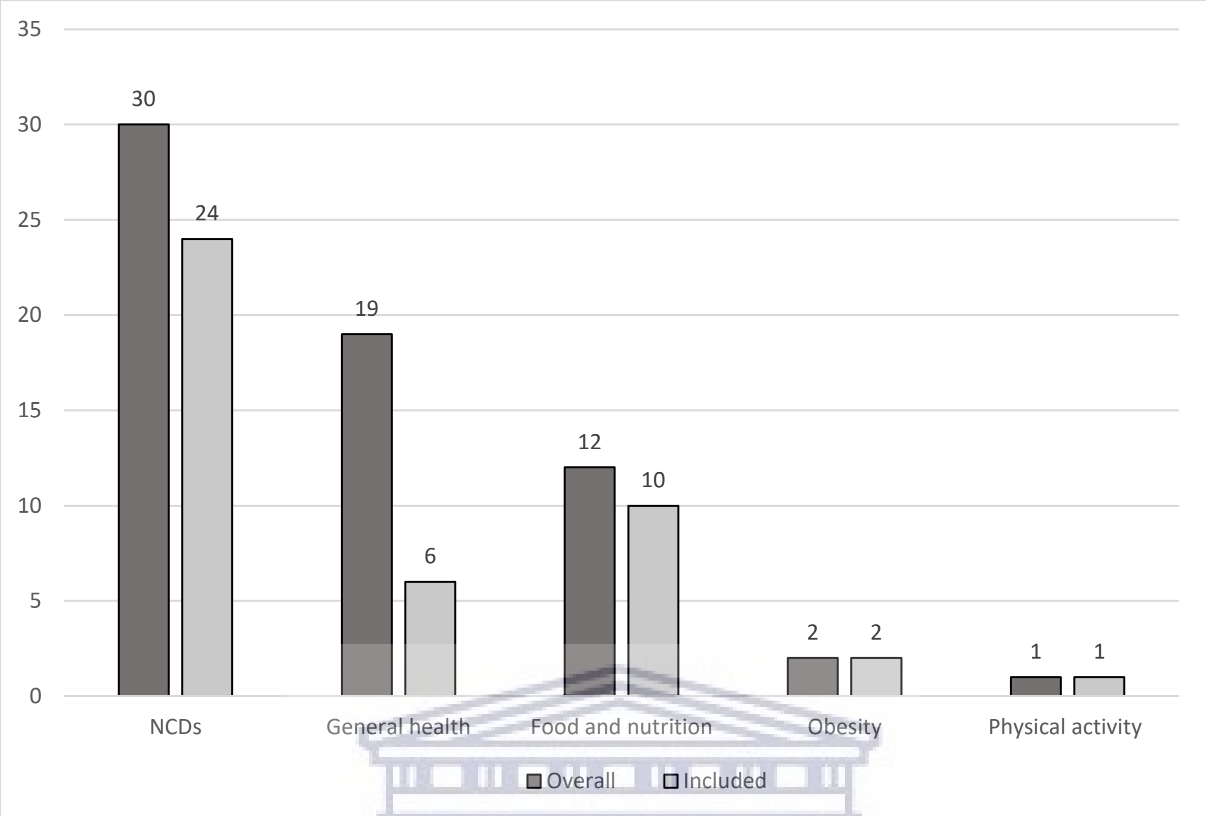

Figure 4.1: National policies reviewed, overall and included

Key policy interventions targeted at the school setting

Nutrition and diet-related policies

These included provision of healthy school meals, promotion of school vegetable gardens, marketing of unhealthy food and beverages in and around the school, integration of the concepts of nutrition and heathy eating in the curricula, professional development for teachers, canteen staff and school doctors, and monitoring of BMI.

Of the documents, majority (51.2%) outlined specific actions to strengthen nutrition education of children. Moreover, provision of healthy school meals was addressed in 18 countries and in different forms. For example, Botswana, Kenya, Nigeria, Guinea-Bissau, and Liberia targeted healthy school meals as a component of school health programme [19,32,37,71,81], Algeria and Seychelles specified free distribution of fruits and drinking water fountains [18,40], and others, including Benin and Ghana, proposed mandatory inclusion of fruits and vegetables in school menus [20,30]. Promotion of vegetable gardens was addressed by six countries [18,39,71–73,78], while Algeria [18], and South Africa [79] targeted regulations on sugars, fats and salt content of food sold near schools. Monitoring of BMI of children [18,19,45], professional development for staff [18,43,71,73], and marketing of unhealthy foods [18,30,67,78,79] were addressed in three, four and five country documents respectively.

PA policies

Nineteen countries including: Algeria [18], Botswana [19], Chad [23], Ghana [30], Seychelles [40], Nigeria [37], and South Africa [79] mentioned the promotion and strengthening of mandatory physical education and or activity in the curriculum as strategies to promote PA. Two countries, Mauritius [80] and Seychelles [40], mentioned organising after-school PA programmes by setting up of health clubs among other measures. Again, about a third [18–20,23,27,28,37,40,43,48,78–80] specified the provision of, and access to adequate recreational facilities to promote active play. Additionally, Algeria [18], Ethiopia [28], Mauritius [80], Seychelles [40], and South Africa [79] outlined specific strategies to promote and support active transport. Professional development and or trained instructors for school staff including PE teachers and school doctors was the focus of Algeria [18], Liberia [75], and Mauritius [80].

Key policy interventions targeted at the family setting

The key policy actions at the family level were: provision of educational materials and programmes, sensitisation to promote healthy lifestyles, promotion of breastfeeding, and home vegetable gardens. Nearly one-half of the countries including Liberia, Mauritius, Morocco, Namibia, Seychelles, and South Africa addressed the promotion of adequate infant and young child feeding including exclusive breastfeeding with continued breastfeeding and adequate complementary feeding. Lesotho [33], Mauritius [67] and South Africa [79] addressed the promotion of home vegetable gardens, while Algeria [18], Burkina Faso [73], Ghana [30], Guinea-Bissau [71], Liberia [75], and Tunisia [78] targeted the sensitisation of parents on healthy diets and importance of PA for health.

Key policy interventions targeted at the general population and community settings

Majority of the policy actions at these settings were at the macro level. These included: regulations on sugars, fats and salt in processed foods, marketing of unhealthy foods and beverages especially to children, tax and subsidy policies, development, implementation and strengthening of transport policies to improve the built and natural environments, and national PA guidelines. The main policy intervention at the community level was health promotion through public education and sensitisation. Of the total policy documents, majority targeted healthy lifestyles namely healthy foods and/ PA. Some nutrition policies outlined in the documents were: regulations on sugars, fats and salt in processed foods/fast foods/ takeaway/restaurant food targeting the food industry and this was outlined in 14 countries including: Benin, Botswana, Cote d'Ivoire, Egypt, Kenya, Morocco, Nigeria, Seychelles, and South Africa.

Table 4.2: Categorisation of childhood overweight/obesity prevention policies (key interventions) addressing unhealthy diets and physical inactivity

Setting	Policy intervention	Environment	Country
School			
Nutrition and diet-related	Provision of healthy school meals (provision of, and access to like fruits and vegetables)	Physical/ Legislative	Algeria, Benin, Botswana, Chad, Egypt, Gabon, Ghana, Guinea-Bissau, Kenya, Liberia, Mauritius, Morocco, Mozambique, Seychelles, South Africa, Tanzania, Tunisia, Zambia
	Promotion of school vegetable gardens	Legislative	Algeria, Burkina Faso, Gabon, Guinea-Bissau, Rwanda, Tunisia.
	Restricting marketing of unhealthy foods and beverages	Legislative	Algeria, Ghana, Mauritius, South Africa, Tunisia
	Food supply near schools (limits on refined sugars, fats and salt	Legislative	Algeria, South Africa
	Strengthen nutrition education	Legislative/ Sociocultural	Algeria, Angola, Botswana, Burkina Faso, Cameroon, Egypt, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Liberia, Madagascar, Mauritius, Morocco, Rwanda, Seychelles, Sierra Leone, South Africa, Tanzania, Tunisia
	Professional development for teachers and school canteen staff, etc.	Physical/ Sociocultural	Algeria, Burkina Faso, Guinea-Bissau, Tanzania
	Monitoring of BMI	Legislative	Algeria, Botswana, Zambia
PA	Mandatory/strengthen physical education and activity in the curriculum	Legislative/ Sociocultural	Algeria, Angola, Botswana, Chad, Egypt, Ghana, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Mauritius, Morocco, Sierra Leone, Seychelles, South Africa, Togo, Tunisia, Zambia
	After-school PA programmes	Physical/ legislative	Mauritius, Seychelles

	Provision of, and access to adequate recreational facilities	Physical	Angola, Algeria, Benin, Botswana, Chad, Egypt, Ethiopia, Mauritius, Nigeria, Seychelles, South Africa, Tanzania, Tunisia
	Promote and support active transport	Physical/ legislative	Algeria, Ethiopia, Mauritius, Seychelles, South Africa
	Professional development/trained instructors for school staff including PE teachers and school doctors	Physical/ Sociocultural	Algeria, Liberia, Mauritius
Family	Educational materials/programmes/sensitisation to promote healthy lifestyles	Physical/ Sociocultural	Algeria, Burkina Faso, Ghana, Guinea-Bissau, Liberia, Tunisia
	Promotion of breastfeeding	Physical/ Sociocultural	Algeria, Botswana, Cameroon, Chad, Egypt, Gabon, Gambia, Guinea-Bissau, Kenya, Liberia, Malawi, Mauritania, Mauritius, Morocco, Namibia, Nigeria, Rwanda, Seychelles, South Africa, Togo, Zambia, Zimbabwe
	Promotion of vegetable gardens	Physical/ Sociocultural	Lesotho, Mauritius, South Africa
General population and Community	Provision of, and access to adequate recreational facilities	Physical/ Legislative	Algeria, Benin, Cameroon, Cote d'Ivoire, Gambia, Ghana, Guinea, Madagascar, Mauritius, Nigeria, Sierra Leone, South Africa, Togo, Tunisia, Zambia
	Provision of, and access to safe walking paths, cycling lanes, public transport, etc.	Physical/ Legislative	Angola, Algeria, Botswana, Congo, Chad, Egypt, Ghana, Madagascar, Mauritius, Morocco, Nigeria, Seychelles, Sierra Leone, South Africa, Togo, Zambia
	PA clubs/organisation of games and sports	Sociocultural	Algeria, Botswana, Egypt, Chad, Ghana, Guinea-Bissau, Mauritius, South Africa, Togo, Tunisia
	Health promotion/awareness campaigns of healthy lifestyles (healthy foods/ PA)	Legislative/ Sociocultural	Angola, Algeria, Benin, Burkina Faso, Cote d'Ivoire, Chad, Central African Republic, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Mauritius, Morocco, Namibia, Niger, Nigeria, Seychelles,

			Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Zambia, Zimbabwe
	Regulations on sugars, fats and salt in processed foods/fast foods/ takeaway/restaurant food	Legislative/ Sociocultural	Benin, Botswana, Congo, Cote d'Ivoire, Chad, Egypt, Ghana, Kenya, Madagascar, Morocco, Nigeria, Seychelles, South Africa, Zambia
	Food taxes and subsidies to promote healthier diets	Economic	Botswana, Chad, Egypt, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Liberia, Mauritius, Morocco, Seychelles, South Africa
	Financial incentives for healthy lifestyle (subsidies on sports equipment and bicycles/rewards for active transport)	Economic	Botswana, Ghana, Tunisia,
	Marketing of unhealthy foods and beverages especially to children	Legislative	Algeria, Botswana, Egypt, Ghana, Guinea-Bissau, Kenya, Mauritius, Morocco, Nigeria, Seychelles, South Africa
	Educational material/training relevant stakeholders for healthy lifestyles e.g. consumers, food manufacturers, NGO, etc.	Physical/ Sociocultural	Algeria, Cameroon, Chad, Egypt, Gabon, Ghana, Mauritius, Morocco, Seychelles, South Africa, Tunisia
	Production, provision of, and access to healthy foods like fruits and vegetables	Physical/ Sociocultural/ Legislative	Benin, Chad, Congo, Cote d'Ivoire, Ethiopia, Guinea-Bissau, Guinea, Liberia, Madagascar, Mauritius, Seychelles, South Africa, Togo
	National PA guidelines/plans	Legislative	Cote d'Ivoire, Egypt, Ethiopia, Ghana, Mauritius, Nigeria, Seychelles, South Africa, Zambia
	Food and nutrition labelling	Sociocultural/ Legislative	Algeria, Egypt, Ethiopia, Ghana, Kenya, Mauritius, Morocco, Namibia, Nigeria, Seychelles, South Africa, Tunisia, Zambia
	Role models for PA	Sociocultural	Ghana, Mauritius, South Africa, Tunisia

Additionally, 13 countries [19,23,27,28,30–33,40,46,56,79,81] addressed fiscal policies to promote healthier diets and discourage unhealthy diets. For instance, the sugar tax was one such strategy implemented by South Africa [79] and Mauritius [56], while Liberia [81] and Egypt [27] mentioned taxation of sugar-sweetened beverages in general. Other countries stated that subsidies would be introduced to promote the production and accessibility of fruits and vegetables. For example, Lesotho [33] specified the exemption of fruits and vegetables from taxation while Guinea [31] mentioned subsidising local production of fruits and vegetables. Furthermore, marketing of unhealthy foods and beverages especially to children was addressed in 11 countries [18,19,27,30,32,37,40,46,67,71,79], in addition to providing adequate nutrition information through food and nutrition labelling (point of sale, product package, front of pack labelling) in 13 countries [18,27,28,30,32,37,40,45,46,67,69,78,79].

Several strategies were outlined to promote PA. Strengthening and implementation of transport policies to improve the built and natural environments were the main strategies outlined in 31 documents. Provision of, and access to adequate recreational facilities to promote active play was addressed in 15 countries including: Algeria [18], Benin [20], Cote d'Ivoire [26], Ghana [30], Madagascar [34], South Africa [79] Togo [44], and Zambia [45]. Furthermore, availability of safe walking paths, cycling lanes, and public transport were outlined in 16 countries, including Angola, Botswana, Congo, Egypt, Madagascar, Morocco, Nigeria, Seychelles, and Togo. In addition, other countries including Cote d'Ivoire, Egypt, Ethiopia, Mauritius, Seychelles, and South Africa, outlined the development, strengthening or implementation of national PA guidelines and plans. Financial incentives for healthy lifestyles such as subsidies on sports equipment and rewards for active transport were the focus of Botswana [19], Ghana [30] and Tunisia [78].

Policy domains

Majority of the policy interventions were legislative, sociocultural and physical domains. With respect to policy settings, legislative, sociocultural and physical domains mainly featured at the school, and community settings, and sociocultural and physical domains at the family setting. Only two were captured under the economic domain, with one each on nutrition and PA and these were at the community level.

4.4 Discussion

This scoping study was conducted to assess the nature, extent and coverage of overweight/obesity prevention policies in Africa and to categorise these policies using the ANGELO framework. The results highlight the availability of national policies targeted at promoting healthy diets and PA at the school, family and community settings. The policies were generally in alignment with global strategies and recommendations. The reviewed policies underscored the importance of multi-sectoral collaborations in creating supportive environments. Only two of the retrieved documents focused on obesity prevention; the remaining documents were on NCDs, nutrition, and general health. The nutrition policies outlined strategies on fruits and vegetables mainly to diversify the diets in order to prevent micronutrients deficiencies among the population. Generally, the majority of the NCD prevention documents detailed policy initiatives to address unhealthy diets and PA, with the exception of Burkina Faso, Burundi, Comoros, Eritrea, Mali, and Rwanda. It was also observed that there were overlap and interaction in the application of the framework. With the exception of the economic domain, the physical, legislative, and sociocultural domains were largely featured.

The WHO recommends a number of interventions to address unhealthy diets and physical inactivity, two of the major risk factors of overweight and obesity, and NCDs [12–14]. Among these policies, those that influence the food environments include: promotion and support of breastfeeding, regulations and restriction on the marketing of unhealthy food and beverages especially to children, subsidies to promote fruits and vegetables intake, taxation of sugar sweetened beverages, nutrition education and nutrition counselling at educational institutions, and mass media campaigns to healthy diets. In the present review, many African countries have indicated policy initiatives to address unhealthy diets and physical inactivity. The findings from this review demonstrate a significant improvement relative to the findings by Lachat and colleagues [82] who observed low coverage of diet and PA policies in African countries.

Although policy initiatives on food legislations by many governments have had strong opposition mainly by the food and beverage industry [83,84], the evidence from developed and low-to-middle income countries demonstrate the feasibility and effectiveness of these recommendations in providing supportive environments. There is considerable evidence that food taxes and subsidies encourage heathy food choices, food preferences and consumption, and subsequent reduction in BMI, obesity and chronic diseases [10,83,85,86]. For example, in their systematic review of high-income countries, Thow and colleagues [86] found that subsidies on healthy foods increased the purchases and consumption of these foods particularly fruits and vegetables by a lower margin relative to the subsidy; however the overall effect on energy intake was inconsistent [86]. In the same analysis, the taxation of sugar sweetened beverages reduced the consumption as well as the energy intake of these beverages proportional to the tax component [86]. In another meta-analysis involving France, Brazil, Mexico and the USA [85], taxation of sugar sweetened beverages increased the demand for healthier alternatives such as milk, and also led to reduction in the prevalence of overweight and obesity [85].

Nutrition labelling is key in providing adequate nutrition information to consumers at the point of sale thereby encouraging healthy food choices and comes in variant forms including front of package labelling and traffic light system. The traffic light system where the contents of sugar, salt, and total fats of packaged foods are indicated using colours is recommended as one of the effective strategies in the prevention of obesity. Nutrition labelling may result in increased purchases of healthy food options and dietary quality [87,88]. Food advertising and marketing to children may influence their preferences and dietary intake and subsequently their weight status [89].

The main policy intervention to promote PA was provision of, and access to adequate recreational facilities to promote active play and availability of safe walking paths, cycling lanes, and public transport, among others. These interventions target the built and natural environments (urban planning and design) and also school policies that facilitate increased participation in PA.

4.5 Strengths and limitations

This is the only study on national policies in African countries that provides information on available national documents outlining key policy interventions to address unhealthy diets, PA, and obesity. Other policy analyses focused on a few selected African countries [90] or implementation of NCD policies [91]. Additionally, an attempt was made to include nearly all African countries, regardless of language. A source of limitation was the categorisation at the domains and sectors as some of the key policy interventions tended to overlap and interact within the framework. The volume of documents to review was another potential source of limitation. Due to the anticipated volume of available documents, the searches were limited to national documents. Language was another challenge that was addressed by resorting to online language translation services.

4.6 Conclusions

Although not comprehensive, this study has provided data on the extent, nature, and coverage of policies and programmes on overweight/obesity prevention in Africa and can be useful as a first point of call for policymakers on unhealthy diets, physical inactivity and obesity policy document. Policy initiatives broadly aligned with global strategies and recommendations. The overlapping and interaction in the initiatives demonstrate the importance of multi-sectoral partnerships in providing supportive environments for healthy behaviours. It is recommended that a comprehensive systematic review and impact studies of available national policies be conducted and this should include implementation, monitoring and evaluation, where applicable and the results made available in a regional repository.

4.7 References

1. Newby PK. Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence. *J Law Med Ethics*. 2007;35(1):35–60.

2. Hills AP, Andersen LB, Byrne NM. Physical activity and obesity in children. *Br J Sport Med*. 2011;45:866–70.

3. Kamath CC, Vickers KS, Ehrlich A, Mcgovern L, Johnson J, Singhal V, et al. Behavioral Interventions to Prevent Childhood Obesity: A Systematic Review and Metaanalyses of Randomized Trials. *J Clin Endocrinol Metab*. 2008;93(12:4606–15. DOI: 10.1210/jc.2006-2411.

4. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: A meta-analysis. *CMAJ*. 2009;180(7):719–26. DOI: 10.1503/cmaj.080966.

5. Dobbins M, Husson H, Decorby K, LaRocca RL. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev*. 2013;(2):Art.No.:CD007651. DOI: 10.1002/14651858.CD007651.p.

6. Hooper L, Abdelhamid A, Moore HJ, Douthwaite W, Skeaff CM, Summerbell CD. Effect of reducing total fat intake on body weight: systematic review and meta-analysis of randomised controlled trials and cohort studies. *BMJ*. 2012;345(dec06 1):e7666–e7666. DOI:10.1136/bmj.e7666.

7. Ledoux TA, Hingle MD, Baranowski T. Relationship of fruit and vegetable intake with adiposity: A systematic review. *Obes Rev*. 2011;12(501):143–50.

8. Friel S, Chopra M, Satcher D. Unequal weight: equity oriented policy responses to the global obesity epidemic. *BMJ*. 2007;335(7632):1241–3.

9. Thow AM, Sanders D, Drury E, Puoane T, Chowdhury SN, Tsolekile L, et al. Regional trade and the nutrition transition: opportunities to strengthen NCD prevention policy in the Southern African Development Community. *Glob Heal Action*. 2015;8(28338). DOI: 10.3402/gha.v8.28338.

10. Thow AM, Jan S, Swinburn B. The effect of fiscal policy on diet , obesity and chronic disease: a systematic review. *Bull World Heal Organ*. 2010;88(8):609–14. DOI: 10.2471/BLT.09.070987.

11. Friel S, Hattersley L, Snowdon W, Thow AM, Lobstein T, Sanders D, et al. Monitoring the impacts of trade agreements on food environments. *Obes Rev*. 2013;14(S1):120–34.

12. WHO. Report of the Commission on Ending Childhood Obesity. World Health Organization. 2016. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

13. WHO. Global Strategy on Diet, Physical Activity and Health. Vol. 8. 2004. p. 1–21.

14. WHO. Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases 2008-2013. Geneva World Heal Organ. 2008;35.

15. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. *Int J Soc Res Methodol Theory Pract*. 2005;8(1):19–32.

16. Adom T, Puoane T, De Villiers A, Kengne AP. Protocol for a scoping review of existing policies on the prevention and control of obesity across countries in Africa. *BMJ Open*. 2017;7(2):e013541. DOI: 10.1136/bmjopen-2016-013541.

17. Swinburn B, Egger G, Raza F. Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity. *Prev Med. (Baltim).* 1999;29:563–70.

18. Algerienne. Plan strategique national multisectoriel de lutte integree contre les facteurs de risque des maladies non transmissibles 2015 - 2019. Ministere de la sante, de la population et de la reforme hospitaliere; 2015.

19. Botswana. Botswana National Multisectoral Strategy for the Prevention and Control of Non-Communicable Diseases. Ministry of Health and Wellness; 2017.

20. Benin. Plan strategique integre de lutte contre les maladies non transmissibles 2014-2018. Ministère de la Santé; 2014.

21. Burkina faso. Plan strategique integre de lutte contre les maladies non transmissibles

2016-2020 Ministère de la santé. 2016.

22. Republique Centrafricaine. Document de politique nationale de prevention et de lutte contre les maladies non transmissibles. 2014.

23. Tchad. Plan multisectoriel de maladies non transmissibles 2017-2021. Ministère de la Santé; 2017.

24. Union des Comores. Document de stratégie nationale de prévention et de lutte contre les maladies non transmissibles. Ministere de Santé, de la Cohésion Ministère de la Santé, de la Solidarité, de la Cohésion Sociale et de la Promotion du Genre; 2013.

25. Congo. Plan national integré de lutte contre les maladies non transmissibles au Congo 2013-2017. Ministere de la sante et de la population; 2013.

26. Côte d'Ivoire. Plan stratégique intégré de prévention et de prise en charge des maladies non transmissibles en Côte d'Ivoire 2015-2019. Ministère de la Santé et de la Lutte contre le Sida; 2014.

27. Egypt, WHO. Egypt Multisectoral Action Plan For Noncommunicable Diseases Prevention and Control 2018-2022. Ministry of Health and Population; 2018.

28. Ethiopia. National Strategic Action Plan (NSAP) for Prevention and Control of Non-Communicable Diseases in Ethiopia. 2014-2016.

29. Eritrea. Non-Communicable Diseases Policy. Ministry of Health; 2008.

30. Ghana. Strategy for the Management, Prevention and Control of Chronic Non-Communicable Diseases in Ghana. Ministry of Health; 2016.

31. Guinée. Programme National Intégré de Prévention et de Contrôle des Maladies Non Transmissibles. Ministère de la Santé et de l'hygiène Publique; 2010.

32. Kenya. Kenya National Strategy for the Prevention and Control of Non-communicable Diseases 2015-2020. 2015.

33. Lesotho. National Multi-Sectoral Integrated Strategic Plan for the Prevention and Control of Non-communicable Diseases (NCDS): 2014-2020. Ministry of Health. 2014.

34. Republique de Madagascar. Politique Nationale de Prévention et Lutte Intégrées contre les Maladies Chroniques Non Transmissibles. Ministere de Sante/WHO.

35. Mali. Politique Nationale de lutte Contre les Maladies Non Transmissibles. Ministère de la Santé; 2013.

36. Moçambique. Plano estratégico nacional de prevenção e controlo das doenças não transmissíveis para período de 2008 - 2014. Ministério da Saúde. 2008.

37. Nigeria. National Policy And Strategic Plan of Action On Non-Communicable Diseases. 2013.

38. Niger. Politique et Plan Strategique Integre de lutte contre les maladies Non Transmissibles (Psimnt) 2012-2015. Ministère de la Santé Publique; 2012.

39. Rwanda. National Food and Nutrition Policy 2013-2018. 2014.

40. Seychelles. Strategy for the Prevention and Control of Non-communicable Diseases, 2016-2025. Ministry of Health; 2016.

41. Sierra Leone. National Non-Communicable Diseases Strategic Plan. 2017.

42. Swaziland. National Non-Communicable Diseases Prevention and Control. Ministry of Health, WHO; 2016.

43. Tanzania. Strategic Action Plan for Prevention and Control of Non communicable Diseases in Tanzania 2016 - 2020. Ministry of Health, Community Development, Gender, Elderly and Children. 2016.

44. Togo. Politique et Plan Strategique Integre de lutte Contre les Maladies Non Transmissibles (PSIMNT) 2012-2015. 2012.

45. Zambia. Zambian Strategic Plan 2013-2016 Non-communicable Diseases and their Risk factors. Version 1. Ministry of Health; 2016.

46. Maroc. Stratégie Multisectorielle de Prévention et de Contrôle des Maladies Non Transmissibles 2016-2025. Ministre de la Santé, l'Organisation Mondiale de la Santé; 2016.

47. Burundi. Plan Strategique Multisectoriel de Securite Alimentaire et Nutritionnelle (PSMSAN) 2014-2017. 2014.

48. Angola. Plano Nacional de Desenvolvimento Sanitário 2012-2025 (PNDS). Vol. 1. 2014.

49. Republic of Burundi. National Health Development Plan. Vol. 151, Ministry Of Public Health And Fighting AIDS National. 2015.

50. Cameroun. Plan National de Développement Sanitaire, PNDS 2016-2020. Ministere de Santé, de la Cohésion Ministère de la Santé Publique; 2016.

51. Repúblicade Cabo Verde. Plano Nacional De Desenvolvimento Sanitário 2012-2016 Preâmbulo. 2012.

52. Djibouti. Plan National de Developpment 2013-2015. Ministere de la Sante; 2013.

53. Gambia. The Gambia National Health Sector Strategic Plan. Ministry of Health and Social Welfare. Ministry of Health and Social Welfare; 2014.

54. Malawi. Health Sector Strategic Plan II (2017-2022). Government of the Republic of Malawi. 2017.

55. Mauritanie. Plan National de Developpement Sanitaire 2012-2020. Ministere de la Santé. 2012.

56. Mauritius. Draft Health Sector Strategy 2017-2021. Ministry of Health and Quality of Life. Ministry of Health and Quality of Life; 2017.

57. Namibia. Namibian National Health Policy Framework. Ministry of Health and Social National Services; 2010.

58. São Tomé et Príncipe. Plano Nacional do Desenvolvimento da Saúde 2017 – 2021. 2017.

59. Senegal. Plan National de Developpement Sanitaire PNDS 2009-2018. Ministere de la Sante et Prevention; 2009. p. 1–86.

60. Somali. Health Sector Strategic Plan January 2013 - December 2016. Ministry of Human Development and Public Services; 2013.

61. Sudan. 25 Years Strategic Plan for Health Sector. Minsitry of Health; 2003.

62. Uganda. Health Sector Development Plan 2015/16 - 2019/20. Ministry of Health; 2015.

63. Zimbabwe. The National Health Strategy for Zimbabwe 2016-2020.

64. South Sudan. The Republic of South Sudan Policy Framework 2013-2016. Ministry of Health. 2013.

65. Somaliland. Somaliland National Health Policy 2011. 2011. p. 1–48.

66. Republique Democratique du Congo. Plan National de Developpement Sanitaire 2016-2020. Ministere de la Sante Publique; 2016.

67. Mauritius. Plan of Action For Nutrition 2009-2010. Ministry of Health and Quality of Life; 2009.

68. Sierra Leone. Ministry of Health and Sanitation. National Food and Nutrition Security Policy 2012 -2016. Ministry of Health and Sanitation. 2012.

69. Namibia. Strategic Plan for Nutrition 2011-2015. Ministry of Health and Social Services; 2014.

70. Uganda. Nutrition Action Plan 2011-2016. Government of Uganda; 2011.

71. Guinee-Bissau. Politique Nationale de Nutrition. Republique de la, Ministere de Publique, Sante.

72. Gabon. Politique Nationale de Securite Alimentaire et Nutritionnelle (PNSAN) 2017-2025. 2017.

73. Burkina Faso. National Nutrition Policy (Politique nationale de nutrition). Ministere de la sante. 2016.

74. Cameroun. Politique Nationale de Nutrition 2012-2021. Ministère de la Santé Publique; 2006.

75. Liberia. National Food Security and Nutrition Strategy. Government of Liberia. 2008.

76. Republique de Madagascar. Plan National d'Action pour la Nutrition (PNAN III 2017-

2021). Ministere de Sante; 2017.

77. Malawi. National Multi-Sector Nutrition Policy 2018-2022. Department of Nutrition HIV and AIDS; 2018.

78. Tunisia. Stratégie de Prévention et de lutte contre l'obésité 2013 - 2017. Ministère de la Santé; 2014.

79. South Africa. Strategy for the prevention and control of obesity. Department of Health; 2015.

80. Mauritius. National Action Plan on Physical Activity 2011-2014. Ministry of Health and Quality of Life; 2011.

81. Liberia. National Policy and Strategic Plan on Health Promotion. Ministry of Health/WHO; 2016.

82. Lachat C, Otchere S, Roberfroid D, Abdulai A, Maria F, Seret A, et al. Diet and Physical Activity for the Prevention of Noncommunicable Diseases in Low- and Middle-Income Countries: A Systematic Policy Review. *PLoS Med.* 2013;10(6):e1001465. DOI:10.1371/journal.pmed.1001465.

83. Pérez-Escamilla R, Lutter C, Rabadan-Diehl C, Rubinstein A, Calvillo A, Corvalán C. Prevention of childhood obesity and food policies in Latin America: from research to practice. *Obes Rev*. 2017; Suppl 2:28-38. DOI: 10.1111/obr.12574.

84. Margetts B. Editorial. *Public Health Nutr.* 2004;7(3):361–3. DOI: https://doi.org/10.1079/PHN2004622.

85. Cabrera Escobar MA, Veerman JL, Tollman SM, Bertram MY, Hofman KJ. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. *BMC Public Health*. 2013;13(1072). DOI: 10.1186/1471-2458-13-1072.

86. Thow AM, Downs S, Jan S. A systematic review of the effectiveness of food taxes and subsidies to improve diets: Understanding the recent evidence. *Nutr Rev*. 2014;72(9):551–65.

87. Miller, SLM, Cassady DL, Applegate EA, Beckett LA, Wilson MD, Gibson TN,

Ellwood K. Relationships among Food Label Use, Motivation, and Dietary Quality. *Nutrients*. 2015;7:1068–80. DOI: 10.3390/nu7021068.

88. Cecchini M, Warin L. Impact of food labelling systems on food choices and eating behaviours: A systematic review and meta-analysis of randomized studies. *Obes Rev*. 2016;17(3):201–10.

89. Sadeghirad B, Duhaney T, Motaghipisheh S, Campbell NRC, Johnston BC. Influence of unhealthy food and beverage marketing on children's dietary intake and preference: a systematic review and meta-analysis of randomized trials. *Obes Rev*. 2016;17(10):945–59.

90. Juma PA, Mohamed SF, Mwagomba BLM, Ndinda C, Mapa-tassou C, Oluwasanu M, et al. Non-communicable disease prevention policy process in five African countries. *BMC Public Health*. 2018;18(S1):961. https://doi.org/10.1186/s12889-018-5825-7.

91. Nyaaba GN, Stronks K, De-Graft Aikins A, Kengne AP, Agyemang C. Tracing Africa's progress towards implementing the Non-Communicable Diseases Global action plan 2013-2020: a synthesis of WHO country profile reports. *BMC Public Health*. 2017. 17:297. DOI: 10.1186/s12889-017-4199-6.

CHAPTER 5

Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana

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Abstract

Introduction: Data on the risk factors for overweight and obesity in Ghanaian school children is limited. The aim of this study was therefore to assess the prevalence of overweight and obesity and associated risk factors in school children in Ghana.

Methods: Data for this study were obtained from a cross-sectional study of 543 children aged between 8 and 11 years who were attending private and public primary schools in the Adentan Municipality of Greater Accra Region, Ghana. Anthropometric, dietary, physical activity, sedentary behaviours, sleep duration and socio-demographic data were collected. BMI-for-age z-scores were used to classify children as overweight/obese. Multivariable logistic regressions were used to assess the determinants of overweight and obesity.

Results: Out of a total of 543 children, 16.4% were overweight or obese. Children living in middle (OR = 1.87; 95% CI = 1.01–3.48) and high SES households (2.57; 1.41–4.68) had increased odds of being overweight or obese compared to those living in low SES household. Attending private school (2.44; 1.39–4.29) and viewing television for more than 2 hours daily (1.72; 1.05–2.82) were significantly associated with increased likelihood of overweight and obesity. Children who slept for more than 9 hours (0.53; 0.31–0.88) and walked or cycled to school (0.51; 0.31–0.82) had lower odds of being overweight or obese.

Conclusions: A number of modifiable risk factors were associated with overweight and obesity in this study. Public health strategies to prevent childhood obesity should target reducing television viewing time, promoting active transport to and from school and increasing sleep duration.

5.1 Introduction

In 2014, the Global Burden of Disease estimated that 23.8% of boys and 22.6% of girls in developed countries were overweight or obese [1] during 1980-2013. At the same period, the prevalence increased from 8.1% to 12.9% in boys and from 8.4% to 13.4% in girls in developing countries [1]. As indicated in **Chapter 1**, there is growing evidence of increasing overweight and obesity among school-aged children in sub-Saharan Africa [2,3]. Preventing unhealthy weight gain from an early age is a public health strategy and identifying the modifiable risk factors in the local context is important for a successful intervention.

Childhood obesity reflects complex interactions between the individual, behaviour and environmental factors [4]. Lifestyle and behavioural changes including consumption of diets high in refined sugars and saturated fats but low in fruits and vegetables, physical inactivity, increased sedentary behaviours and short sleep duration have contributed to the increasing prevalence in children and adults [5–11]. Moreover, studies in developed and developing countries have linked SES to obesity prevalence [2,12–14]. In Africa, family SES has been linked to the type of school a child attends and risk of overweight/obesity [2,14]; children from higher SES households are more likely to attend private or affluent schools and have higher risk of becoming overweight or obese compared with children from low SES households.

The nutrition transition associated with rapid urbanisation and globalisation are major contributing factors of unhealthy lifestyles in developing countries including Ghana [9,10,15]. There is growing evidence of increasing prevalence of overweight and obesity among children under the age of five [16] and school-aged children [17,18] in Ghana. During the primary school period, unhealthy weight gains may arise from energy imbalance resulting from poor dietary habits [19] and physical inactivity [17]. Despite these, older children, unlike children under 5 and adolescents are usually not targets of representative health surveys in Ghana

[16,20]. While a number of individual studies involving Ghanaian children have reported increasing prevalence [17,18,21,22], fewer research have investigated the independent associations of risk factors. The objective of this study was therefore to describe the prevalence of overweight and obesity and to examine the associated risk factors in Ghanaian school children.

5.2 Methods

Study design and population

This was a cross-sectional study that involved children aged 8-11 years attending private and public primary schools in the Adentan Municipality of Greater Accra Region, Ghana. Adentan is one of the 213 districts in Ghana. The Adentan Municipality was chosen because it is one of the fastest growing municipalities and a high proportion (62.5%) of the population resides in urban areas [23].

The study was approved by the Ethical Review Committees of the Ghana Health Service and the Senate Research Committee of the University of the Western Cape (Appendix VIII). Approval was also obtained from the Municipal Education Directorate of the Ghana Education Service as well as from the Heads of all participating schools. Written informed consent were given by parents/legal guardians of children and verbal assent was given by each participating child (Appendix IX).

Sampling

A minimum sample size of 206 was estimated based on an overweight/obesity prevalence of 15% among school children in urban Ghana [24], using the formula for prevalence studies [25]. This was multiplied by design effect for cluster sampling of 2 to give a sample of 412. Assuming a non-response rate of 10%, the sample size was adjusted to 453 children. Fourteen schools (Appendix IV) were randomly selected from a list of basic schools in the district obtained from the Municipal Education Directorate of the Ghana Education Service using a random cluster (school type) sampling technique. In each school, all apparently healthy children aged 8 - 11 years were eligible. Exclusion criteria were children with known medical conditions such as diabetes because some medications like insulin treatment in such individuals predisposes them to excess weight gain [26]. None of the children was however excluded from the study.

Simple random sampling technique (balloting) was used to select pupils from each selected school. The children were asked to pick from a bowl, papers that were pre-coded as “yes” or “no”. The number of children selected from each school ranged from 40 to 100. In each class, sampling was stratified on gender so that boys were sampled separately from girls. A total of 790 invitations and consent forms were distributed to those who picked “yes” for parental approval. Out of this, 562 returned with informed parental consent (71.1%) and were sampled.

Data collection

Dietary, physical activity, sedentary behaviours and sleep duration

A pre-tested questionnaire (Appendix V) was used to obtain data from the children by trained research assistants. Each child was given a printed form and pencil to write their responses. Questions and response options were read out in the classroom setting and the children were encouraged to answer independently under the supervision of the research assistants, who also ensured that children responded to the previous question before proceeding to the subsequent questions. This approach was adopted because of the younger children (8 - 9 years), as it helped them to concentrate for a longer period during data collection.

Questions on dietary behaviour were adapted from instruments with documented reliability and validity [27]. Dietary data collected included eating breakfast before school, fruits and vegetables intake, fried foods, consumption of sweetened beverages and soft drinks, and eating sweets, chocolates and chips for snacks. Responses were “No”, “sometimes, 2-3 times a week”; and “Yes, more than 3 times a week for breakfast, fried foods, sweetened beverages and soft drinks. For snacks, fruits and vegetables, responses were “No/rarely”, and “Yes, more than 3 times a week”.

Questions on PA level was collected using a modified version of the International Physical Activity Questionnaire for Children [28]. Questions were grouped in 9 categories. The frequency of performing certain activities one week prior to the study was reported. Each of the 9 items was scored using a scale of 1 to 5 and the mean of the items used to calculate the final summary score. The PA level was categorised as: light (score <2), moderate (score 2–4), and vigorous (score = 5) with a higher score indicating a higher level of activity [28]. The cut-off points for meeting PA recommendations were defined as ≥ 2.9 for boys and ≥ 2.7 for girls [29].

To assess the mode of transportation to and from school, children responded to “how they usually travelled to and from school in the last seven days” with response options “walking/cycling, “bus, car, vehicle” or “both”. The responses were dichotomised as “walking/cycling” and “motorised”. Children responded to the frequency of playing video/computer games. The time spent in viewing television daily was reported in hours and dichotomised as moderate (< 2 hours) and excessive (≥ 2 hours). Screen time was used as a measure of sedentary behaviour. Sleep duration was assessed by asking the usual time of going to bed at night and usual time of waking up in the morning on a typical weekday and weekend or holiday. We dichotomised sleep duration as short (< 9 hours) and sufficient (≥ 9 hours) based on the recommendations by the National Sleep Foundation [30].

Socio-demographic data

A structured questionnaire was used to collect the following data on demographic and household characteristics: gender, age, parents' occupation, household size, source of water and sanitation, and fuel for cooking. Additional data on possession of household assets including television, radio, car/motorbike, refrigerator, washing machine, telephone, computer, cable TV and microwave oven were collected.

Anthropometry

The dependent variable was overweight/ obesity. Body weight and height were collected following standard procedures [31]. Weight was measured to the nearest 0.1 kg with an electron digital scale (Seca 869, GmbH & Co, Germany). Children were weighed in their school uniforms but asked to remove shoes, socks, watches, sweaters, jackets and items in the pockets. Height was measured to the nearest 0.1 cm using the Shorr Board (Shorr Productions, Olney, MD). All measurements were done in duplicates by the same research assistants. From the averages of the duplicate measures, BMI was computed as body weight (in kilogramme) divided by height (in metre square). BMI-for-age z-scores (BAZ) were used to categorise pupils as thin, normal weight, overweight or obese [32]. Data collection was done at the schools' premises.

Statistical analysis

Variables on source of water and sanitation, and household assets were subjected to principal component analysis. The first component was extracted to create wealth scores of the household which were then split into thirds and reported as low SES (lowest third), middle SES (middle third) and high SES (highest third) households using Filmer and Pritchett approach [33]. Categorical variables were reported as counts and percentages, and mean and standard deviations for continuous variables. For group comparisons, chi-square test and student t-test were performed.

For the purposes of analysis, we collapsed overweight (pre-obesity) and obesity into one variable “overweight or obesity” and other weight categories as “non-overweight/obesity”. The proportions of children who were overweight or obese was computed as BAZ > +1.0 SD [32]. Multivariable logistic regressions were used to identify the independent variables: sociodemographic characteristic, dietary, PA and sedentary behaviours associated with overweight or obesity while controlling for age and gender. Variables that correlated ($p < 0.05$) or tended to be associated with the outcome variable (p-values < 0.1) at the univariable levels were selected and included in the models. In the multivariable analyses, only variables that were associated with overweight/obesity ($p<0.05$) were retained. Covariates such as age, gender, SES, PA and dietary habits were forced in all multivariable models. All analyses were performed with Stata 13.0 (College Station Texas. USA) using cases with complete data. Statistical significance was set at $p<0.05$.

5.3 Results

Background and behavioural characteristics

This analysis involves data from 543 children. The sociodemographic characteristics of children are presented in **Table 5.1**. The mean age of children who participated in the study was 9.8 ± 1.0 years with majority being girls (62.4%). Compared with public schools, more children attending private schools live in households in the high SES category (16.2% vs 50.4%; $p<0.0001$).

The behavioural characteristics of the children are summarised in **Table 5.2**. Fruits and vegetables intakes were high (91.5% and 87.5%). Generally, the intakes did not differ by gender or school type. Compared with children who attended public schools, a significantly higher proportion of children in private schools consumed breakfast (78.3% vs 65.7%; p =

0.001), chips, sweets and chocolates snacks (68.7% vs 57.9%; p = 0.009), fried foods (56.2% vs 40.6%; p<0.0001), and sweetened beverages and soft drinks (84.2% vs 74.2%; p = 0.004).

Table 5.1: Background characteristics of children by gender and type of school [a, b]

	Overall	Gender		p-value	Type of school		p-value
		Girls (n=339)	Boys (n=204)		Private (n=272)	Public (n=271)	
Number (%)	543 (100)	339 (62.4)	204 (37.6)	0.265	272 (50.1)	271 (49.9)	
Age (years)	9.8 ± 1.0	9.8 ±1.0	9.9 ± 1.0		9.8 ± 1.0	9.9 ± 1.0	0.725
Age groups				0.217			0.764
8-9	199 (36.7)	129 (38.0)	70 (34.3)		98 (36.0)	101 (37.3)	
10-11	344 (63.4)	210 (62.0	134 (65.7)		174 (64.0)	170 (62.7)	
Household size				**0.020**			0.396
≤ 3 people	31 (5.7)	17 (5.0)	14 (6.9)		16 (5.9)	15 (5.5)	
Between 4 and 6	323 (59.5)	210 (62.0)	113 (55.4)		170 (62.5)	153 (56.5)	
Between 7 and 10	168 (30.9)	94 (27.7)	74 (36.3)		78 (28.7)	90 (33.2)	
More than 10	21 (3.9)	18 (5.3)	3 (1.4)		8 (2.9)	13 (4.8)	
Father's occupation				0.913			**<0.0001**
Artisan	149 (27.4)	96 (28.3)	53 (26.0)		34 (12.5)	115 (42.2)	
Trading	58 (10.7)	36 (10.6)	22 (10.8)		42 (15.4)	16 (5.9)	
Professional	181 (33.3)	112 (33.0)	69 (33.8)		138 (50.7)	43 (15.9)	
Other	117 (21.6)	69 (20.3)	48 (23.5)		42 (15.4)	75 (27.7)	
I do not know	18 (3.3)	12 (3.5)	6 (2.9)		12 (4.4)	6 (2.2)	
Unemployed/retired	20 (3.7)	14 (4.1)	6 (2.9)		4 (1.5)	16 (5.9)	
Mother's occupation				0.311			**0.003**
Artisan	75 (13.8)	46 (13.6)	29 (14.2)		38 (14.0)	37 (13.7)	
Trading	290 (53.4)	187 (55.2)	103 (50.5)		142 (52.2)	148 (54.6)	
Professional [c]	99 (18.2)	57 (16.8)	42 (20.6)		65 (23.9)	34 (12.6)	
Other	35 (6.5)	23 (6.8)	12 (5.9)		12 (4.4)	23 (8.5)	
I do not know	5 (0.9)	5 (1.5)	-		2 (0.7)	3 (1.1)	
Unemployed/retired	39 (7.2)	21 (6.2)	18 (8.8)		13 (4.8)	26 (9.6)	
SES of household				0.639			**<0.0001**
Low	181 (33.3)	116 (34.2)	65 (31.9)		41 (15.1)	140 (51.7)	
Middle	181 (33.3)	115 (33.9)	66 (32.3)		94 (34.6)	87 (32.1)	
High	181 (33.3)	108 (31.9)	73 (35.8)		137 (50.4)	44 (16.2)	

[a] Values presented as numbers and percentages; [b] Mean (SD);
[c] Professionals include doctors, lawyers, engineers, pharmacists and teachers

Table 5.2: Behavioural characteristics of children by gender and type of school [a, b]

	Overall	Gender		p-value	Type of school		p-value
		Girls (n=339)	Boys (n=204)		Private (n=272)	Public (n=271)	
Breakfast				0.343			**0.001**
No	152 (28.0)	95 (28.0)	57 (27.9)		59 (21.7)	93 (34.3)	
2-3days/week	93 (17.1)	64 (18.9)	29 (14.2)		41 (15.1)	52 (19.2)	
3 or more times/week	298 (54.9)	180 (53.1)	118 (57.8)		172 (63.2)	126 (46.5)	
Fruits				0.069			0.213
No/rarely	46 (8.5)	23 (6.8)	23 (11.3)		19 (7.0)	27 (10.0)	
3 or more times/week	497 (91.5)	316 (93.2)	181 (88.7)		253 (93.0)	244 (90.0)	
Vegetables				0.084			0.808
No/rarely	68 (12.5)	36 (10.6)	32 (15.7)		35 (12.9)	33 (12.2)	
3 or more times/week	475 (87.5)	303 (89.4)	172 (84.3)		237 (87.1)	238 (87.8)	
Chips, sweets, chocolates				0.107			**0.009**
No/rarely	199 (36.7)	133 (39.2)	66 (32.4)		85 (31.3)	114 (42.1)	
3 or more times/week	344 (63.3)	206 (60.8)	138 (67.6)		187 (68.7)	157 (57.9)	
Fried foods				0.357			**<0.0001**
No	156 (28.7)	109 (32.1)	47 (23.0)		89 (32.7)	67 (24.7)	
2-3 times/week	124 (22.8)	71 (20.9)	53 (26.0)		30 (11.0)	94 (34.7)	
More than 3 times/week	263 (48.4)	159 (46.9)	104 (51.0)		153 (56.3)	110 (40.6)	
Sweetened beverages and soft drinks				0.787			**<0.0001**
No	104 (19.1)	68 (20.1)	36 (17.7)		46 (16.9)	58 (21.4)	
2-3 times/week	149 (27.4)	92 (27.1)	57 (27.9)		55 (20.2)	94 (34.7)	
More than 3 times/week	290 (53.4)	179 (52.8)	111 (54.4)		171 (62.9)	149 (43.9)	
Mean PA **score** [b]	2.56 ± 0.56	2.55 ±0.54	2.57 ±0.61	0.652	2.52 ± 0.57	2.60 ± 0.57	0.116
PA **level**				0.388			0.995
Low	91 (16.8)	52 (15.3)	39 (19.1)		46 (16.9)	45 (16.6)	
Moderate	444 (81.8)	283 (83.5)	161 (78.9)		222 (81.6)	222 (81.9)	
High	8 (1.4)	4 (1.2)	4 (2.0)		4 (1.5)	4 (1.5)	
Meeting PA guidelines				0.065			**0.006**
No	357 (65.8)	213 (62.8)	144 (70.6)		194 (71.3)	163 (60.1)	
Yes	186 (34.2)	126 (37.2)	60 (29.4)		78 (28.7)	108 (39.9)	
Transport to and from school				0.362			**<0.0001**
Walking/cycling	330 (60.8)	201 (59.3)	129 (63.2)		138 (50.7)	192 (70.9)	
Motorised	213 (39.2)	138 (40.7)	75 (36.8)		134 (49.3)	79 (29.1)	
TV Watch duration							0.056
2 hours or less/day	337 (62.1)	203 (59.9)	134 (65.7)	0.177	158 (58.1)	179 (66.1)	
More than 2 hours/day	206 (37.9)	136 (40.1)	70 (34.3)		114 (41.9)	92 (33.9)	
Playing video/ computer games				**0.030**			0.449
No/rarely	330 (60.8)	218 (64.3)	112 (54.9)		161 (59.2)	169 (62.4)	
3 times or more/week	213 (39.2)	121 (35.7)	92 (45.1)		111 (40.8)	102 (37.6)	
Sleep duration				0.810			0.074
Less than 9 hours	130 (23.9)	80 (23.60)	50 (24.5)		74 (27.2)	56 (20.7)	
9 hours or more	413 (76.1)	259 (76.4)	154 (75.5)		198 (72.8)	215 (79.3)	

[a] Values presented as number and percentages; [b] mean (SD)

The overall mean PA score was 2.56 ± 0.56. The majority of the children (81.8%) engaged in moderate PA with only a few (1.4%) participating in high PA. Overall, about one-third met PA recommendations levels with a higher proportion of girls than boys (37.2% and 29.4%), and more children in public compared with those in private schools (39.9% vs 28.7%; p =0.006).

Additionally, the mode of transport to and from school differed by school type, but not by gender. A significantly higher proportion of children attending private schools used cars, vehicles or bus compared with their counterparts in public schools (49.3% vs 29.1%, p<0.0001). Majority (62.1%) spent less than 2 hours daily viewing television and this did not differ by gender or type of school. Moreover, a higher proportion of boys than girls (45.1% vs 35.7%; p = 0.03) played video and computer games. The majority of the children had sufficient sleep at night; only 23.9% slept for less than 9 hours.

Prevalence of overweight and obesity

With regard to BMI status, 6.1% of the children were thin, 77.5% were normal weight, 9.2% overweight and 7.2% obese (**Table 5.3**). More girls (10.6%) than boys (6.9%) were overweight whereas more boys (9.3%) than girls (5.9%) were obese. Nonetheless, the observed differences were not significant. A significantly higher proportion of children attending private schools were overweight and obese (12.9% and 11.0%) compared with those in public schools (5.5% and 3.3%). Overall prevalence of overweight (and obesity) was 16.4%; 16.5% of girls and 16.2% of boys and by school type 23.9% private and 8.8% public.

Table 5.3: Anthropometric characteristics of children by gender and type of school

	Overall	Gender		p-value	Type of school		p-value
		Girls (n=339)	Boy (n=204)		Private (n=272)	Public (n=271)	
BMI categories (%)				0.230			**<0.0001**
Thinness	33 (6.1)	22 (6.5)	11 (5.4)		18 (6.6)	15 (5.5)	
Normal weight	421 (77.5)	261 (77.0)	160 (78.4)		189 (69.5)	232 (85.6)	
Overweight	50 (9.2)	36 (10.6)	14 (6.9)		35 (12.9)	15 (5.5)	
Obesity	39 (7.2)	20 (5.9)	19 (9.3)		30 (11.0)	9 (3.3)	

BMI: body mass index; Thinness: BAZ < −2SD; Overweight: +1SD < BAZ < +2SD; Obese: + ≥2SD BAZ [32]

Factors associated with overweight and obesity

Table 5.4 shows the factors associated with overweight or obesity. In the gender and age-adjusted analyses, children living in middle SES (OR= 1.87, 1.01–3.48) and high SES households (OR= 2.57, 1.41–4.68) were more likely to be overweight or obese compared with those living in low SES households. Children who attended private schools had higher odds of overweight or obesity compared with those attending public schools (OR= 3.23, 1.95–5.35) while children who viewed television for more than 2 hours daily (OR= 2.08, 1.31–3.28) were twice likely to be overweight or obesity.

Active transport to and from school (OR= 0.39, 0.25–0.62) was associated with decreased likelihood of overweight or obesity as compared with motorised transport. Additionally, longer sleep duration (for at least 9 hours) was associated with decreased odds of overweight or obesity (OR =0.41, 0.25–0.66).

Intake of sweetened beverages and soft drinks, chips, sweets and chocolate for snack, breakfast, fruits and vegetables, and overall PA were not significantly associated with overweight or obesity.

After adjusting for SES, age, gender, PA and dietary habits, attending private school (AOR = 2.44, 1.39–4.29) and viewing television for at least 2 hours daily (AOR = 1.72, 1.05–2.82) were significantly associated with increased likelihood of overweight and obesity whereas sleeping for at least 9 hours (AOR = 0.53, 0.31–0.88), and using active transport to and from school were associated with decreased odds.

Table 5.4: Factors associated with overweight or obesity

	Odds ratio	**95% CI**	**p-value**	**Adjusted Odds Ratio [a]**	**95% CI**	**p-value**
Age group						
8-9	1					
10-11	0.73	0.46 – 1.16	0.183			
Gender						
Girls	1					
Boys	0.97	0.61 – 1.56	0.917			
School type						
Public	1			1		
Private	3.23	1.95 – 5.35	**<0.0001**	2.44	1.39 – 4.29	**0.002**
Household SES						
Low	1			1		
Medium	1.87	1.01 – 3.48	**0.048**	1.30	0.67 – 2.55	0.437
High	2.57	1.41 – 4.68	**0.002**	1.27	0.66 – 2.66	0.494
Eat breakfast						
No	1					
2-3 days/week	1.01	0.51 – 2.00	0.984			
More than 3 days	0.91	0.54 – 1.53	0.717			
Eat fruits						
No	1					
Yes	0.789	0.37 – 1.70	0.544			
Eat vegetables						
No	1					
Yes	0.723	0.38 – 1.37	0.319			
Eat chips, sweets, chocolate snacks						
No	1					
Yes	1.17	0.72 – 1.88	0.529			
Fried foods						
No	1					
2-3 times/week	0.89	0.46 – 1.72	0.728			
More than 3 times/week	1.11	0.65 – 1.89	0.699			
Sweetened beverages and soft drinks	1					
No	1.62	0.79 – 3.30	0.184			
2-3 times/week	1.39	0.72 – 2.68	0.329			
More than 3 times						
PA ***level***						
Low	1					
Moderate	0.83	0.46 – 1.49	0.529			
High	0.62	0.07 – 5.40	0.667			
Mode of transport to/from school						
Motorised	1			1		
Walking/cycling	0.39	0.25 – 0.62	**<0.0001**	0.51	0.31 – 0.82	**0.006**
TV watch duration						
2 hours or less/day	1			1		
More than 2 hours/day	2.08	1.31 – 3.28	**0.002**	1.72	1.05 – 2.82	**0.031**
Sleep duration						
8 hours or less	1			1		
9 hours or more	0.41	0.25 – 0.66	**<0.0001**	0.53	0.31 – 0.88	**0.015**

[a] Models adjusted for: age, gender, SES, PA and dietary behaviours

5.4 Discussion

The results of this study highlight the burden of overweight and obesity, the behavioural and sociodemographic correlates in school children aged 8-11 years living in an urban area in Ghana. Among these urban children, the overall prevalence of overweight or obesity was 16.4%, supporting results from previous studies in South Africa, Tanzania and Kenya [3,34–36], and also in developed countries [12,37]. In a study involving Kenyan urban school children aged 9-11 years, an overweight/obesity prevalence of 20.8% was reported [36]. In another study among school children aged 7-18 years in South Africa [3], overweight or obesity prevalence was of 22.9%. While the prevalence in the present study may be lower than what had been reported in other countries, the results has demonstrated the burden of overweight and obesity in Ghanaian school children considering that the participants in the present study were younger (8-11 years). The observed trend is mostly consistent with the nutrition transition and urbanisation in the region [13].

Positive associations were found between overweight or obesity, SES and attending private school, a finding supportive of results from previous studies [14,17,36,38]. Results from a recent systematic review of 20 studies involving school-aged children from sub-Saharan Africa suggested that children from the highest SES households and attending affluent or private schools were significantly more likely to be overweight or obese [14].

High SES households in developing countries may have access to high energy foods and drinks and processed foods compared with low SES households [39,40]. Moreover, there may be increased use of technology [40] such as cars, electronic devices and indoor entertainments facilities like gaming consoles and televisions in the high SES households compared to low SES households. In this study, significantly higher proportion of children attending private schools were from higher SES households, consumed high energy foods, snacks and drinks, and used motorised transport to and from school compared to children attending public schools, consistent with the aforementioned findings. Additionally, more children in private schools were engaged in sedentary activities compared to those in public schools, though not significant. These dietary and sedentary habits could contribute to weight gain among the children [34]. The results from this study however contrast observations from developed countries where inverse associations exist between SES and overweight or obesity prevalence [37,41,42]. This has been attributed to low consumption of healthy foods [43], less PA and high sedentary behaviours in low SES groups [44].

The present study did not observe an association of overweight or obesity with overall PA participation. However a significant inverse association was found with active transport to and from schools, consistent with previous studies [17,34,45,46]. For example in the International Study of Childhood Obesity, Lifestyle and Environment (ISCOLE) multinational study involving 12 countries, active transport was associated with lower risk of obesity [45]. Children who engage in active transport to school had higher odds of meeting MVPA recommendations [36,47,48]. However other studies also reported conflicting results of an association [11].

A significant inverse association was found between sleep duration and overweight or obesity in the present study, an observation consistent with epidemiological evidence in children and adolescents [5–7,49–51]. For example results from one recent systematic review and meta-analysis indicate short sleep duration increases the risk of childhood obesity [5]. Likewise, results from cross-sectional and prospective studies highlighted consistent inverse associations between sleep duration and the risk of obesity [51]. The underlying mechanisms through which sleep influences weight status are not well-understood. Nonetheless, results from 29 studies conducted in 16 countries involving children and adolescents suggest changes in food intake pathways [51] and excessive media use [52] may play a role. Shorter sleep duration may result in several hormonal changes and metabolic abnormalities [51]. While available evidence suggests that sleep influences weight status through increased appetite, hunger and food intake [53,54], the evidence in support of reduced energy expenditure through decreased PA and increased sedentary behaviour is conflicting [55].

The association of television viewing time and overweight or obesity observed in this study is consistent with previous studies [7,56–59]. Results from a large sample of children and adolescents from mostly low-to-middle income countries demonstrated a positive association between television time and BMI [56]. Similarly, results from a meta-analysis of 14 cross-sectional studies and 24 reports involving 106169 children suggested that increased TV viewing is associated with higher risk of childhood obesity [58]. Also, findings from a review by Tremblay et al. [59] indicated that viewing television for more than two hours a day was associated with unfavourable health outcomes including body composition of children and youth. Although it does not capture the whole spectrum of sedentary behaviour, television viewing, which is most commonly used as a proxy for sedentary behaviour in children and adolescents [59], appears to be more closely associated with weight status in children.

Several potential mechanisms have been proposed to explain the link between television viewing and obesity. These include limited time available to engage in outdoor games leading to overall reduced PA [60,61], increased energy intake via snacking while viewing television as well as exposure to advertisements involving high energy foods and snacks [61,62]. Among US children, hours of television watch was positively associated with total energy intake and inversely associated with PA [61]. Evidence from Australia, the USA and eight European countries suggests an association between overweight in children and the number of advertisements per hour on children television, particularly those advertisements that promote the consumption of energy-dense, nutrient-poor foods [62]. It is however worth noting that playing video and computer games was not associated with being overweight or obese in the present study contrary to results from other studies.

Unlike other studies [10,42,63–65], no evidence of an association was found among overweight/obesity with dietary intake and overall PA. Physical education and PA are mandatory requirement of the basic school curriculum in Ghana and as such all healthy school-going children are expected to fully participate. Nonetheless, data available suggest that only 50% of Ghanaian children and adolescents in schools engage in sports [66]. In the present study, the proportion of children who met recommended PA guidelines was 34.2% consistent with results from Physical Activity Report Card [66], suggesting low PA participation. Despite not meeting the guidelines, it is possible majority of the children engaged in games and sporting activities during and after school hours. This could partly explain the lack of association between PA and overweight or obesity.

5.5 Strengths and limitations

The present study was conducted in an urban district hence the findings can be generalised to apparently healthy children in urban schools in Ghana. Another strength of the study was the objective measurement of weight and height as opposed to self-reported anthropometric data. Furthermore, PA was assessed using PAQ-C, a validated tool for PA assessment among children in the school settings. Additionally, the sleep duration cut-off points used were based on guidelines of a well-recognised organisation.

There were limitations to the interpretation of the findings of the current study. Firstly, the study design was cross-sectional and inferences of causality could not made. Secondly, self-reported data obtained from children and this has its inherent challenges including: social desirability, recall bias and misreporting [67]. The lack of association with dietary intake could be attributed to inaccuracies in measuring dietary data by recall, and under-reporting of snack, fatty foods, and foods rich in carbohydrates, commonly observed in obese individuals [67]. Since data was not collected on quantities of foods and drinks consumed, it is possible that children in the overweight/obesity category consumed these foods less often but in higher quantities. Data on sleep duration could also be a source of potential limitation. However, from the pilot study which was conducted in private and public schools, reading of time/clock was not a challenge in children aged 8-11 years. In addition, grouping the wealth score of the households into thirds may have resulted in ranking the poor and the very poor incorrectly. Nevertheless this methodology is reliable in ranking household SES status in these settings in the absence of income and expenditure data [33]. Another potential limitation worth noting was that the multilevel structure of the data was not accounted for in the analyses. Although several potential covariates including PA and dietary habits were controlled for in the analyses, these were not objectively assessed. Data on an important confounder, parental BMI was not collected. Despite these limitations, the data collected was reliable and reflected what had been reported in the literature on the issues of childhood overweight and obesity.

5.6 Conclusions

Changes in economic status and sociodemographic profiles associated with urbanisation favour lifestyle behaviours shifts towards less PA, increased sedentary habits and unhealthy dietary patterns. Several correlates such as attending private school, short sleep duration, high level of television viewing, and motorised transport were associated with overweight and obesity among school children in urban Ghana. Public health interventions to address childhood overweight and obesity could target both homes and schools. Television viewing may represent one important area of intervention targeting obesity prevention in children. At the home settings, parents could consider restricting time spent in television viewing among school children. We recommend the promotion and support of regular active transport by the schools and families.

5.7 References

1. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2014/06/02. 2014;384(9945):766–81.

2. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3): e92846. DOI: 10.1371/journal.pone.0092846.

3. Negash S, Agyemang C, Matsha TE, Peer N, Erasmus RT, Kengne AP. Differential prevalence and associations of overweight and obesity by gender and population group among school learners in South Africa: a cross-sectional study. *BMC Obes*. 2017;4(1):29. DOI: http://doi.org/10.1186/s40608-017-0165-1.

4. Swinburn B, Egger G, Raza F. Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity 1. *Prev Med. (Baltim)*. 1999;29:563–70.

5. Li L, Zhang S, Huang Y, Chen K. Sleep duration and obesity in children: A systematic review and meta-analysis of prospective cohort studies. *J Paediatr Child Health*. 2017;53(4):378–85.

6. Chen X, Beydoun MA, Wang Y. Is Sleep Duration Associated With Childhood Obesity? A Systematic Review and Meta-analysis. *Obes (Silver Spring)*. 2008;16(2):265–74. DOI:10.1038/oby.2007.63.

7. Katzmarzyk PT, Barreira T V, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11: Results from a 12-country study. *Obes (Silver Spring)*. 2015/07/15. 2015;23(8):1696–702.

8. Huang J-Y, Qi S-J. Childhood obesity and food intake. *World J Pediatr*. 2015;11(2):101–7. DOI: http://doi.org/10.1007/s12519-015-0018-2

9. Candib LM. Obesity and diabetes in vulnerable populations: Reflection on proximal and distal causes. *Ann Fam Med*. 2007;5(6):547–56.

10. Newby PK. Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence. *J Law Med Ethics*. 2007;35(1):35–60.

11. Larouche R, Saunders TJ, John Faulkner GE, Colley R, Tremblay M. Associations between Active School Transport and Physical Activity, Body Composition, and Cardiovascular Fitness: A Systematic Review of 68 Studies. *J Phys Act Heal*. 2014;11(1):206–27. DOI: http://doi.org/10.1123/jpah.2011-0345.

12. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief*. 2010;127(51):1–8.

13. Ziraba AK, Fotso JC, Ochako R. Overweight and obesity in urban Africa: A problem of the rich or the poor? *BMC Public Health*. 2009;9(1):465. DOI: http://doi.org/10.1186/1471-2458-9-465.

14. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. *Clin Obes*. 2016/01/20. 2016;6(1):19–32. DOI: 10.1111/cob.12130.

15. Popkin BM, Gordon-Larsen P. The nutrition transition: Worldwide obesity dynamics and their determinants. *Int J Obes*. 2004;28:S2–9.

16. Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF Macro. 2009. Ghana Demographic and Health Survey 2008. Accra, Ghana: GSS, GHS, and ICF Macro.

17. Aryeetey R, Lartey A, Marquis GS, Nti H, Colecraft E, Brown P. Prevalence and predictors of overweight and obesity among school-aged children in urban Ghana. *BMC Obes*. 2017;4(1):38. DOI:10.1186/s40608-017-0174-0.

18. Mogre V, Gaa PK, Nagumsi R, Abukari S. Overweight , Obesity and Thinness and Associated Factors Among School- Aged Children (5-14 Years) in Tamale. *Eur Sci J*. 2013;9(20):160–75.

19. Ochola S, Masibo PK iny. Dietary intake of schoolchildren and adolescents in developing countries. *Ann Nutr Metab*. 2014;64:24–40.

20. Peltzer K, Pengpid S. Overweight and obesity and associated factors among school-aged adolescents in Ghana and Uganda. *Int J Env Res Public Heal*. 2011/11/11.

2011;8(10):3859–70. DOI: 10.3390/ijerph8103859.

21. Pengpid S, Peltzer K. Overweight and Obesity and Associated Factors among School-Aged Adolescents in Six Pacific Island Countries in Oceania. *Int J Env Res Public Heal*. 2015;12(11):14505–18. DOI: 10.3390/ijerph121114505

22. Mohammed H, Vuvor F. Prevalence of childhood overweight/obesity in basic school in Accra. *Ghana Med J*. 2013/05/11. 2012;46(3):124–7.

23. Ghana Statistical Service. Adentan Municipality: Population and housing census. Vol. 2, District Analytical Report. 2014.

24. Ghana School Survey. Nutrition and obesity report of the Ghana school survey results dissemination workshop. Accra. Department of Nutrition and Food Science, University of Ghana and School of Human Nutrition and Dietetics, McGill University, Montreal; 2012.

25. Daniel WW. Biostatics; a foundation for analysis in the health sciences. 7th Edition. New York: John Wiley and sons. 1999.

26. Onge ES, Miller SA, Motycka C, DeBerry A. A review of the treatment of type 2 diabetes in children. *J Pediatr Pharmacol Ther*. 2015;20(1):4–16.

27. Wilson AM, Magarey AM, Mastersson N. Reliability and relative validity of a child nutrition questionnaire to simultaneously assess dietary patterns associated with positive energy balance and food behaviours, attitudes, knowledge and environments associated with healthy eating. *Int J Behav Nutr Phys Act*. 2008;5(5).

28. Kowalski KC, Crocker PRE, Donen RM. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. Coll Kinesiol Univ Saskatchewan. 2004;(August):1–37.

29. Voss C, Ogunleye AA, Sandercock GRH. Physical Activity Questionnaire for children and adolescents: English norms and cut-off points. *Pediatr Int*. 2013;55(4):498–507.

30. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National sleep foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Heal*. 2015;1(1):40–3. DOI: http://dx.doi.org/10.1016/j.sleh.2014.12.010.

31. World Health Organization. Training Course on Child Growth Assessment. Geneva: WHO; 2008.

32. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. B*ull World Heal Organ*. 2007;85(10):812–9.

33. Filmer D, Pritchett L. Estimating Wealth Effects Without Expenditure Data--Or Tears: An Application to Educational Enrollments in States of India. *Demography*. 2001;38(1):115–32. DOI: http://doi.org/10.1353/dem.2001.0003.

34. Mwaikambo SA, Leyna GH, Killewo J, Simba A, Puoane T. Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. *BMC Public Health*. 2015/12/23. 2015;15:1269. DOI: 10.1186/s12889-015-2598-0.

35. McKersie J, Baard ML. Obesity in 7 - 10-year-old children in urban primary schools in Port Elizabeth. *South African J Sport Med*. 2014;26(2):55.

36. Muthuri SK, Wachira LJ, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. *BMC Public Health*. 2014;14(9):436. DOI: https://doi.org/10.1186/1471-2458-14-436.

37. Sanigorski AM, Bell C, Kremer PJ, Swinburn B. High childhood obesity population in an Australian population. *Obesity*. 2007;15(8):1908–12.

38. Ajayi EO, Elechi HA, Alhaji MA. Prevalence of overweight/obesity among primary school pupils in Urban Centre, Nigeria. *Saudi J Obesity*. 2015;3:59–65.

39. Hanson MD, Chen E. Socioeconomic status and health behaviors in adolescence: A review of the literature. *J Behav Med*. 2007;30(3):263–85.

40. Dinsa GD, Goryakin Y, Fumagalli E, Suhrcke M. Obesity and socioeconomic status in developing countries: a systematic review. *Obes Rev*. 2012;(11):1067–79. DOI: 10.1111/j.1467-789X.2012.01017.x

41. Rogers R, Eagle TF, Sheetz A, Woodward A, Leibowitz R, Song M, et al. The Relationship between Childhood Obesity, Low Socioeconomic Status, and

Race/Ethnicity: Lessons from Massachusetts. *Child Obes*. 2015;11(6):691–5. DOI: https://doi.org/10.1089/chi.2015.0029.

42. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocr Rev*. 2012;33(1):48–70.

43. Drewnowski A. Obesity, diets, and social inequalities. *Nutr Rev*. 2009;67(Suppl. 1):S36–S39.

44. Drenowatz C, Eisenmann JC, Pfeiffer KA, Welk G, Heelan K, Gentile D, et al. Influence of socio-economic status on habitual physical activity and sedentary behavior in 8- to 11-year old children. *BMC Public Health*. 2010;10. DOI: 10.1186/1471-2458-10-214.

45. Sarmiento OL, Lemoine P, Gonzalez SA, Broyles ST, Denstel KD, Larouche R, et al. Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries. *Int J Obes Suppl*. 2016/05/07. 2015;5(Suppl 2):S107-14.

46. Larouche R, Lloyd M, Knight E, Tremblay MS. Relationship Between Active School Transport and Body Mass Index in Grades 4-6 children. *Pediatr Exerc Sci.* 2011 23(3):322-30.

47. Denstel KD, Broyles ST, Larouche R, Sarmiento OL, Barreira T V, Chaput J-P, et al. Active school transport and weekday physical activity in 9–11-year-old children from 12 countries. *Int J Obes Suppl*. 2015;5:S100–6.

48. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert E V, et al. Physical Activity of Children: A Global Matrix of Grades Comparing 15 Countries. *J Phys Act Heal*. 2014;11(s1):S113–25. DOI:http://doi.org/10.1123/jpah.2014-0177.

49. Rosi A, Calestani MV, Parrino L, Milioli G, Palla L, Volta E, et al. Weight status is related with gender and sleep duration but not with dietary habits and physical activity in primary school Italian children. *Nutrients*. 2017;9(6): 579. DOI: https://doi.org/10.3390/nu9060579

50. Morrissey B, Malakellis M, Whelan J, Millar L, Swinburn B, Allender S, et al. Sleep duration and risk of obesity among a sample of Victorian school children. *BMC Public Health*. 2016;16(1):1–8. DOI: http://dx.doi.org/10.1186/s12889-016-2913-4

51. Hart CN, Cairns A, Jelalian E. Sleep and Obesity in Children and Adolescents. *Pediatr*

Clin North Am. 2012;58(3):715–33.

52. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Med*. 2010;11(8):735–42. DOI: http://dx.doi.org/10.1016/j.sleep.2010.02.006.

53. Westerlund L, Ray C, Roos E. Associations between sleeping habits and food consumption patterns among 10-11-year-old children in Finland. *Br J Nutr*. 2009;102(10):1531–7. DOI: 10.1017/S0007114509990730.

54. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. *Sleep*. 2010;33(9):1201–9.

55. Chaput J-P, Tremblay A. Insufficient Sleep as a Contributor to Weight Gain: An Update. *Curr Obes Rep*. 2012;1(4):245–56. DOI: https://doi.org/10.1007/s13679-012-0026-7.

56. Braithwaite I, Stewart AW, Hancox RJ, Beasley R, Murphy R, Mitchell EA. The Worldwide Association between Television Viewing and Obesity in Children and Adolescents: Cross Sectional Study. *PLoS One*. 2013;8(9). DOI: 10.1371/journal.pone.0074263.

57. Peck T, Scharf RJ, Conaway MR, DeBoer MD. Viewing as little as 1 hour of TV daily is associated with higher change in BMI between kindergarten and first grade. *Obesity*. 2015;23(8):1680–6.

58. Zhang G, Wu L, Zhou L, Lu W, Mao C. Television watching and risk of childhood obesity: A meta-analysis. *Eur J Public Health*. 2016;26(1):13–8.

59. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2011;8(1):98. DOI: http://doi.org/10.1186/1479-5868-8-98

60. Dutra GF, Kaufmann CC, Pretto ADB, Albernaz EP. Television viewing habits and their influence on physical activity and childhood overweight. *J Pediatr (Rio J)*. 2015;91(4):346–51. DOI: http://dx.doi.org/10.1016/j.jped.2014.11.002

61. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television Watching, Energy Intake, and Obesity in US Children. *Arch Pediatr Adolesc Med*.

2001;155:360–5.

62. Lobstein T, Dibb S. Evidence of a possible link between obesogenic food advertising and child PubMed Commons. *Obes Rev*. 2005;6(3):203–8.

63. Hu FB. Resolved: There is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev*. 2013;14(8):606–19.

64. Zakrzewski JK, Gillison FB, Cumming S, Church TS, Katzmarzyk PT, Broyles ST, et al. Associations between breakfast frequency and adiposity indicators in children from 12 countries. *Int J Obes Suppl*. 2016/05/07. 2015;5(Suppl 2):S80-8.

65. Mushtaq MU, Gull S, Mushtaq K, Shahid U, Shad MA, Akram J. Dietary behaviors, physical activity and sedentary lifestyle associated with overweight and obesity, and their socio-demographic correlates, among Pakistani primary school children. *Int J Behav Nutr Phys Act*. 2011;8(1):130. DOI: https://doi.org/10.1186/1479-5868-8-130

66. Ocansey R, Aryeetey R, Sofo S, Delali MB, Pambo P, Nyawornota VK. Results From Ghana's 2014 Report Card on Physical Activity for Children and Youth. *J Phys Act Health*. 2014;11(Supp 1):21–5.

67. Heitmann BL, Lissner L. Dietary underreporting by obese individuals-is it specific or non-specific? *BMJ*. 1995;311:986–9.

CHAPTER 6

Diagnostic accuracy of body mass index in defining obesity: analysis of cross-sectional data from Ghanaian children

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Abstract

Introduction: Screening methods for childhood obesity are based largely on published BMI criteria. Nonetheless, their accuracy in African children is largely unknown. The diagnostic accuracies of the WHO, CDC, and IOTF BMI-based criteria in defining obesity using the deuterium dilution technique as criterion method was evaluated in a sample of primary school children from Ghana.

Methods: Data on anthropometric indices and body fat were collected from 183 children aged 8-11 years in a cross-sectional study. The sensitivity, specificity, and predictive values were calculated. Receiver operating characteristics area under the curve (AUC) was used to evaluate the overall accuracy and performance analysis of the BMI criteria to discriminate children with excess body fat from those with normal body fat.

Results: The overall sensitivity of WHO, CDC, and IOTF criteria were 59.4% (95% CI: 40.6-76.3), 53.1% (34.7-70.9), and 46.9% (29.1-65.3) respectively. By contrast, the overall specificity was high, ranging from 98.7% by WHO to 100.0% by IOTF. The AUC were 0.936 (0.865-1.000), 0.924 (0.852-0.995), and 0.945 (0.879-1.000) by the WHO, CDC, and IOTF criteria respectively for the overall sample. The prevalence of obesity by the WHO, CDC, IOTF and deuterium-derived PBF were 11.5%, 10.4%, 8.2% and 17.5% respectively, with significant positive correlations between the BMI z-scores and PBF.

Conclusions: The BMI-based criteria were largely specific but with moderate sensitivities in detecting excess body fat in Ghanaian children. To improve diagnostic accuracy, direct measurement of body fat and or other health risk factors should be considered in addition to BMI.

6.1 Introduction

The adverse health effects of obesity are related to excess body fat, calling for accurate methods for diagnosis, particularly among children. At present, the screening methods for obesity are based largely on BMI. Despite its inherent limitations to distinguish between fat mass (FM) and fat free mass (FFM), both of which contribute to body weight [3], BMI has been traditionally used in epidemiological studies as a proxy for adiposity due to its relative simplicity and affordability. Nonetheless, BMI is a measure of excess weight, not excess body fat and changes with age, gender and maturation in children [3].

Different BMI criteria have been developed for the classification of weight status. These are: the WHO reference, derived from the z-score of the mean BMI-for-age after computing standard deviations [4]; the CDC, based on the BMI-for-age percentile methodology [5]; and the IOTF [6] definition from the lambda, mu, and sigma (LMS) methodology for the calculation of the z-score.

A number of reference methods are available for measurement of body fatness. These include: under water weighing, dual-energy X-ray absorptiometry (DXA), total body potassium, air displacement plethysmography, bioelectrical impedance, and isotope dilution method [7]. Some of these methods are limited to laboratory settings, costly and may not be suitable for children [7,8]. The isotope dilution method is one of the safe, non-invasive methods for body composition assessment that enables measurements of body fat under free-living conditions [8].

Most studies among children and adolescents in Africa apply BMI-based criteria to estimate overweight and obesity [9]. Nonetheless, at the continental level, the diagnostic accuracy of the published BMI references to detect excess body fat among children is largely unknown;

only few studies have compared the BMI criteria against a criterion measure of body fat [10,11]. The present study aimed to evaluate the diagnostic accuracy of the CDC-, IOTF- and WHO- based criteria in defining obesity in a sample of Ghanaian primary school children using the deuterium dilution technique as a criterion method.

6.2 Methods

This was a cross-sectional analysis of 8-11 year old school children in six primary schools in an urban area in Ghana. Data on anthropometric indices and PBF were collected.

Study population

A convenient sample of 183 children from three private and three public schools in the Adentan Municipality of the Greater Accra Region of Ghana was selected. The participants were a sub-sample from a larger study on childhood obesity involving 543 children from 14 schools and comprised 111 girls and 72 boys. Details of the recruitment and selection of participants have been previously described in **Chapter 5** [12].

Data collection

Anthropometry

Body weight and height were measured in duplicates following standard protocols (details in **Chapter 5**).The means of the duplicate measurements were used to compute BMI. BMI-for-age was calculated and obesity defined as BMI-for-age z-score ≥ +2.0 SD by WHO [4]; BMI-for-age percentile > 95^{th} percentile by CDC [5]; and BMI-for-age z-score adjusted to reflect the cut-off point at age 18 years by IOTF [6].

Total body water for percent body fat estimation

Body fat of participants was assessed using the deuterium dilution method with Fourier transform infrared spectrometer (FTIR) following the IAEA guidelines [13]. Children were asked not to eat for at least two hours prior to data collection. Pre-dose saliva samples were collected from children after which each child received a dose of given weight of deuterium oxide labelled water (99.8% purity, Cambridge Isotope Laboratories Inc. Andover, MA) based on their body weight [13] to drink. The doses were prepared in batches prior to the study. No food or drinks were allowed during the equilibration period. Two additional samples were collected 3 and 3.5 hours after drinking the dose. The samples were transported on ice to the laboratories and stored at - 20°C prior to analysis.

Deuterium enrichment of the saliva samples were measured using FTIR (Shimadzu 8300, Vienna, Austria) at the Ghana Atomic Energy Commission following IAEA guidelines [13]. Samples were analysed in duplicates and the mean enrichment for each time point was calculated. Total body water (TBW) was calculated from the mean deuterium enrichment at time zero with the use of a correction factor (deuterium space) for non-aqueous dilution of deuterium oxide using the age-and gender- specific values for the hydration of FFM for children [14]. Where only one time point data was available, that was used to calculate the TBW.

Deuterium space = dose ingested (mg)/deuterium enrichment of saliva (mg/kg)

TBW (kg) = deuterium space/1.041

FFM was computed from the TBW as:

FFM (kg) = TBW (kg)/age-and gender- specific hydration factor

The FM was calculated as the difference between body weight and the FFM and expressed as a percentage of the body weight.

FM = Weight (kg) – FFM (kg); expressed as percentage (PBF)

There is no universally accepted definition for excess body fat using isotope dilution methods in children. For the purposes of this analysis, excess body fat was defined as body fat > 25% for boys and >30 % for girls respectively [15].

Ethical considerations

Ethics approvals were obtained from the Senate Research Committee of the University of Western Cape (ID NO: 15/5/5) and Ethical Review Committee of the Ghana Health Service (ID NO: GHS-ERC: 01/07/13). Approval was also obtained from the Municipal Education Directorate of the Ghana Education Service and from the heads of participating schools. Since the study involved children minors, written informed consents were obtained from the parents or legal guardians. They were given assurance on the safety of the deuterium dilution techniques. They were informed that toxic effects of deuterium were not expected at the given doses to be used in the study. Verbal assent was given by each participating child after explaining the study.

Statistical analysis

All analyses were performed with Stata 13.0 (College Station Texas. USA). Results are expressed as means (± SDs) or medians (and 25^{th}-75^{th} percentiles) for continuous variables, while categorical variables are reported as frequencies and percentages. Chi-square test, Student t-test, and the Mann-Whitney U test were used for comparison as appropriate. Spearman's correlation was used to assess the relationship between PBF and WHO, CDC, and IOTF BMI-for-age z-scores. The performance of these published BMI criteria to discriminate children with excess body fat from those with normal body fat was evaluated. The sensitivity (the proportion of children with excess body fat who have high BMI-for-age z-scores), specificity (the proportion of children who do not have excess body fat and who do not have high BMI-for-age z-scores), positive predictive value (proportion of children with high BMI-for-age z-scores who have excess body fat), negative predictive value (proportion of children with low BMI-for-age z-scores who do have excess body fat), and Receiver operating characteristics (ROC) curves and area under the curves for the BMI references, were computed. Statistical significance was set at p <0.05.

6.3 Results

Descriptive characteristics and obesity prevalence of children

The descriptive characteristics and prevalence of obesity by the different diagnostic criteria are summarised in **Table 6.1**. The median (25^{th}-75^{th} percentiles) age of the study participants was 10 (9-10) years. No significant difference was observed between boys and girls in the median weight, height and BMI. However, girls had significantly higher PBF than the boys (21.3% vs 14.7%; p < 0.0001). Obesity prevalence varied by gender and the criteria used, although not statistically significant.

Table 6.1: Descriptive characteristics and obesity prevalence of children based on different diagnostic criteria

	Overall (N = 183)	Boys (N = 72)	Girls (N = 111)	p-value
Median Age (y)	10 (9, 10)	10.0 (9, 10)	10.0 (9, 10)	
Median Weight (kg)	30.7 (27.2, 37.5)	29.9 (27.5, 34.9)	31.3 (27.1, 39.1)	0.339
Mean Height (cm)	139.5 ± 8.2	138 ± 7.2	140.1 ± 8.81	0.232
Median BMI (kg/m^2)	15.7 (14.8, 18.0)	15.5 (14.8, 17.1)	16.0 (14.5, 18.7)	0.617
Median BMI z-score	-0.40 (-1.09, 0.63)	-0.51 (-1.08, 0.19)	-0.22 (-1.16, 0.68)	0.387
Median PBF (%)	19.3 (14.1, 26.1)	14.7 (11.6, 21.1)	21.3 (16.7, 27.4)	**<0.0001**
WHO, % (n)	11.5 (21)	13.9 (10.0)	9.9 (11)	0.409
CDC, % (n)	10.4 (18)	11.1 (8)	9.0 (10)	0.641
IOTF, % (n)	8.2 (15)	8.3 (6)	8.1 (9)	0.957
D2O, % (n)	17.5 (32)	16.7 (12)	18.0 (20)	0.814

Data are presented as median (25^{th}, 75^{th} percentiles); mean ± SD; Percentage (frequency); CDC: Centers for Disease Control and Prevention; D2O: Deuterium oxide; IOTF: International Obesity Task Force; WHO: World Health Organization; BMI: body mass index; PBF: percent body fat

The overall prevalence based on the WHO, CDC, IOTF, and PBF were 11.5%, 10.4%, 8.2% and 17.5% respectively. Across criteria, the overall highest obesity prevalence was by PBF; 18.0% girls and 16.7% boys were classified as obese ($p = 0.814$). Obesity prevalence based on the WHO criteria was 13.9% among boys and 9.9% among girls ($p = 0.409$). Using the CDC and IOTF cut-offs, the prevalence among boys were 11.1% and 8.3%, and 9.0% and 8.1% among girls respectively. Except for the deuterium method, all diagnostic criteria classified higher proportion of boys as obese compared with girls, although the differences were not significant. There were significant positive correlations between the BMI z-scores and PBF (**Figures 6.1, 6.2, & 6.3**). Across criteria, the correlation coefficients rho (ρ) were 0.638, $p < 0.0001$; 0.635, $p < 0.001$ and 0.625, $p < 0.0001$ for WHO, CDC and IOTF respectively. By gender, the corresponding values for WHO, CDC, and IOTF were higher in girls (0.694, 0.713, 0.719, all $p < 0.0001$) compared with boys (0.550, 0.532, and 0.562, all $p < 0.0001$).

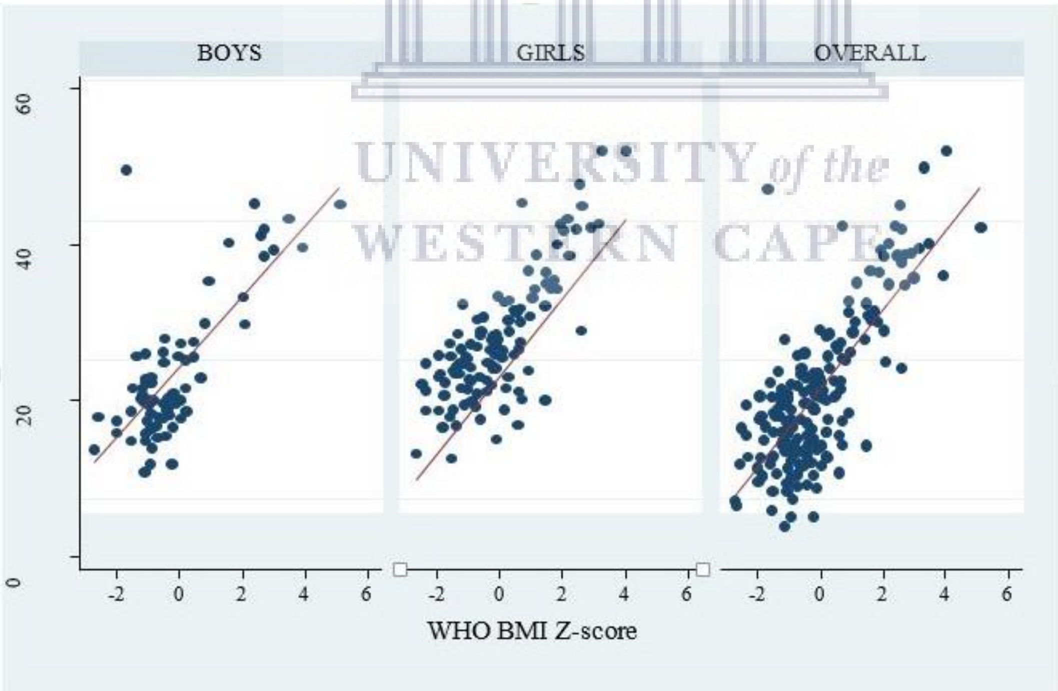

Figure 6.1: Spearman correlation between PBF measured by the deuterium dilution method and WHO BMI z-score

Legend: The dots represent PBF and the red line represent the fitted values.

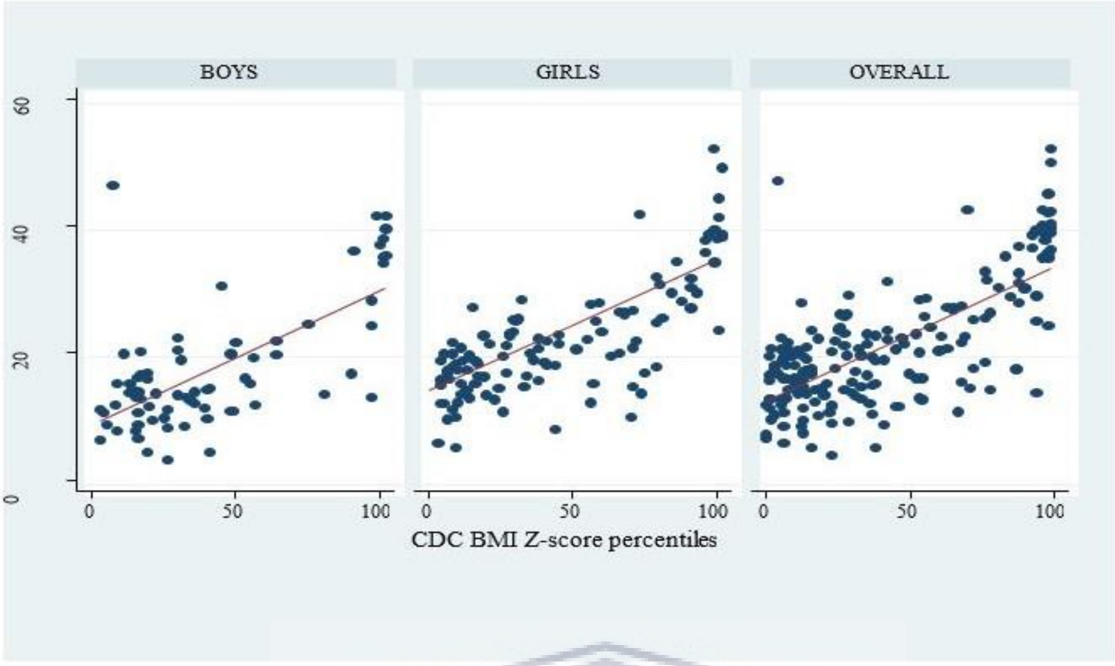

Figure 6.2: Spearman correlation between PBF measured by the deuterium dilution method and CDC BMI z-score percentiles

Legend: The dots represent PBF and the red line represent the fitted values

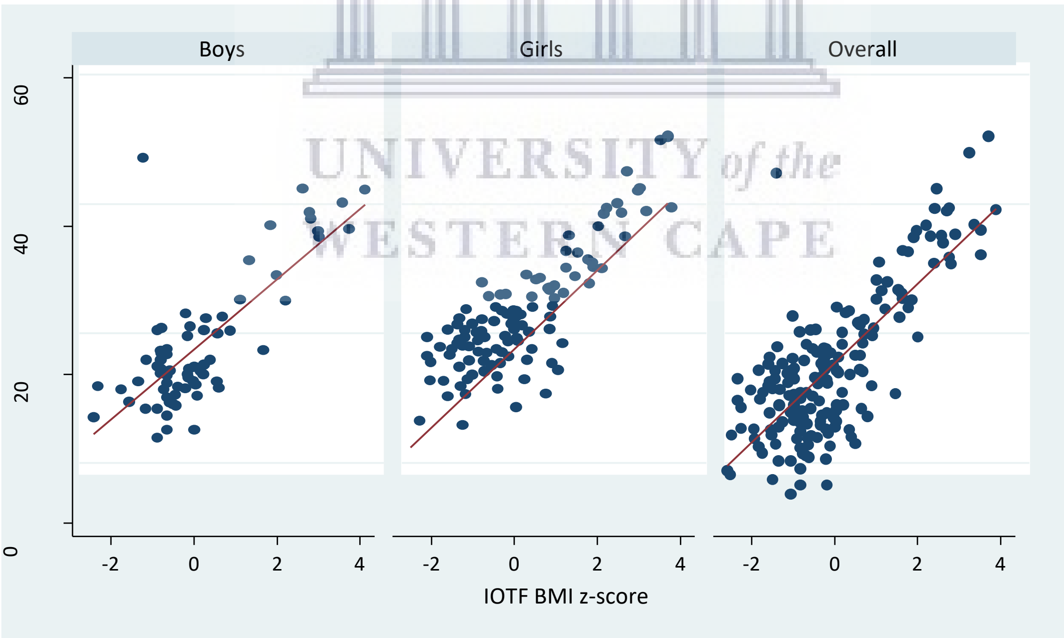

Figure 6.3: Spearman correlation between PBF measured by the deuterium dilution method and IOTF BMI z-score

Legend: The dots represent PBF and the red line represent the fitted values

Diagnostic accuracy and performance of BMI criteria for defining obesity

The diagnostic performance of BMI-based criteria for classifying deuterium method-based obesity is presented in **Table 6.2**. The overall sensitivity was 59.4% (40.6-76.3), 53.1% (34.7-70.9), and 46.9% (29.1-65.3) by WHO, CDC and IOTF criteria respectively. The sensitivity was high among boys with the WHO criterion 75.0% (42.8-94.5) and low among girls using the CDC and IOTF criteria 45.0% (23.1-68.5). By contrast, the specificity was high across the criteria in the overall sample ranging from 98.7% (95.3-99.8) by WHO to 100.0 (97.6-100.0) by IOTF. Furthermore, the positive predictive values (PPV) in the overall sample ranged from 90.5% (69.6-98.8) by WHO and 100.0% (80.5-100.0) by IOTF. The negative predictive values (NPV) were higher with WHO based criterion; 91.9% (86.7-95.7) and 89.9% (84.3-94.0) by IOTF. The sensitivity, specificity, PPV and NPV were similar across all criteria by gender.

Table 6.2: Diagnostic accuracy of BMI-based criteria for defining obesity in children using the deuterium-derived PBF as a reference method

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
		Overall		
WHO	59.4 (40.6-76.3)	98.7 (95.3-99.8)	90.5 (69.6-98.8)	91.9 (86.7-95.7)
CDC	53.1 (34.7-70.9)	99.3 (96.4-99.9)	94.4 (72.7-99.9)	90.9 (72.7-99.9)
IOTF	46.9 (29.1-65.3)	100.0 (97.6-100.0)	100.0 (80.5-100.0)	89.9 (84.3-94.0)
		Boys		
WHO	75.0 (42.8-94.5)	98.3 (91.1-99.9)	90.0 (55.5-99.8)	95.1 (86.5-99.0)
CDC	66.7 (34.9-90.1)	100.0 (94.0-100.0)	100.0 (63.1-100.0)	93.8 (84.8-98.3)
IOTF	50.0 (21.1-78.9)	100.0 (94.0-100.0)	100.0 (54.1-100.0)	90.9 (81.3-96.6)
		Girls		
WHO	50.0 (27.2-72.8)	98.9 (94.0-99.9)	90.9 (58.7-99.8)	90.0 (82.4-95.1)
CDC	45.0 (23.1-68.5)	98.9 (94.0-99.9)	90.0 (55.5-99.8)	89.1 (81.3-94.4)
IOTF	45.0 (23.1-68.5)	100.0 (96.0-100.0)	100.0 (66.4-100.0)	89.2 (81.5-94.4)

CI: confidence interval; CDC: Centers for Disease Control and Prevention; IOTF: International Obesity Task Force; WHO: World Health Organization; PPV: positive predictive value; NPV: negative predictive value; PBF: percent body fat

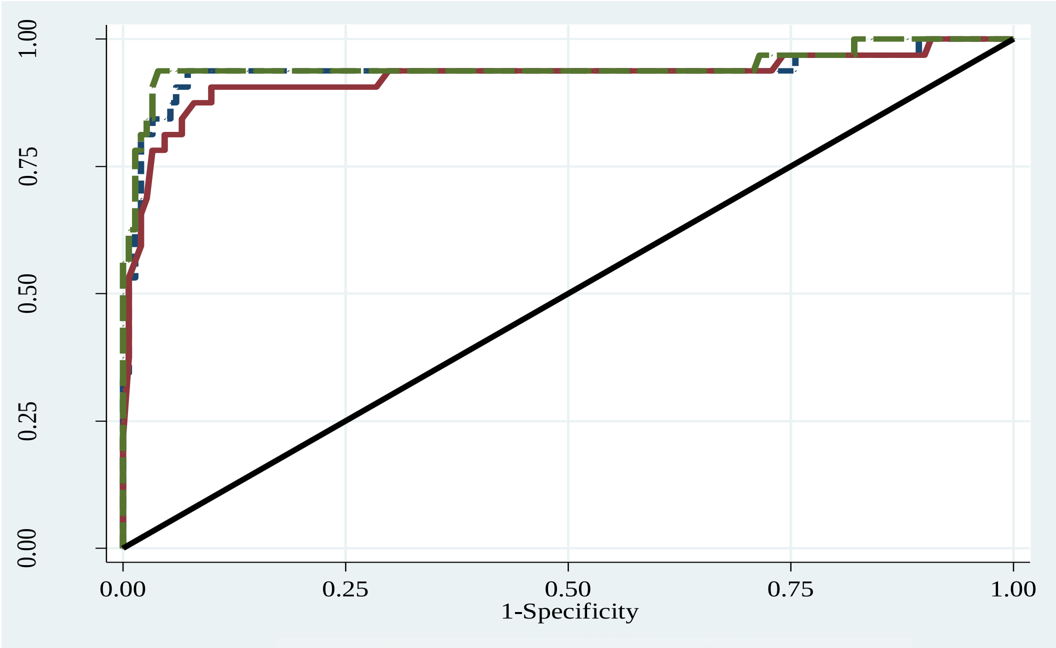

Figure 6.4: Receiver operating characteristics curve for WHO, CDC, and IOTF criteria

Legend: Long broken forest green line: ROC area for IOTF, AUC = 0.945. Dash navy line: ROC area for WHO, AUC = 0.936. Solid maroon line: ROC area for CDC, AUC = 0.924. Diagonal line: ROC area for reference, AUC = 0.500.

The overall accuracy and performance analysis of the BMI-for-age z-score and BMI-for-age percentiles in identifying obese children is indicated by the Receiver operating characteristics (ROC) area under the curve (AUC). The AUC areas were 0.936 (0.865-1.000), 0.924 (0.852-0.995), and 0.945 (0.879-1.000) by the WHO, CDC, and IOTF criteria respectively for the overall sample (**Figure 6.4**). The AUC did not differ in the overall sample and also by gender (Appendix VII, Supplementary Figures 1, 2, & 3) for all criteria.

Empirical cut-point estimation for defining obesity

Using the Youden index J point approach of the empirical cut-point estimation (**Table 6.3**), the WHO, CDC, and IOTF cut-points that optimise sensitivity, specificity, PPV and NPV for obesity were 0.68, 69.5% and 0.50 respectively for the overall sample. The corresponding optimal cut-offs were 0.86, 87.5%, and 0.50 for boys; and 0.68, 69.5%, and 0.50 for girls.

Table 6.3: Optimal cut-point estimation of WHO, CDC, and IOTF criteria for diagnosis of childhood obesity

	Cut-off	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	AUC (95% CI)
			WHO			
Overall	0.68	93.8 (79.2-99.2)	92.7 (87.3-96.3)	73.2 (57.1-85.8)	98.6 (95.0-99.8)	0.932 (0.885-0.980)
Boys	0.86	91.6 (61.5-99.8)	96.7 (88.5-99.6)	84.6 (54.5-98.1)	98.3 (90.9-99.6)	0.942 (0.857-1.000)
Girls	0.68	95.0 (75.1-99.9)	90.1 (82.1-95.4)	67.9 (47.6-84.1)	98.8 (93.5-99.7)	0.926 (0.868-0.983)
			CDC			
Overall	69.5	90.6 (75.0-98.0)	90.1 (84.1-94.3)	65.9 (50.1-79.5)	97.8 (93.8-99.5)	0.903 (0.847-0.960)
Boys	87.5	83.3 (51.6-97.9)	91.7 (81.6-97.2)	66.7 (38.4-88.2)	96.5 (87.9-99.6)	0.875 (0.759-0.991)
Girls	69.5	95.0 (75.1-99.9)	89.0 (80.7-94.6)	65.5 (45.7-82.1)	98.8 (93.4-99.9)	0.920 (0.813-0.979)
			IOTF			
Overall	0.50	50.0 (31.9-68.1)	100.0 (97.6-100.0)	100.0 (79.4-100.0)	90.4 (84.9-94.4)	0.750 (0.660-0.840)
Boys	0.50	58.3 (27.7-84.8)	100.0 (94.0-100.0)	100.0 (59.0-100.0)	92.3 (82.5-97.5)	0.792 (0.646-0.937)
Girls	0.50	45.0 (21.1-68.5)	100.0 (96.0-100.0)	100.0 (66.4-100.0)	89.2 (81.5-94.5)	0.725 (0.613-0.837)

CI: confidence interval; WHO BMI-for-age z-score: World Health Organization Body mass index for age z-score; CDC BMI-for-age: Centers for Disease Control and Prevention; IOTF: International Obesity Task Force BMI-for-age: BMI-for-age: body mass index-for-age; PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curves

6.4 Discussion

This study provides the findings of the accuracy of the published BMI z-score for WHO, CDC, and IOTF to detect excess body fat in pre-adolescent school children in Ghana. The results show that BMI as an indicator of obesity had high specificity with mostly high predictive values across diagnostic criteria. Nonetheless, none of the published criteria achieved optimal rates of sensitivity. Across criteria, at least 40% of the children who were obese were misclassified. Area under the ROC curve indicated that BMI is an acceptable tool for diagnosing excess body fat. Moreover, the diagnostic accuracy of these references were similar across the overall samples and when stratified by gender. We observed positive correlation between the deuterium-derived PBF and the published BMI z-score. Furthermore, the optimal BMI cut-off points for defining obesity, as determined for the present sample were lower; 0.86 for boys, 0.68 for both girls and overall by WHO reference; 87.5% for boys, 69.5% for both girls and overall samples by CDC reference; and 0.50 for boys, girls, and overall sample by IOTF reference.

Several factors are known to influence the diagnostic performance of BMI-based criteria to detect excess body fat. These include the methods of body composition assessment, the cut-offs to define excess percent body fat in the evaluation of the BMI-criteria, and characteristics of the references population such as ethnicity, maturity and gender [16–20]. The low-to-moderate sensitivity and high specificity reported in the present study are generally consistent with the literature [11,17,21–24]. Furthermore, BMI underestimated adiposity in South Asian children while among children of African origin, body fat was overestimated [18,19]. The present results contrast findings from a systematic review and meta-analysis of the diagnostic performance of BMI, where a pooled sensitivity of 73.0% and specificity of 93.0% were reported [25].

Although the methodologies for assessing body fat may differ, many studies have consistently reported low sensitivity of IOTF criterion compared with other criteria for diagnosing childhood obesity [17,23,26,27]. For example, using multisite skinfold thicknesses as the measure of body fat, Zimmermann et al. [23] found that IOTF criterion had low sensitivity relative to the CDC in a national sample of 6-12 year old Swiss children. Deurenberg-Yap et al. [17] also observed lower overall prevalence of obesity by IOTF criterion compared to CDC criterion in Asian adolescents. In another study, BMI percentiles had low sensitivity but high specificity in Italian school children aged 8-12 years [22]. On the other hand, BMI showed higher sensitivities and moderate specificities in Brazilian children aged 7-12 years. The authors further observed that the WHO-based criterion was the least sensitive compared to the IOTF [28], contrary to the present study where the IOTF was least sensitive among the three BMI criteria. Among African children, the evidence is limited. A 2018 pooled analysis of data from a relatively large sample of African school children aged 8-11 years from eight countries reported low sensitivity (29.7%) and high specificity (99.7%) for the WHO BMI definition [11], using deuterium oxide method as reference criterion for body fat [11]. In comparison to the aforementioned African study, the present study reported higher sensitivity (59.4%) but with similar specificity (98.7%).

The strong positive correlations observed between BMI and percent body fat was similar to results from previous studies [26,29–31]. In a cohort of Swiss school children aged 8-11 years, BMI and body fat were highly correlated particularly in the upper half of the BMI regardless of gender, suggesting that BMI is a good proxy for body fat in children with higher BMI. The authors concluded that BMI could be a good surrogate for body fat in pre-pubertal children [29]. Results from studies that applied body fat derived from deuterium oxide are inconsistent. While the present results echo those among Moroccan adolescents [31], they are contrary to results among Brazilian [32], Australian and Sri Lankan children [33], where low to moderate associations between body fat and BMI indices were found. Contrary to findings from previous studies [16,17,21], we did not find differences between boys and girls with respect to indices of diagnostic accuracy, although boys tended to have higher values relative to girls.

In comparison to the published BMI cut-offs to diagnose obesity, the derived optimal cut-off points for the present sample were lower across all criteria. This is not surprising given that the BMI reference cut-offs were generated from diverse populations. The present results suggest that it is appropriate to develop country/ and population-specific BMI cut-off points to improve diagnosis of childhood obesity instead of the universally references. For example while the present cut-offs for WHO (0.86 for boys and 0.68 for girls) is similar to that reported in an African sample [11], in an Asian population these were 1.86 for boys and 1.38 for girls [17].

These findings have public health implications in the management of childhood obesity. In adults, low to normal BMI with increased body fat is associated with an elevated risks for cardiovascular disease [19,34,35]. The results from the present study indicate that many children with normal BMI-for-age z-scores or percentiles had excess body fat hence BMI could be very useful for detecting excess body fat. Nonetheless, where BMI-for-age is the only criterion in screening children, low sensitivity and moderate sensitivity could lead to misclassification. This is because BMI cannot discriminate body fat and FFM (and the high BMI could be due to high FFM and not necessarily excess fat). This misclassification would lead to missed opportunities for interventions.

6.5 Strengths and limitations

This is one of the first studies to evaluate the diagnostic performance of the BMI-based reference criteria to detect obesity in primary school children from in Ghana. The use of deuterium to assess body fat in the children is another strength of this study. The deuterium dilution technique employed in the study is safe, accurate and non-invasive for assessing body composition and obtaining data on body fat and FFM. There are limitations of the present study that need to be considered in interpretation of the findings. The prohibitive costs of deuterium dilution techniques precluded recruitment of a random-representative large sample with broader age range and generation of body fat percentiles. Additionally, the results could only be generalised to children aged 8-11 years. There is currently no definite cut-off for body fat with deuterium technique. However, the criteria used [15] is associated with elevated risk of cardiovascular disease and has been consistently used. Moreover, the optimal cut-offs derived in the present study have not been cross-validated in an independent sample.

6.6 Conclusions

The prevalence of obesity varied with the diagnostic criteria applied. The published BMI references were related to PBF in children aged 8-11 years indicating that BMI could be used as a proxy of body fat for screening purposes in this population. The current BMI references for diagnosing obesity in children are largely specific but less sensitive in detecting excess body fat in Ghanaian children. These apparent limitations should be considered by healthcare professionals in diagnosing children. To improve diagnostic accuracy and minimise misclassification, more than one reference could be employed in addition to the direct assessment of body fat and or other health risk factors where practicable.

6.7 References

1. Reilly JJ. Health consequences of obesity. *Arch Dis Child*. 2003;88(9):748–52.

2. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. *Int J Obes*. 2011;35(7):891–8.

3. Wells JCK. A Hattori chart analysis of body mass index in infants and children. *Int J Obes Relat Metab Disord*. 2000;24(3):325–9.

4. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Heal Organ*. 2007;85(10):812

5. Kuczmarski R, Ogden CL, Guo S, Grummer-Strawn L, Flegal K, Al. E. CDC Growth Charts for the United States: methods and development. *Vital Health Stat*. 2000. p. 1–190.

6. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1–6.

7. Goran MI. Measurement Issues Related to Studies of Childhood Obesity: Assessment of Body Composition, Body Fat Distribution, Physical Activity, and Food Intake. *Pediatrics*. 1998;101:505–18.

8. Duren DL, Sherwood RJ, Czerwinski SA, Lee M, Choh AC, Siervogel RM, et al. Body composition methods: Comparisons and interpretation. *J Diabetes Sci Technol*. 2008;2(6):1139–46.

9. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3):1–26. DOI: 10.1371/journal.pone.0092846.

10. Craig E, Reilly J, Bland R. Body fatness or anthropometry for assessment of unhealthy weight status? Comparison between methods in South African children and adolescents. *Public Heal Nutr*. 2012/10/05. 2013;16(11):2005–13.

11. Diouf A, Adom T, Aouidet A, El Hamdouchi A, Joonas NI, Loechl CU, et al. Body mass index vs deuterium dilution method for establishing childhood obesity prevalence, Ghana, Kenya, Mauritius, Morocco, Namibia, Senegal, Tunisia and United Republic of Tanzania. *Bull World Health Organ*. 2018; 96:772–781. DOI: http://dx.doi.org/10.2471/BLT.17.205948.

12. Adom T, De Villiers A, Puoane T, Kengne AP. Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana. *BMC Obesity*. 2019; 6:14. DOI: https://doi.org/10.1186/s40608-019-0234-8

13. IAEA. Introduction to body composition assessment using the deuterium dilution technique with analysis of saliva samples by Fourier transform infrared spectrometry. *IAEA Hum Heal* Ser No. 12. 2010;(12):96.

14. IAEA. Assessment of body composition and total energy expenditure in humans using stable isotope technique. *IAEA Hum Heal* Ser No. 10. 2009;3(3):133.

15. Williams DP, Going SB, Lohman TG, Harsha DW, Srinivasan SR, Webber LS, et al. Body Fatness and Risk for Elevated Blood-Pressure, Total Cholesterol, and Serum-Lipoprotein Ratios in Children and Adolescents. *Am J Public Health*. 1992;82(3):358–63.

16. Neovius MG, Linné YM, Barkeling BS, Rossner SO. Sensitivity and specificity of classification systems for fatness in. *Am J Clin Nutr*. 2004;80(3):597-603.

17. Deurenberg-Yap M, Niti M, Foo LL, Ng SA, Loke KY. Diagnostic accuracy of anthropometric indices for obesity screening among Asian adolescents. *Ann Acad Med Singapore*. 2009;38(1):3–8.

18. Hudda MT, Nightingale CM, Donin AS, Fewtrell MS, Haroun D, Lum S, et al. Body mass index adjustments to increase the validity of body fatness assessment in UK Black African and South Asian children. *Int J Obes*. 2017;41(7):1048–55.

19. Nightingale CM, Rudnicka AR, Owen CG, Cook DG, Whincup PH. Patterns of body size and adiposity among UK children of South Asian, black African-Caribbean and white European origin: Child Heart And health Study in England (CHASE Study). *Int J Epidemiol*. 2010/11/04. 2011;40(1):33–44.

20. Liu A, Byrne NM, Kagawa M, Ma G, Poh BK, Ismail MN, et al. Ethnic differences in

the relationship between body mass index and percentage body fat among Asian children from different backgrounds. *Br J Nutr*. 2011;106(9):1390–7.

21. Reilly JJ, Dorosty AR, Emmett PM, Avon Longitudinal Study of Pregnancy and Childhood Study Team. Identification of the obese child: adequacy of the body mass index for clinical practice and epidemiology. *Int J Obes Relat Metab Disord*. 2000; 24(12):1623-7.

22. Bedogni G, Iughetti L, Ferrari M, Malavolti M, Poli M, Bernasconi S, et al. Sensitivity and specificity of body mass index and skinfold thicknesses in detecting excess adiposity in children aged 8-12 years. *Ann Hum Biol*. 2003;30(2):132–9.

23. Zimmermann MB, Gubeli C, Puntener C, Molinari L. Detection of overweight and obesity in a national sample of 6-12-y-old Swiss children: accuracy and validity of reference values for body mass index from the US Centers for Disease Control and Prevention and the International Obesity Task Force. *Am J Clin Nutr*. 2004 May;79(5):838-43.

24. Gläßer N, Zellner K, Kromeyer-Hauschild K. Validity of body mass index and waist circumference to detect excess fat mass in children aged 7-14 years. *Eur J Clin Nutr*. 2011;65(2):151–9.

25. Javed A, Jumean M, Murad MH, Okorodudu D, Kumar S, Somers VK, et al. Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: A systematic review and meta-analysis. *Pediatr Obes*. 2015;10(3):234–44.

26. Nichols SD, Cadogan F. BMI-based obesity cutoffs and excess adiposity in a Caribbean adolescent population of African origin. *Eur J Clin Nutr*. 2009;63(2):253–8.

27. Reilly JJ. Diagnostic accuracy of the BMI for age in paediatrics. *Int J Obes*. 2006;30(4):595–7.

28. da Silva KS, da Silva Lopes A, da Silva FM. Sensitivity and specificity of different classification criteria for overweight in schoolchildren from João Pessoa, Paraíba, Brazil. *Rev Nutr*. 2010;23(1):27–35.

29. Dencker M, Thorsson O, Lindén C, Wollmer P, Andersen LB, Karlsson MK. BMI and objectively measured body fat and body fat distribution in prepubertal children. *Clin*

Physiol Funct Imaging. 2007;27(1):12–6.

30. Gómez-Campos R, Langer RD, De Fátima Guimarães R, Martini MCS, Cossio-Bolaños M, De Arruda M, et al. Accuracy of body mass index cutoffs for classifying obesity in Chilean children and adolescents. *Int J Environ Res Public Health*. 2016;13(5):1–9.

31. Mehdad S, Hamrani A, El Kari K, El Hamdouchi A, Barakat A, El Mzibri M, et al. Body mass index, waist circumference, body fat, fasting blood glucose in a sample of Moroccan adolescents aged 11-17 years. *J Nutr Metab*. 2012;2012. DOI: http://dx.doi.org/10.1155/2012/510458

32. Bila WC, De Freitas AE, Galdino AS, Ferriolli E, Pfrimer K, Lamounier JA. Deuterium oxide dilution and body composition in overweight and obese schoolchildren aged 6-9 years. *J Pediatr (Rio J)*. 2016;92(1):46–52.

33. Wickramasinghe VP, Cleghorn GJ, Edmiston KA, Murphy AJ, Abbott RA, Davies PSW. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. *Ann Hum Biol*. 2005;32(1):60–71.

34. Romero-Corral A, Somers VK, Sierra-Johnson J, Korenfeld Y, Boarin S, Korinek J, et al. Normal weight obesity: A risk factor for cardiometabolic dysregulation and cardiovascular mortality. *Eur Heart J*. 2010;31(6):737–46.

35. World Health Organization. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet*. 2004;363(9403):157–63.

CHAPTER 7

Association between school-level attributes and weight status of Ghanaian primary school children

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Abstract

Introduction: Little is known about the impact of the school environmental context on the emerging childhood obesity in Africa. We examined the association of the schools' contextual factors with BMI, abdominal obesity and overweight (including obesity) in urban Ghana.

Method: Using cross-sectional data from 543 school children aged 8-11 years attending 14 primary schools, we applied multilevel logistic regressions and linear regression models to investigate the association of child- and school level attributes with overweight, abdominal obesity, and BMI.

Results: We observed significant variance of the random effects of schools in BMI (2.65, $p < 0.05$), abdominal obesity (0.85; $p < 0.05$), and overweight (1.41, $p < 0.05$), with school contextual levels accounting for 19.7%, 20.6%, and 30.0% of the total variability observed in BMI, abdominal obesity and overweight respectively. Attending high SES level school, private school and school with increased after-school recreational facilities were associated with higher BMI. Children were more likely to be overweight if they attended a high SES level school, had access to healthy foods at school, and after-school recreational facilities. Regarding abdominal obesity, attending a school with increased PA facilities decreased the odds; however the odds increased if they attended a school with access to after-school recreational facilities.

Conclusion: A number of school-level factors were associated with BMI, overweight and abdominal obesity of children in the present study. Our results provide support for improved school environment to reduce overweight and obesity.

7.1 Introduction

It is well established that the aetiology of obesity is multifactorial [1]. Given the limited success of individual behavioural-based interventions to address the increasing prevalence of overweight and obesity [2], it is imperative to consider other factors outside of the individual. The ecological model, which postulates that changes in individual outcomes are influenced not only by individual-level factors such as age, gender, genetics and race/ethnicity, but also by the socio-cultural, economic, and environmental contexts in which the individual lives, has been widely used in health promotion [3–6]. The ecological model is useful in providing better understanding of the multiple factors that may either facilitate or serve as barriers to making healthy choices. For the school-going child, the school is considered one important setting for the development of health-related behaviours and health outcomes.

Schools are identified as one of the potential settings to deliver nutrition and PA interventions aimed at reducing childhood obesity [2,7] as school children a spend considerable amount of their waking hours in the school settings. Prior research has investigated the associations of school demographics, school PA and food policies and resources, school neighbourhood, support for active transport, after-school recreational facilities and programmes in relation with the obesity epidemic [8–13]. Other studies have also examined school environments and health-related behaviours such as nutrition and PA [14–17]. The evidence from these studies underscores the importance of the school food and PA environments in shaping dietary and PA behaviours of school children and adolescents, and subsequently weight status. While the evidence is limited with regard to the contributions of school-level factors to the health-related behaviours and the emerging trend of childhood obesity in Africa, even fewer studies have examined the correlates of obesity in the context of the school environment using a multilevel approach. Moreover, the evidence provided by the aforementioned studies may not be generalizable to low-to-middle income countries like Ghana. Thus it is imperative to investigate the influence of the school contextual factors on child weight status, to inform the design and implementation of appropriate interventions. The present study aimed to examine the association of the schools' contextual factors with BMI, abdominal obesity and overweight (including obesity) in learners in urban Ghana.

7.2 Methods

Study design and study population

Details of the study design and population have been described in **Chapter 5**. Anthropometric data was collected by objective methods. Child- and school- level variables were obtained by self-report.

Outcome variables

The outcome variable was child weight status, defined as BMI, overweight (including obesity) and abdominal obesity. Weight, height (previously described in **Chapter 5**), and waist circumference were measured by trained research assistants. Waist circumference was measured with a Seca measuring tape (tension tape) to the nearest 0.1 cm with the participants' arms relaxed at the sides and following normal expiration. BMI was calculated and BMI-for-age z-score (BAZ) was computed with the WHO AnthroPlus v.1.0.4 and used to categorise pupils into overweight (BAZ >= 1.0 SD) or not overweight (BAZ < 1.0 SD) [18]. Waist-to-height ratio (WHtR) was calculated from the average of the height and waist circumference. Abdominal obesity was defined as WHtR $\geq$ 0.45 in girls and $\geq$ 0.46 in boys [19].

Individual (child) level explanatory variables

Age was computed as the difference of date of birth and date of measurement. Children self-reported their gender by responding to the question "Are you a boy or a girl?" Data on household SES indicators were obtained from self-reports (Appendix V). Household SES was evaluated using variables on source of water and sanitation, and household assets which were subjected to principal component analysis. The first component was extracted to create wealth scores of the household which were then split into three and reported as poor (lowest 40%), middle SES (40%) and rich (highest 20%) households [20]. Child age was modelled as a continuous variable. Two variables for wealth score were included, one continuous and the other categorical.

School level explanatory variables

The school heads/administrators completed interview-administered questionnaires (Appendix VI) on perceived built environment of neighbourhood/community surrounding the schools, school food environment and PA environment, policies and practices of PA and healthy eating. Two variables were used as indicators of school-level SES; the type of school (private/public) and aggregated wealth scores, computed from household wealth scores of individual children attending the same school. The school type was dummy coded as public = 0 and private = 1. The school-level SES was treated as a continuous variable in the analysis.

To assess the perceived neighbourhood quality, questions were asked on seven selected variables including land-mix use/access, places for walking and bicycling, free or low cost playgrounds or recreational facilities, aesthetic, traffic and crime rate. Four-point Likert scales responses ranging from "strongly disagree (1) to strongly agree (4) were used. Responses were collapsed and dichotomised into strongly disagree/somewhat disagree and strongly agree/somewhat agree. Negatively worded items were reverse coded and a summary score "Perceived neighbourhood quality" was generated from 6 items (Cronbach alpha = 0.81), as one item was constant (that is no variability) such that a higher score indicates favourable environment. Perceived neighbourhood quality was modelled as a continuous variable.

To assess school policies and practices, respondents provided answers to the questions "*Does your school have written policies or practices concerning PA?", "Does your school have* *written policies or practices concerning healthy eating?"* Options were "*No/not applicable", "Yes, existing written policies", "Yes, written policies still under development*" and "*yes, practices.*

The respondents answered the questions: "*Is structured PA currently in the weekly timetable for the pupils*", "*How many sessions per week, and "How long is each PA session*". Minutes spent per week for PA was computed from the number of sessions and time spent in PA and included as a continuous variable.

Six items were used to assess schools' support for active transport to and from school. The respondents answered questions on variables on safe walking/bicycling areas, and allow or encourage children to use bicycles and protective headgear like helmet. The response options included: no/I do not know (0) and yes (1). One item "*Identify safe routes to use for walking and cycling to and from school*", was constant and was therefore excluded from the analysis. A new variable "Support for active transport" was generated from the summary score of the remaining five (5) items (Cronbach alpha = 0.55), where a higher score indicated favourable ratings.

Access to 13 facilities on and off school grounds during school hours were used: fitness room, secure change room lockers, art room and music room, playground equipment like footballs, skipping ropes, basketballs, playgrounds, outdoor sport fields like basketball courts and any paved area for skipping; running tracks, playground equipment like basketballs, footballs, skipping ropes, netballs, gym, dance studio, auditorium for aerobics. A score of 1 was assigned where available, and 0 not available/do not know. Access to facilities on and off school grounds during school hours were compared with not available/do not know. Five (5) items were excluded (fitness room, secure change room lockers, art room and music room because none of the schools had these facilities) and one other item (playground equipment like footballs, skipping ropes, basketballs, etc.) was reported to be available in all 14 schools so was also excluded from analysis. A new quantitative variable "PA facility index" was generated from the summary score based on seven items (Cronbach alpha = 0.60).

Respondents answered the questions "*Do pupils have access to the cafeterias, school shops, as well as restaurants close to school (within 1 km radius) where they can buy foods or drinks during school hours*?" The available options were yes and no. In addition, a checklist of foods and drinks on sale at the facilities was completed. If an item was available, a score of yes (1), or no (0) was given. Foods were categorised as healthy (raw fruits, raw vegetable salads, cooked meals, 100% fresh fruit juices) and less healthy (chocolates; sweets/toffees; sodas/soft drinks; packaged fruit juices; cakes, cookies, biscuits; chips; sausages rolls, doughnuts and & pies; regular chips & crackers; popcorn; and ice creams) and composite scores generated for each school with higher scores indicating availability of these foods. The Cronbach alpha coefficient was 0.70 for healthy foods (four items) and 0.76 for less healthy foods (10 items). These were treated as continuous variables in the analysis.

Availability and accessibility of recreational facilities provided by the school outside school hours was assessed using four items: 1) equipment (e.g., basketballs, skipping ropes, footballs); 2) indoor facilities, 3) outdoor facilities (e.g., playing fields, paved activity areas; and 4) gymnasium. A score of 1 was given where available, otherwise 0. A summary score "After-school recreational facilities" was generated (Cronbach alpha = 0.70) and modelled as a continuous variable.

Statistical analysis

All analyses were conducted with Stata 13.0 (College Station Texas. USA). Mean and standard deviation, median and 25-75th percentiles, student t-test and Mann-Whitney test were used for continuous variables while frequencies and percentages, and chi-square (χ^2) test were used for categorical variables. Mixed effects models were used to account for the hierarchical nature of the data (pupils nested within schools). To estimate the association of binary outcomes, overweight and abdominal obesity, with child- and school level variables, mixed effects logistic regressions models (*melogit* command) with schools as random effects were fitted. The null model (model with no explanatory variables) was first fitted to report the random effects of the schools and also the intraclass correlation coefficient (ICC). Univariable analyses were then performed with each of the explanatory variables, individually. Explanatory variables which tended to contribute to the variability of outcome variables at $p < 0.20$ were selected and included in the multivariable models. The estimated fixed-effects coefficients are reported as odds ratios (ORs), 95% confidence intervals (CI) and standard errors (SE).

For the continuous BMI variable, mixed effects linear regressions models with schools as random effects were performed to estimate the association of BMI with child- and school- level explanatory variables. Similar to the mixed effects logistic regressions, the null model was fitted after which three other models, model 2 (individual level variables), model 3 (school level variables) and model 4 (individual and school levels variables) were fitted to estimate the effects of the variables. For model 4, only variables that contributed significantly to the variability in BMI were included. Estimates are maximum likelihood-based using the *mixed* command. Results are reported as estimates with 95% CI and SE. For all analyses, significance was set at $p<0.05$. Child age and gender were controlled for in all multivariate models.

7.3 Results

Descriptive statistics

Table 7.1 summarises the descriptive statistics at the individual (child) and school levels. The study reports data from 543 school children (37.6% boys). Half of the children attended private

(50.1%) schools with median age 10 (25^{th} -75^{th} percentiles 9, 11) years. The overall mean BMI and WHtR were 17.03 (SD 3.56) kg/m^2 and 0.43 (SD 0.05). The corresponding prevalence of overweight (including obesity) and abdominal obesity were 16.4% and 18.8%. Children attending private schools had significantly higher BMI and WHtR compared to their peers in public schools: 17.72 (SD 4.29) kg/m^2 vs 16.34 (SD 2.47) kg/m^2, $p<0.0001$; and 0.43 (SD 0.06) vs 0.42 (SD 0.03); $p=0.026$. Additionally, more than two-thirds of the children who were overweight, and 63.7% of those with abdominal obesity were attending private schools.

Nearly all the participating schools (seven private and six public) have some policies and practices on PA, which were existing, under development and or undergoing implementation. Policies and practices on nutrition and healthy eating were available in 90.4% (six private and six public) of the schools. Moreover, 81.7% of the children attended schools (seven private and five public) that had structured PA in the weekly timetable. Whereas over half (52.8%) of the schools had cafeteria, 34.4% had school shops. All (95.0%) but one private school reported that the communities surrounding the schools had fast food outlets. Overall summary scores for healthy and less healthy foods were 2.44 (SD 1.06) and 8.24 (SD 2.04) respectively. Children attending private schools had more options of both healthy (3.16 vs 1.72 $p<0.0001$) and less healthy (9.10 vs 7.37; $p<0.0001$) food available compared to their counterparts in public schools.

Table 7.1: Descriptive statistics at the individual and school levels

	Overall	Private	Public	p-value
Continuous variables*				
Individual level (N=543)				
Median Age (years)	10 (9, 11)	10 (9,11)	10 (9,11)	0.756
Mean BMI (kg/m^2)	17.03 (3.56)	17.72 (4.29)	16.34 (2.47)	<0.0001
Mean WHtR	0.43 (0.05)	0.43 (0.06)	0.42 (0.03)	0.026
Household wealth index	0.27 (-1.47, 1.69)	1.10 (-0.11, 2.16)	-0.87 (-2.43, 0.51)	<0.0001
School level (n=14)				
School-level SES score	0.11 (-0.34, 0.79)	0.78 (0.34, 1.27)	-0.34 (-1.73, -0.20)	<0.0001
Healthy foods score	2.44 (1.06)	3.16 ± 0.85	1.72 ± 0.70	<0.0001
Less healthy foods score	8.24 (2.04)	9.10 ± 1.07	7.37 ± 2.39	<0.0001
PA facility index	3.54 (1.30)	4.21 ± 1.07	2.87 ± 1.16	<0.0001
Mean minutes per week for PA	69.00 (16.43)	76.5±19.31	60.00±0.00	<0.0001
After-school recreational facilities score	0.65 (0.97)	0.93 ± 1.23	0.37 ± 0.48	<0.0001
Support for active transport score	2.59 (1.19)	2.75 ± 1.12	2.43 ± 1.24	0.002
Perceived neighbourhood quality score	3.71 (1.83)	3.99 ± 1.11	3.43 ± 2.3	0.0004
Categorical variables*				
Individual level				
Gender				0.833
Boys	37.6 (204)	49.5 (101)	50.5 (103)	
Girls	62.4 (339)	50.5 (171)	49.5(168)	
Household SES				<0.0001
Poor	40.1 (218)	26.1 (57)	73.9 (161)	
Middle	40.0 (217)	60.4 (131)	39.6 (86)	
Rich	19.9 (108)	77.8 (84)	22.2 (24)	
Overweight (including obesity)	16.4 (89)	73.0 (65)	27.0 (24)	<0.0001
Abdominal obesity	18.8 (102)	63.7 (65)	36.3 (37)	0.002
School level				
PA policies and practices	94.3 (512)	47.1 (241)	52.9 (271)	< 0.0001
Nutrition and healthy eating policies and practices	90.4 (491)	44.8 (220)	55.2 (271)	<0.0001
PA on timetable	81.7 (444)	88.6 (241)	74.9 (203)	<0.0001
Presence of school cafeteria	52.8 (287)	73.9 (212)	26.1 (75)	<0.0001
Presence of school shop	34.4 (187)	100. 0(187)	-	<0.0001
Fast food outlets close to school	95.0 (516)	52.7 (272)	47.3(244)	<0.0001

BMI: Body mass index; WHtR: waist-to-height ratio; SES: socioeconomic status; *For continuous variables, data are presented as mean (standard deviation), median (25th-75th percentiles) are reported and percent (frequency) for categorical variables.

More facilities were available and accessible to children in private schools than those attending public schools. The overall mean PA facility index, after-school recreational facilities, schools' support for active transport and perceived neighbourhood quality were: 3.54 (SD 1.30), 0.65 (SD 0.97), 2.59 (SD 1.19) and 3.71 (SD 1.83). Children spent an average of 69.0 minutes (SD 16.4) weekly on PA. Moreover, the PA facility index was higher in private, compared to public schools (4.21 vs 2.87; $p<0.0001$). On average, children in private schools spent more time per week in physical activities than those in public schools (76.5 minutes vs 60.0 minutes; $p<0.0001$). Also, the summary score of after-school recreational facilities was higher in private compared to public schools (0.93 vs .037; $p<0.0001$). Schools' support for active transport was 2.75 vs 2.43 in private and public schools respectively ($p=0.0018$). Additionally, the perceived school neighbourhood quality were 3.99 ± 1.11 and 3.43 ± 2.3 ($p=0.0004$) in private and public schools.

Table 7.2: Individual and school factors associated with overweight

	Univariable models [a]			Multivariable models [b]		
	OR (95% CI)	**SE**	**p-value**	**OR 95% CI**	**SE**	**p-value**
Intercept (null model)	0.150 (0.074, 0.303)	0.054				
Age	0.931 (0.710, 1.220)	0.128	0.604	1.031 (0.791, 1.343)	0.139	0.823
Gender (Boys)	0.901 (0.540, 1.502)	0.235	0.689	0.921 (0.551, 1.540)	0.241	0.755
Median household wealth index	1.068 (0.915, 1.246)	0.084	0.404	-	-	-
Household SES						
Poor	1					
Middle	1.398 (0.751, 2.560)	0.442	0.290	-	-	-
Rich	1.220 (0.562, 2.648)	0.482	0.615	-	-	-
School-level SES	2.052 (1.433, 2.939)	0.376	**<0.0001**	1.998 (1.153, 3.462)	0.560	**0.014**
School type (Private)	4.190 (1.350, 13.004)	2.421	**0.013**	0.399 (0.110, 1.442)	0.262	0.161
School cafeteria	3.815 (1.245, 11.690)	2.179	**0.019**	1.329 (0.458, 3.857)	0.722	0.601
School shop	5.067 (1.744, 14.721)	2.757	**0.003**	1.343 (0.557, 3.237)	0.603	0.511
Fast food outlets close to school	1.379 (0.091, 20.851)	1.911	0.871	-	-	-
Healthy foods	2.313 (1.265, 4.229)	0.712	**0.006**	1.577 (1.055, 2.358)	0.323	**0.026**
Less healthy foods	1.274 (0.946, 1.716)	0.193	0.110	0.944 (0.735, 1.214)	0.121	0.656
PA facility index	0.848 (0.672, 1.071)	0.101	0.167	0.835 (0.661, 1.054)	0.099	0.129
Minutes per week for PA	0.980 (0.935, 1.028)	0.024	0.420	-	-	-
School support for active transport	0.936 (0.547, 1.603)	0.267	0.810	-	-	-
Perceived neighbourhood quality	1.263 (0.845, 1.887)	0.259	0.255	-	-	-
After-school recreational facilities	1.849 (1.187, 2.883)	0.419	**0.007**	1.375 (1.013, 1.866)	0.214	**0.041**
PA policies and practices	0.217 (0.020, 2.325)	0.263	0.207	-	-	-
Nutrition and healthy eating policies and practices	1.076 (0.131, 8.808)	1.154	0.946	-	-	-
PA on timetable	0.571 (0.087, 3.741)	0.547	0.559	-	-	-
Random effects						
School level	1.408 (0.485, 4.090)	0.766				
ICC	0.300 (0.128, 0.554)	0.114				

[a] Univariable models using mixed effects logistic regression; [b] Explanatory variables with p-values less than 0.20 were forced into the same multivariable model (full model). Covariates adjusted for: school-level SES, school type, school cafeteria, school shop, healthy foods, less healthy foods, PA facility index, after-school recreational facilities, gender and child's age. OR: odds ratio, SE: standard error; CI: confidence intervals. PA: physical activity; SES: socioeconomic status; overweight: BAZ >= 1.0 SD

Factors associated with overweight (including obesity)

Table 7.2 shows factors associated with overweight. In the null model, the variance of random effects of schools was 1.408 ($p < 0.05$) and the ICC was 0.300, suggesting that 30% (12.8 to 55.4%) of the total variance observed in overweight in the study was at the school level. In univariable analyses, school-level SES, school type, availability of cafeteria and shops at the schools, healthy foods and after-school recreational facilities predicted the likelihood of overweight. Children were more likely to be overweight if they attended private school, 4.19 (1.35, 13.00) and a higher school-level SES, 2.05 (1.43, 2.94). Availability of school cafeteria and shops significantly increased the likelihood of overweight by 3.82 (1.25, 11.69) and 5.07 (1.74, 14.72) respectively. Similarly, availability of healthy foods increased the odds by 2.31 (1.26, 4.23), as did also after-school recreational facilities 1.85 (1.19, 2.88). In the model mutually adjusted for all significant predictors and variables that tended to be related to overweight at $p < 0.2$ (less healthy foods and PA facility index) in univariable models, the likelihood of overweight increased by 2.00 (1.15, 3.46) with every unit increase in school-level SES. Moreover, for every extra unit increase in the availability of healthy foods and after-school recreational facilities, the odds of overweight increased by 1.58 (1.06, 2.36) and 1.38 (1.01, 1.87) respectively. The school type, school cafeteria and shops were not significant in the adjusted model. Individual level variables were not significantly associated with the odds of being overweight. None of the school variables decreased the likelihood of overweight.

Factors associated with abdominal obesity

As presented in **Table 7.3**, in the null model, the variance of random effects of schools was 0.85 ($p < 0.05$) and the ICC was 0.206. This indicates that the school level contributes 20.6% (8.3% to 42.4%) of the total variance observed in abdominal obesity in the study sample. Higher school-level SES (1.64 (95% CI: 1.16, 2.32)); availability of cafeterias (2.66 (1.02, 6.96)) and shops (3.47 (1.41, 8.56)) at the schools; and after-school recreational facilities (1.82

(1.32, 2.49)) were significantly associated with abdominal obesity in the univariable analyses. In the mutually adjusted model, additional variables that tended to be related to abdominal obesity (school type, healthy foods and PA facility index) in the univariable analyses were included. For every extra unit increase in PA facility index, the likelihood of abdominal obesity significantly decreased by 0.78 (0.63, 0.97), whereas the availability and accessibility of after-school recreational facilities increased the odds by 1.64 (1.23, 2.19). Individual level variables were not significantly associated with the odds of abdominal obesity.

Factors associated with BMI

Table 7.4 summarises the multilevel analysis of individual and school level variables associated with child BMI. In model 1 (null model), the variance of the random effects of schools was significant (2.65, $p < 0.05$). The ICC was 0.197, indicating that 19.7% of the total variance observed in child BMI existed at the school level. In model 2 (individual level), none of the variables (age, gender, household wealth index) were significantly associated with BMI. At the school level, model 3, school-level SES ($\beta = 0.96$, $p < 0.0001$), private school ($\beta = 1.74$, $p = 0.028$), availability of school cafeteria ($\beta = 1.83$, $p = 0.017$) and shops ($\beta = 2.34$, $p = 0.001$), healthy foods ($\beta = 0.77$, $p = 0.046$), less healthy foods ($\beta = 0.38$, $p = 0.048$) and after-school recreational facilities ($\beta = 1.134$, $p < 0.0001$) predicted child BMI. In model 4, (individual and school levels), child age ($\beta = 0.40$, $p = 0.008$), school-level SES ($\beta = 1.02$, $p < 0.0001$), private school ($\beta = -1.80$, $p = 0.006$), and after-school recreational facilities ($\beta = 0.89$, $p = 0.0001$), predicted BMI. At the individual level, none of the child level variables considered in the present study made substantial contributions to the overall variability in BMI. Nonetheless, in model 4, we observed a significant contribution of child age.

Table 7.3: Individual and school factors associated with abdominal obesity

	Univariable model [a]			Multivariable model [b]		
	OR (95% CI)	**SE**	**p-value**	**OR (95% CI)**	**SE**	**p-value**
Intercept (null model)	0.209 (0.120, 0.362)	0.059				
Age	1.108 (0.857, 1.432)	0.145	0.433	1.145 (0.891, 1.471)	0.146	0.289
Gender (Boy)	0.879 (0.545, 1.418)	0.214	0.597	0.888 (0.549, 1.437)	0.218	0.629
Median household wealth index	1.018 (0.885, 1.170)	0.072	0.805	-	-	-
Household SES						
Poor	1			-	-	-
Middle	1.262 (0.721, 2.211)	0.361	0.416	-	-	-
Rich	1.236 (0.607, 2.517)	0.448	0.559	-	-	-
School-level SES	1.636 (1.155, 2.317)	0.290	**0.006**	1.501 (0.951, 2.369)	0.349	0.081
School type (Private)	2.420 (0.880, 6.655)	1.249	0.087	0.489 (0.150, 1.593)	0.295	0.235
Presence of school cafeteria	2.661 (1.017, 6.962)	1.306	**0.046**	1.401 (0.678, 2.896)	0. 519	0.362
Presence of school shop	3.473 (1.410, 8.555)	1.597	**0.007**	1.234 (0.531, 2.871)	0.532	0.625
Fast food outlets close to school	0.597 (0.075, 4.756)	0.632	0.626	-	-	-
Healthy foods	1.556 (0.968, 2.503)	0.377	0.068	1.253 (0.881, 1.783)	0.225	0.210
Less healthy foods	1.166 (0.910, 1.495)	0.148	0.224			
PA facility index	0.822 (0.663, 1.019)	0.090	0.073	0.782 (0.627, 0.974)	0.088	**0.028**
Minutes per week for PA	0.993 (0.960, 1.027)	0.017	0.694	-	-	-
School support for active transport	0.940 (0.614, 1.438)	0.204	0.775	-	-	-
Perceived neighbourhood quality	1.128 (0.821, 1.550)	0.183	0.456	-	-	-
After-school PA facilities	1.815 (1.323, 2.492)	0.293	<**0.0001**	1.642 (1.233, 2.187)	0.240	**0.001**
PA policies and practices	0.308 (0.046, 2.081)	0.300	0.227	-	-	-
Nutrition and healthy eating policies and practices	0.715 (0.149, 3.427)	0.512	0.675	-	-	-
PA on timetable	0.702 (0.157, 3.132)	0.535	0.642	-	-	-
Random effects						
School level	0.871 (0.299, 2.421)	0.044				
ICC	0.206 (0.083, 0.424)	0.087				

[a] Univariable models using mixed effects logistic regression; [b] Explanatory variables with p-values less than 0.20 were forced into the same multivariable model (full model). Variables adjusted for: school-level SES, school type, school cafeteria, school shop, healthy foods, PA facility index, after-school recreational facilities, gender and child's age. OR: odds ratio, SE: standard error; CI: confidence intervals. PA: physical activity; SES: socioeconomic status

Table 7.4: Individual and school factors associated with BMI

	Model 1 Null model Estimate (95% CI)	SE	Model 2 Individual Estimate (95% CI)	SE	Model 3 School Estimate (95% CI)	SE	Model 4 Individual & school Estimate (95% CI)	SE
Fixed effects								
Individual level								
Intercept	17.136 (16.233, 18.038)	0.460						
Age			0.304 (-0.002, 0.609)	0.156			**0.396** (0.102, 0.691)*	0.150
Gender (Boys)			0.011 (-0.563, 0.583)	0.293			0.001 (-0.571, 0.573)	0.292
Household wealth index			0.010 (-0.152, 0.172)	0.083				
Household SES								
Poor (ref)								
Middle			0.113 (-0.547, 0.774)	0.337				
Rich			0.132 (-0.726, 0.990)	0.438				
School level								
School-level SES					**0.959** (0.481, 1.437)**	0.244	**1.015** (0.499, 1.530)**	0.263
School type (private)					**1.744** (0.185, 3.303)*	0.795	**-1.795** (-3.078, -0.513)*	0.654
School cafeteria					**1.832** (0.324, 3.340)*	0.769	0.742 (-0.330, 1.814)	0.547
School shop					**2.344** (0.926, 3.762)*	0.724	0.276 (-0.781, 1.333)	0.539
Fast foods restaurants close to school					1.101 (-2.401, 4.602)	1.787	-	-
Healthy foods					**0.769** (0.012, 1.526)*	0.386	0.306 (-0.136, 0.748)	0.225
Less healthy foods					**0.382** (0.003, 0.762)*	0.194	-0.094 (-0.306, 0.119)	0.108
PA facility index					-0.143 (-0.391, 0.105)	0.126	-	-
Minutes per week for PA					-0.014 (-0.064, 0.035)	0.025	-	-
School support for active transport					-0.136 (-0.840, 0.568)	0.359	-	-
Perceived neighbourhood quality					0.176 (-0.327, 0.678)	0.256	-	-
After-school recreational facilities					**1.134** (0.562, 1.705)**	0.291	**0.894** (0.525, 1.263)**	0.23
PA policy					-2.957 (-6.088, 0.174)	1.597	-	-
Nutrition policy & healthy eating policy					-0.657 (-3.247, 1.933)	1.321	-	-
PA on timetable					-1.098 (3.585, 1.389)	1.269	-	-
Random effects								
Individual level	**10.802** (9.574, 12.187)**	0.665						
School level	**2.650** (1.121, 6.265)**	1.163						
ICC	0.197 (0.093, 0.370)	0.070						

Explanatory variables that were significant compared with the empty model were selected for the final model (model 4). Variables included: school-level SES, school type, school cafeteria, school shop, healthy food, less healthy foods, after-school recreational facilities, gender and child's age. [b] Linear mixed models used, where variables were modelled as fixed effects and school as random effects. SE: standard error; CI: confidence intervals. * = p<0.05; **=p < 0.0001

7.4 Discussion

The results indicate that generally, private schools tended to have facilities that promote healthy choices (both food and PA environments), and also unhealthy options (food environment) compared to public schools, which were resource-constrained. The proportions of children with abdominal obesity and overweight (including obesity) were higher in private schools. The study found that individual and school level factors were independently and jointly related to BMI, abdominal obesity and overweight in these children. The school context explained between 19.7% and 30.0% of the school level variability in weight status. We found significant associations of child weight status with school type, school-level SES, availability of school cafeterias (providing school meals) and school shops (sale of competitive foods and beverages), healthy foods, less healthy foods, PA facility index, availability and accessibility of after-school recreational facilities. With respect to individual level variables, only age was significantly related to BMI. School policies and practices on PA were unrelated to child weight status.

School type explained the highest percentage of variability in individual child BMI. We observed that children attending private and higher SES schools have higher BMI, and increased odds of abdominal obesity and overweight compared to their peers attending public and lower SES schools. When controlling for individual and school-level variables, the association with school-level SES was seen with BMI and overweight, but not abdominal obesity. The school type continued to be linked with only BMI, but the direction of the association changed such that children attending private schools had lower BMI compared to their counterparts attending public schools. Our findings paralleled those from prior research among African populations that suggested that attending affluent, private or high SES school increases the odds of overweight and obesity [21,22]. On the other hand, studies conducted in the US [12,23] found that children attending higher SES schools had lower BMI. Higher SES schools tend to have more resources that would promote healthy behaviours and hence lower the odds of overweight and obesity in developed countries.

School food environment has a significant impact on children's eating behaviours [14] and subsequently body weight [8,10], as more than one-third of the daily caloric intake occurs while at school [24]. Our results suggest that over one-third of the children have access to school cafeterias and shops with a wide selection of both healthy and less healthy foods options, although there were fewer healthy options. This suggests the nutrition and healthy eating policies and practices were poorly implemented or enforced. We observed that the availability of less healthy foods was positively associated with BMI but not overweight and abdominal obesity; and the association was no longer significant after controlling for school-level SES, school type, cafeterias, shops, healthy foods, after-school recreational facilities, age and gender.

This analysis adds to an earlier study that found that less healthy foods at school was positively associated with higher BMI and obesity/overweight [8,10]. Prior research indicated that the absence of school shops and snack bars and also limiting the availability of less healthy foods in school shops were associated with reduced intake of sugar sweetened beverages and energy dense snacks [14,24]. We observed that the availability of healthy foods tend to increase the risk of overweight, abdominal obesity and high BMI, which is counterintuitive. We had expected the availability of healthy foods to be associated with healthy dietary intake, and with lower risk of obesity. This finding indicates that healthy foods did not protect the children from poor dietary habits. Given the increased exposure to less healthy options, food preference, the main determinant of food intake in children [25], could have contributed to poor dietary behaviours, thus the overall intake of these foods would displace the healthy options in the diets. Notably, the home food environment, an equally important context for developing food preferences and dietary habits in children [26–28], was not captured in the present analyses.

Among the PA environments considered in the present study, only PA facility index was significantly associated with abdominal obesity, but not overweight or BMI. Availability and accessibility to play equipment and resources provide children with the opportunities to be physically active during school hours. Children attending schools that had more PA facilities both on and off grounds tend to have lower odds of abdominal obesity than their counterparts who were attending schools that were poorly-resourced, consistent with existing research [9]. In the aforementioned study conducted among adolescents, those who had access to these facilities were less likely to be overweight. Some existing research has linked the provision of recreational facilities both at the school level and school community to increased PA [15] while results from other studies were mixed [11]. Evidence from a meta-analysis by Morton and colleagues [11] indicated that the association was with activity-specific facilities but not the overall PA resources. Nonetheless, the evidence linking school PA facilities to child weight status has been inconsistent. Researchers found little or no significant association between PA resources and programmes and weight status in adolescents attending middle to high schools [29].

After-school programmes may promote increased participation in extracurricular PA and related-health outcomes among children and adolescents [17]. Our results suggest that children attending schools with increased access to after-school recreational facilities had higher risk for increased BMI, overweight and abdominal obesity. The counterintuitive finding could be due to some individual and school level confounding variables that were not considered in the analysis. We did not report on after-school programmes being offered to the children. One possible explanation is that the availability of these facilities were not associated with organised sports with trained physical education staff to supervise the children. Moreover, the need for academic excellence may lead to more time being allocated to extra classes than extra sporting activities. Thus children may not have adequate time to engage in after-school programmes despite the facilities being available.

7.5 Strengths and limitations

Strengths of the present study include the application of multilevel modelling to account for the hierarchical nature of the data and use of objective measures of height and weight. There are limitations of the present work which should be noted. The cross-sectional design of the study precludes the inferences of causal relationships. At best, we could say that associations exist between the examined variables and the outcome variables. Another potential source of limitation was that maternal educational, a significant predictor of child weight was not controlled for in the analysis. We did not report on dietary and PA behaviours of the children at school which could provide explanations to the observed variability since the present work focused on school environment and weight outcomes.

7.6 Conclusions

A number of school-level factors were associated with BMI, overweight and abdominal obesity of the children in the present study. Unhealthy weight status was significantly higher in children in private compared to public schools. The fact that children spend significant amount of time in schools could present a window of opportunity to impact healthy lifestyle behaviours which are likely to be maintained through adulthood thereby reducing the prevalence of overweight. Our results add to the limited and inconsistent findings in this area and provide support for improved school environment to reduce the overweight epidemic.

7.7 References

1. Swinburn B, Egger G, Raza F. Dissecting Obesogenic Environments: The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity. *Prev Med (Baltim).* 1999;29:563–70.

2. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: A meta-analysis. *CMAJ*. 2009;180(7):719–26. DOI: 10.1503/cmaj.080966.

3. Davison KK, Birch L. Childhood overweight: a contextual model and recommendations for future research. *Obes Rev*. 2001;2(3):159–71.

4. Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ, Public Health Approaches to the Prevention of Obesity (PHAPO) Working Group of the International Obesity Task Force (IOTF). Obesity prevention: the case for action. *Int J Obes*. 2002;26(3):425–36.

5. McLeroy K, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Heal Educ Q*. 1988;15(4):351–77.

6. Townsend N, Foster C. Developing and applying a socio-ecological model to the promotion of healthy eating in the school. *Public Health Nutr*. 2013;16(6):1101–8.

7. Khambalia AZ, Dickinson S, Hardy LL, Gill T, Baur LA. A synthesis of existing systematic reviews and meta-analyses of school-based behavioural interventions for controlling and preventing obesity. *Obes Rev*. 2012;13(3):214–33.

8. Fox MK, Dodd AH, Wilson A, Gleason PM. Association between School Food Environment and Practices and Body Mass Index of US Public School Children. *J Am Diet Assoc*. 2009;109(2):S108–17.

9. Leatherdale ST. A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 to 4 students. *BMC Public Health.* 2013;13:982. DOI: https://doi.org/10.1186/1471-2458-13-982.

10. Mâsse LC, de Niet-Fitzgerald J, Watts AW, Naylor P-J, Saewyc EM. Associations between the school food environment, student consumption and body mass index of Canadian adolescents. *Int J Behav Nutr Phys Act*. 2014;11(1):29. DOI: 10.1186/1479-5868-11-29.

11. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EMF. The school environment and adolescent physical activity and sedentary behaviour: A mixed-studies systematic review. *Obes Rev*. 2016;17(2):142–58.

12. Richmond TK, Subramanian S V. School level contextual factors are associated with the weight status of adolescent males and females. *Obesity*. 2008;16(6):1324–30.

13. Harrison F, Jones AP, van Sluijs EMF, Cassidy A, Bentham G, Griffin SJ. Environmental correlates of adiposity in 9-10 year old children: Considering home and school neighbourhoods and routes to school. *Soc Sci Med*. 2011;72(9):1411–9.

14. Hanks AS, Just DR, Smith LE, Wansink B. Healthy convenience: Nudging students toward healthier choices in the lunchroom. *J Public Heal (Oxf)*. 2012;34(3):370–6.

15. Sallis JF, Floyd MF, Rodríguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. 2012;125(5):729–37.

16. Leatherdale ST, Manske S, Faulkner G, Arbour K, Bredin C. A multi-level examination of school programs, policies and resources associated with physical activity among elementary school youth in the PLAY-ON study. *Int J Behav Nutr Phys Act*. 2010;7:1–13. DOI: https://doi.org/10.1186/1479-5868-7-6.

17. Beets MW, Beighle A, Erwin HE, Huberty JL. After-School Program Impact on Physical Activity. *AMEPRE*. 2009;36(6):527–37.

18. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Heal Organ*. 2007;85(10):812–9.

19. Nambiar S, Hughes I, Davies PSW. Developing waist-to-height ratio cut-offs to define overweight and obesity in children and adolescents. *Public Health Nutr*. 2010;13(10):1566-74. DOI: 10.1017/S1368980009993053.

20. Filmer D, Pritchett L. Estimating Wealth Effects Without Expenditure Data--Or Tears: An Application to Educational Enrollments in States of India. *Demography*. 2001;38(1):115–32.

21. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. *Clin Obe*s. 2016/01/20. 2016;6(1):19–32.

22. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3):e92846. DOI: 10.1371/journal.pone.0092846.

23. Miyazaki Y, Stack M. Examining individual and school characteristics associated with child obesity using a multilevel growth model. *Soc Sci Med*. 2015;128:57–66.

24. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School Food Environments and Practices Affect Dietary Behaviors of US Public School Children. *J Am Diet Assoc*. 2009;109(2):S91–107.

25. Gibson EL, Wardle J, Watts CJ. Fruit and vegetable consumption, nutritional knowledge and beliefs in mothers and children. *Appetite*. 1998;31(2):205–28.

26. Golan M, Crow S. Parents Are Key Players in the Prevention and Treatment of Weight-related Problems. *Nutr Rev*. 2004;62(1):39–50.

27. Vepsäläinen H, Mikkilä V, Erkkola M, Broyles ST, Chaput J-P, Hu G, et al. Association between home and school food environments and dietary patterns among 9-11-year-old children in 12 countries. *Int J Obes Suppl*. 2015;5(Suppl 2):S66-73.

28. Brown R, Ogden J. Children's eating attitudes and behaviour: A study of the modelling and control theories of parental influence. *Health Educ Res*. 2004;19(3):261–71.

29. Richmond TK, Elliott MN, Franzini L, Kawachi I, Caughy MO, Gilliland MJ, et al. School programs and characteristics and their influence on student BMI: Findings from healthy passages. *PLoS One*. 2014;9(1):e83254. DOI: 10.1371/journal.pone.0083254.

CHAPTER 8

Summary of findings and discussion, conclusions, limitations and recommendations

8.0 Introduction

Background

The chapter provides summary of findings and discussion, limitations of study, public health implications, and recommendations.

Aim

The aim of the thesis was to describe the prevalence of overweight and obesity and associated factors among school children aged 8-11 years in primary schools in Adentan Municipality, Ghana. The study further sought to review the available literature on childhood obesity in the African context to provide evidence to support the design and improvement of appropriate school-based interventions for the prevention and control of obesity among African learners.

Summary of methodology

This thesis utilised a cross-sectional study design which was conducted in two phases: In ***Phase I***, the available literature on prevalence of overweight and obesity, school-based interventions targeting healthy behaviours and weight status, and national policies to prevent and control obesity was reviewed and synthesised in chapters 2 – 4. In ***Phase II***, the prevalence and correlates of overweight and obesity, the diagnostic accuracy of the published BMI references to detect excess body fat, and the contributions of school attributes to the observed weight status were examined in a cross-sectional study of Ghanaian school children, summarised in chapters 5 – 7.

8.1 Summary of findings

Phase I: Systematic review, meta-analysis and scoping review of overweight/obesity prevalence, and interventions at the school and policy levels

The objective of **Chapter 2** was to estimate the prevalence of overweight and obesity among primary school learners aged 6 – 12 years in Africa according to different diagnostic criteria, and population level characteristics in a systematic review and meta-analysis. From the 45 studies included, the pooled overweight and obesity prevalence were 9.4% and 5.0% and varied significantly across the CDC-, IOTF- and WHO- diagnostic criteria. Additionally, the area of residence and the SES level of the school a child attended were associated with overweight and obesity across all criteria. For example, children who were attending private, and urban schools were significantly more overweight and obese as compared with those attending public, and rural schools regardless of the diagnostic criteria used. Furthermore, the results did not show significant gender differences in primary school learners, although the estimates of the pooled prevalence of overweight and obesity were always higher in girls compared with boys.

In **Chapter 3**, research on school-based interventions that focused on promoting healthy eating and PA, and preventing childhood obesity among learners aged 9 – 15 years in Africa were identified and synthesised in a systematic review. Only a limited number of studies were found. Although inconsistent, the results showed that school-based interventions broadly improved weight status and some energy-balance related health behaviours of children. For example, intake of fruits and vegetables significantly improved in intervention groups in some studies. In other studies, no significant effects were observed in the consumption of sugar-sweetened beverages in the intervention groups. Furthermore, interventions resulted in significant improvements in the scores of nutrition and PA knowledge, self-efficacy, attitudes, and intention to engage in healthy behaviours in majority of the studies that evaluated these outcomes. Again, higher proportions of children in the intervention groups, relative to the controls, met the WHO recommended PA guidelines in other studies.

In **Chapter 4**, a scoping review was performed to identify and categorise national policies to prevent obesity in selected African countries using the ANGELO framework. Only two of the retrieved documents focused on obesity prevention; the remaining documents were on NCDs, nutrition, and general health. The majority of the NCD documents detailed strategies and key interventions to address unhealthy diets and physical inactivity. Key policy initiatives by many countries targeted the school, family, and community settings, and macro environments, and broadly aligned with global recommendations. The policies largely focused on the physical, legislative, and sociocultural domains while the economic domain was less emphasised. Additionally, in all settings (school, family, and community), nutrition and diet-related policy initiatives were in the majority and included: provision of healthy school meals, restrictions on marketing of unhealthy foods and beverages, strengthening nutrition education, monitoring of

BMI, regulations on sugars, fats and salt in processed foods/fast foods/ takeaway/restaurant food, and food taxes and subsidies to promote healthy eating. Overlapping and interactions of policies were observed in the application of the framework. For instance, an economic policy such as sugar tax was combined with limiting the intake of sugar-sweetened beverages through public education on the health benefits of such a behavioural change, which is a sociocultural policy. This indicates the importance of multi-sectoral approach to obesity prevention.

Phase II: School-based survey

In **Chapter 5**, the objective was to describe the prevalence of overweight and obesity and to examine the associated risk factors in Ghanaian school children. The study found that 16.4% of the children were overweight (9.2%) or obese (7.2%), with the prevalence being significantly higher in private schools. In univariable adjusted models (gender- and age- adjusted), middle- and high- SES households, attending private schools and excessive television viewing were associated with higher odds of overweight/obesity, whereas active commuting to and from school and adequate sleep decreased the likelihood. After adjusting for all variables in the multivariable model, private school attendance and excessive television viewing were significantly associated with increased likelihood of overweight/obesity. On the other hand, adequate sleep and active commuting to and from school significantly decreased the odds. The association with household SES no longer existed in the mutually adjusted model.

The study in **Chapter 6** aimed to evaluate the diagnostic accuracy of the CDC-, IOTF- and WHO-based BMI diagnostic criteria in defining obesity compared to the percentage body fat by the deuterium dilution method in a sample of Ghanaian primary school children. The study showed that obesity prevalence by deuterium-derived PBF was the highest across the criteria. As expected, the body fat differed by gender; girls tended to have significantly higher PBF compared to boys. The BMI-for-age z-scores correlated positively with PBF and had high specificities with corresponding high predictive values. Nevertheless, none of the criteria achieved optimal sensitivity. The diagnostic accuracy, indicated by the ROC AUC was similar across all criteria and showed that BMI is an acceptable tool for diagnosing excess body fat in Ghanaian children. The BMI-for-age z-scores that optimise sensitivity, specificity, PPV and NPV for obesity were lower than the published cut-off points.

The objective of **Chapter 7** was to examine the association of the schools' contextual factors with BMI, abdominal obesity and overweight (including obesity) in urban Ghana. The study found that availability of school health policies and practices did not impact the nutrition and PA environments in the expected directions. Results from the null models indicated that the school level contributed 30.0%, 20.6% and 19.7% of the total variance observed in overweight, abdominal obesity and BMI respectively. In the univariable analyses, 1) school-level SES, school type, cafeteria, shops, healthy foods, and after-school recreational facilities predicted overweight, and 2) higher school-level SES, private school, cafeteria, shops, less healthy foods and after-school recreational facilities were associated with increased abdominal obesity while PA facility index decreased the likelihood.

After adjusting for all significant predictors in the multivariable analyses, school SES, healthy foods, and after-school recreational facilities were significantly associated with child overweight, while PA facility index and after-school recreational facilities remained significant predictors of abdominal obesity. In the school level model, school-level SES, private school, cafeteria, shops, healthy and less healthy foods, and after-school recreational facilities were positively associated with child BMI. At the individual and school levels' model, child age, school-level SES, private school, and after-school recreational facilities were associated with child BMI. None of the individual level variables were significantly associated with the odds of overweight, abdominal obesity, and BMI in the univariable analyses.

8.2 Discussion

This section is organised and discussed to reflect how individual characteristics and the socioecological contexts in which the child is embedded (interpersonal, school, and community and policy environments) may be contributing to prevalence of overweight and obesity.

8.2.1 Prevalence of overweight and obesity

Results from both the systematic review and meta-analysis, and the cross-sectional survey showed that prevalence of overweight and/ obesity was high in African learners particularly in urban, private schools and differed by the diagnostic criteria used. Compared to a 2014 review of 68 studies from sub-Saharan Africa also in school-aged children and youth aged 5 – 17 years which estimated 10.6% overweight and 2.5% obesity [1], overweight prevalence was similar but higher obesity from the meta-analysis. Likewise, the high prevalence among children attending urban schools is consistent with what has been reported in other studies in Ghana, sub-Saharan Africa and elsewhere [1–5].

The published BMI references correlated well with the deuterium-derived PBF and were highly specific; nonetheless the observed sensitivity to detect excess body fat in Ghanaian school children was moderate in the present study. Low sensitivity indicates that many children with excess body fat could be misclassified as non-obese. The study also found that many children with normal BMI-for-age z-scores or percentiles had excess body fat. It should be noted that low or normal BMI with increased body fat is associated with increased risk of metabolic syndrome in both children and adults [6,7]. The accuracy of BMI increases with increasing body fat, making it useful for detecting excess body fat in children who are obese. Nonetheless, in thin and overweight children, high BMI may be largely due to FFM. Diagnostic performance is dependent on several factors including characteristics of the study population and the reference for evaluating excess body fat. The inability of BMI to distinguish FM and FFM may have contributed to the underestimation as observed in other research [8,9]. These results indicate that other measures of body composition such as waist circumference, and or other health risk factors associated with obesity should be considered as an indicator of overall health in the screening and management of childhood obesity.

8.2.2 Policy and community influences

The increasing trend in obesity among African learners, particularly in urban areas may be due to the changing food, built and natural environments associated with urban sprawl. Rapid urbanisation and trade liberalisation in African countries have opened up the domestic markets to foreign direct investments including globalisation of the food markets (resulting from reduced tariff or non-tariff barriers) which influence the food environment [10]. Changes in the food environment lead to shifts in dietary patterns from traditional diets of staple foods, whole grains, fruits and vegetables to ultra-processed foods high in vegetable oils, sugar sweetened soft drinks, salt, and animal-sourced foods, subsequently influencing body weight.

Implementing effective food policies has been challenging [11]. In the present study, many African countries have made significant efforts at the national level to provide supportive environments for healthy choices as a way of curbing the growing obesity crisis. The specified initiatives that targeted the food environment have been shown to impact on the dietary behaviours and overweight/obesity. For example, given the influence of food marketing to development of dietary habits and obesity in children, many countries including Australia, Chile, Sweden, Norway, and South Korea have some regulations on marketing food and non-core foods to children [12]. As the evidence suggests, aggressive marketing tactics by the food industry targeted at children [13], food taxes and subsidies [14,15], and food and nutrition labelling [16,17] have all been shown to influence food preferences, purchase of healthy food options and dietary quality in previous studies.

Regarding PA, limited space for public amenities like neighbourhood recreational facilities, congestion, unsafe neighbourhood arising from violence and increased crime rates affect the PA environment. Urban design and planning to improve neighbourhood walkability, including connectivity of streets, land-mix use, and availability of public open spaces and sports facilities, and access to these facilities by reducing barriers aforementioned are all important facilitators of PA. Crime (perceived or objectively assessed) and safety have been associated with outdoor PA especially among children [18–20]. The present study found that some key initiatives outlined to promote PA participation included the provision of and access to adequate recreational facilities, safe neighbourhoods with walking paths, cycling lanes, and public transport. Likewise, one of the main policy interventions at the community level was health promotion through public education and sensitisation of healthy lifestyles (healthy foods/ and PA). Through health promotion and social marketing, the sociocultural norms and practices on diets and PA of the population can be influenced to healthier lifestyles [21].

8.2.3 School level influences

Depending on the outcome measure, child weight status (overweight, obesity, abdominal obesity, and BMI) was associated with: cafeteria and shops, healthy foods, PA facility index, and after-school recreational facilities. Additionally, the availability of less healthy foods was positively associated with BMI but not overweight and abdominal obesity, and the association was no longer significant after controlling for school-level SES, school type, cafeterias, shops, healthy foods, after-school recreational facilities, age, and gender. It was noted that PA facility index decreased the likelihood of abdominal obesity. Except for healthy foods and after-school recreational facilities, all associations were in the expected directions.

The associations of healthy and less healthy foods and beverages, and weight status found in the present study are consistent with findings from other studies [22] and highlight the importance of the food environments as a whole in shaping food choices and eating behaviour, and subsequently influencing body composition. The counterintuitive association between healthy foods and overweight in this study suggests that the availability of healthy foods alone may not be adequate in the fight to prevent overweight and obesity. Given that dietary patterns result from food preferences as well as access to and availability of varieties of foods, it appears the increased exposure to the less healthy foods may have competed with and outweighed the healthy options.

For example, in a cross-sectional study using a nationally representative data from 287 schools and 2314 children in grades one through 12, Briefel et al. [23], showed that not offering low-nutrient, high-energy foods such as French fries and sugar-sweetened beverages at school lunches, school shops and snack bars actually reduced the mean daily energy intake from these foods in elementary and middle school learners. In a separate analysis using the same data, the availability of these foods either as subsidised school meals or near food service area, and consumption were associated with higher BMI z-score and obesity [24]. Furthermore, there was strong evidence for availability of fruits and vegetable and consumption in children in a systematic review of school-based interventions to promote healthy eating habits [25]. There is also the tendency to overconsume foods that are considered healthy thus increasing energy intake.

PA facilities and after-school recreational facilities were independently associated with body composition but in different directions. An inverse association of PA facilities during school hours and child weight status was observed in the present study, parallel to findings from a growing number of studies [26,27]. On the other hand, availability of after-school recreational facilities was positively associated with weight status. Presupposing that access to these facilities would promote PA levels among children, the paradoxical observation in the present study could be due to limited time for after-school PA participation, lack of supervision, or individual correlates that were not accounted for. Sports facilities on and off school grounds may promote increased PA [28,29], but for them to be effective they must be accompanied by supervised after-school PA participation which may in turn lead to increased energy expenditure and favourable body composition. Additionally, the phenomenon of after-school classes is popular in basic schools in Ghana. While it is organised by both private and public schools, it is more common in the private or high SES schools. Participation in these after-school classes may displace time available for other extra-curricular activities including sports and may partly explain these observations.

Furthermore, this study found that school-based interventions were valuable in improving health behaviours and weight status of learners, broadly in line with documented evidence [30–33]. Generally, multicomponent interventions targeting individual behaviours and the environments concurrently are more likely to be effective in the improvement of outcomes relative to single component interventions. For example, Verstraeten et al. [31] showed that outcomes were favourable when multicomponent interventions were integrated into the school curriculum [31]. Given that children spend significant amount of their waking time at school, this period could be used to impact healthy lifestyle behaviours thereby reducing the prevalence of unhealthy weight.

8.2.4 Interpersonal level

Generally, family SES is consistently related to obesity but the direction may differ depending on the human and economic development of the country. In developed countries, an inverse association with overweight/obesity is reported [34] whereas higher family SES is linked to higher likelihood of overweight/obesity in developing countries [35–37]. In the present study, children in middle-to-high SES households were more likely to be overweight or obese, similar to other studies in Ghana and elsewhere in Africa [3,5,37]. Also, parental employment, an indicator of family SES, differed significantly between private and public schools. It should be noted that in Ghana, public unlike private schools are funded by the government thus many low SES families tend to enrol their wards in these schools. Indeed, in their review in 2016, Fruhstorfer et al. [37] showed positive relationships of family SES and affluent or private school attendance with childhood overweight or obesity in sub-Saharan Africa.

There are several possible explanations. Parental and family environment may impact body composition of children by influencing dietary intake, PA and sedentary behaviours through home supportive environments. For example, working habits, parental education and occupation, health knowledge, attitudes and behaviours such as feeding practices, and availability and accessibility of healthy foods and recreational facilities, and playing the role of social models all contribute to the development of health behaviours [38–40].

In developing countries including Ghana, increased family SES could reflect in higher disposable incomes for abundance of high-energy, low nutrient foods as well as healthy foods, whereas lower SES families may generally have limited access to food. Children from higher SES households may equally have increased access to technology such as cars, electronic devices, computers, and indoor entertainments facilities, but also increased number of PA equipment at home which may influence energy expenditure. Moreover, children from lower SES households especially in Africa may engage in daily household chores which contribute to increased energy expenditure while children from higher SES families may have house helps. Likewise, maternal full time employment which contributes to improved annual income and hence higher SES has been linked to poor eating habits and sedentary behaviours, and higher overweight rates in children [41]. Mothers who work longer hours may have limited time available to prepare fresh family meals and may depend on convenience foods and higher frequency of eating away from home. These practices have been positively associated with increases in weight gains in some studies [42–44]. As observed earlier, international fast food chains and supermarkets in Ghana are mainly patronised by middle-to-high income earners [45]. Additionally, longer hours of parental employment may lead to increased sedentary activities particularly television viewing time of children.

Furthermore, parenting styles (like setting limits and rules on sedentary behaviours and intake of unhealthy foods); feeding practices (example providing access to fruits and vegetables; nonresponsive feeding such as using ice-cream, chips, sweets, and soft drinks as rewards for eating vegetables or good behaviour; pressure-to-eat by encouraging children to eat all the food on their plate regardless of portion size served; or forcing children to eat when not hungry); and modeling of healthy behaviours (like performing activities with the children as family recreation), all contribute to development of children's dietary and PA behaviours. For instance, in a cross-sectional study of 253 parent/girl dyads in the US, intake of soft drink, fruit and vegetables, PA participation, and television viewing in adolescent girls were consistently associated with parental modelling [39]. In other studies, family support and parental modelling were positively associated with PA of children [38,46]. Perception of obesity in African countries especially among females may also favour excess body weight [47].

8.2.5 Intrapersonal level

Overweight/obesity was associated with sleep duration, television viewing, active transport, but not overall PA in the present study. For example, active transport and adequate sleep were inversely associated with overweight or obesity, whereas excessive television viewing increased the odds. Child age was only associated with BMI in the mutually adjusted individual and school level model.

The results on sleep duration and overweight/obesity are similar to available evidence suggesting that shorter sleep duration presents a potential risk in weight gain in childhood [48–51]. For example, Touchette and colleagues showed in a longitudinal prospective cohort study of 1138 young children that short sleep duration was significantly associated with a higher risk of overweight and obesity in childhood independent of other energy-related behaviours [51]. Shorter sleep duration can cause changes in screen time behaviours as well as several hormonal changes and metabolic abnormalities [48] leading to increased appetite, hunger and increased food intake [52,53] during more awake time. Nonetheless, the evidence in support of reduced energy expenditure through decreased PA and increased sedentary behaviour is conflicting [54] partly due to methodological differences including the protocols for assessing energy expenditure, and inter-individual variability.

The current study found an association of television viewing with overweight/obesity which is consistent with the available literature [55,56]. For instance, in one study of children and youth [55], viewing television for more than two hours a day was associated with unfavourable health outcomes including body composition, metabolic syndrome and cardiovascular disease. Several mechanisms to explain the association include: limited time available for outdoor PA leading to reduced energy expenditure; exposure to food advertising of high-energy, poor nutrient food products targeting children [57,58]; and excessive snacking of these less healthy foods while viewing television [59]. A study in South Africa that investigated content analysis of television food advertisements found that majority of the foods advertised were frequently shown at family viewing time and involved mainly foods of poor nutritional quality like sweets, desserts, fast foods and sweetened beverages [58].

PA influences body composition through increased energy expenditure. It is well-documented that physically active children are less likely to have higher PBF and be obese compared with children who are less physically active [60]. Contrary to the beneficial effects, no association of PA with overweight/obesity was observed in the present study. This may be due to methodological issues, including individual characteristics of study participants, level of PA, study size, and study design.

The unexpected results are however similar to previous findings [61–64]. The evidence from three reviews involving learners either appear to suggest that PA interventions does not improve BMI and waist circumference [61,62], or mixed [63]. In one review, for example 22 studies out of a total of 38 showed no difference, 14 found positive relationship with 3 reporting no association [63]. These results also agree with those from adults in South Africa showing no association of PA with body composition [64].

Regarding the link between active transport and overweight/obesity, the results from the present study are largely in agreement with findings from other studies [5,65,66]. This study showed that significantly more learners in private schools used motorised transport relative to those in public schools. It should be noted that in Ghana, the majority of children in public schools engage in active transport to school since they are most often enrolled in nearby schools and even those who attend schools that are long distance from their homes use public transport and walked the rest of the journey from the bus stops to and from school. It is speculated that those children who engaged in walking or cycling to school were more likely to meet recommended PA guidelines of the WHO, and this may in turn result in increased energy expenditure, and ultimately lower body weight.

8.3 Conclusions and Public health implications

The present study presented a window of opportunity to identify the correlates and provide the evidence to support childhood obesity prevention and control efforts targeting school children in the African context. Childhood overweight/obesity and abdominal obesity among school children in the Adentan Municipality were 16.4% and 18.8%. A number of individual and environmental factors were associated with child weight depending on the outcome measure. Prevalence of all indicators of unhealthy weight (overweight/obesity and abdominal obesity, higher BMI, and WHtR) was higher in children in private or higher SES level schools, in children who had access to healthy food options at school, and after-school recreational facilities, and in children who viewed television for more than 2 hours daily. Among children who slept for at least 9 hours, who walked or cycled to and from school, and who had access to increased PA facilities during school hours, the odds were lower.

While most of these factors were in the expected directions, a few were counterintuitive. The findings from this study confirm the notion that health outcomes are determined by individual but also environmental factors and underscores the need for a more holistic approach in tackling the obesogenic environments. The findings which add to the limited and inconsistent findings in this area reinforce the need for a multi-sectoral approach when designing interventions to curb the obesity epidemic. The physical characteristics of the school food and nutrition, and PA environments are relevant targets for interventions. Given that children spend significant amount of their waking time at school this period could be used to impact healthy lifestyle behaviours which are likely to be maintained through adulthood thereby reducing the prevalence of unhealthy weight.

8.4 Strengths and limitations of the study

A strength of the study was the objective measurement of anthropometric data. Furthermore, PAQ-C is a validated tool for PA assessment among children in the school settings. Additional strength was the application of stable isotope (deuterium oxide) to assess the body fat in the children. Deuterium is safe, accurate and non-invasive for assessing body composition and obtaining data on body fat and FFM. Moreover, the questions were adapted from valid and reliable existing instruments in similar studies.

There are limitations to the present study which must be noted. Firstly, the study design was cross-sectional and therefore precludes inferences of causal relationships. Another limitation was the method of data collection, which is self-report. This could have introduced errors associated with social desirability and recall bias. Also, this study could not evaluate parental BMI, maternal education, and the home food and PA environments. Given that these variables are significant predictors of child weight, they would have helped to provide explanations to the observed associations. Additionally, study-specific strengths and limitations have been reported in the relevant chapters.

8.5 Contributions of the thesis

This study builds upon prior research by focusing on the pre-adolescence age group which is largely under-represented in national health research surveys compared to the pre-school and adolescence periods. This thesis also extends previous obesity literature by examining individual factors as well as various aspects of the PA and food environments, multiple data sources to provide evidence on childhood obesity and prevention in Africa, and evaluating the accuracy of the WHO, IOTF, and CDC BMI references to detect excess body fat in Ghanaian learners using stable isotope technique as the criterion method. The research reported in this thesis makes an important contribution to knowledge in the field of obesity research by producing a contemporary policy document (an upstream approach) of key intervention initiatives by African countries to make healthy choices the default option in the home, the school and the community. Moreover, the study has contributed to the limitations of BMI-for-age z-scores to diagnose obesity in children. Among Ghanaian learners, the BMI-for-age criteria have moderate sensitivity and may lead to missed opportunities for public health interventions as a result of misclassification.

8.6 Recommendations

Multiple factors were found to be associated with overweight, obesity, abdominal obesity, and BMI. Majority of these factors were consistent with the literature. The following recommendations are made:

Future research directions

It is recommended that objective measures such as accelerometry for PA and doubly-labelled water for energy expenditure be incorporated in future research of childhood obesity and the school environments to validate the information obtained through self-report. These are likely to reduce the effect of recall bias and social desirability associated with self-report. Determinants of PA, dietary and sedentary behaviours should be thoroughly investigated. Mediation analysis of how child behaviours like PA, eating behaviours and other health behaviours mediate or moderate child weight in the school context should be considered. The family/home environments should also be fully explored since the home is one important setting for the development of childhood obesity. Given the limited studies on childhood obesity prevention in the school settings across Africa, it is needful to explore the possibility of large multi-site and well-designed studies. These studies should employ harmonised methodologies and be theory-driven with direct parental involvement. Furthermore, researchers should consider incorporating formative research prior to implementation, as well as integrating interventions into already existing healthy lifestyle school programmes (regular school curricula) and structures to ensure maximum reach, sustainability and effectiveness. Moreover, comprehensive systematic reviews should be conducted on the policy environment with regard to obesity prevention. These recommendations would improve the effectiveness of school-based obesity intervention and also contribute to the evidence base across Africa.

Home and school

It is recommended that parental rules and regulations on television viewing, particularly time spent in viewing television and sleep times be enforced. The family should promote and encourage consumption of fruits and vegetable and discourage intake of high energy snacks, sugar sweetened beverages by ensuring that making healthy choices become the default option for the whole family.

The schools should strengthen available health committees in charge of health and wellness issues. Although school support for active transport did not predict childhood overweight/obesity in the present study, it is recommended that the schools put structures in place to promote active transport among children by encouraging cycling, and use of small vehicles to schools. Given the abundance of less healthy foods available to the children, concerted efforts should be made to regulate the marketing of these foods and drinks at the school tuck shops, canteens and cafeterias, and food service points near schools. Public health efforts should be geared towards decreasing the less healthy options at schools as the availability and accessibility influence eating behaviour. Schools should strengthen structured physical education and PA lessons in the weekly time table, and where practicable, organise after-school PA activities programmes for children, to be supervised by qualified personnel since PA does not only influence weight but other health outcomes.

Government

Provision of PA facilities especially to public schools should be considered since these facilities were mostly inadequate. It is also recommended that PA activities and the school food environment be monitored by the relevant government institutions to ensure that policies are strictly adhered to.

Healthcare professionals

To improve diagnosis and management of childhood obesity, healthcare professionals and physicians should be made aware of the limitations of the BMI. Where possible, more than one BMI-for-age reference should be employed to diagnose obesity, in addition to the direct assessment of body fat and or other health risk factors. Also, lifestyle behavioural changes should be re-enforced in counselling sessions as preventative measures, where these are not already part of the management regime.

8.7 References

1. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS One*. 2014;9(3):e92846. DOI: 10.1371/journal.pone.0092846.

2. Chirita-Emandi A, Barbu CG, Cinteza EE, Chesaru BI, Gafencu M, Mocanu V. Overweight and Underweight Prevalence Trends in Children from Romania – Pooled Analysis of Cross-Sectional Studies between 2006 and 2015. *Obes Facts*. 2016;(9):206–220.

3. Aryeetey R, Lartey A, Marquis GS, Nti H, Colecraft E, Brown P. Prevalence and predictors of overweight and obesity among school-aged children in urban Ghana. *BMC Obes*. 2017;4(1):38. DOI: 10.1186/s40608-017-0174-0

4. Negash S, Agyemang C, Matsha TE, Peer N, Erasmus RT, Kengne AP. Differential prevalence and associations of overweight and obesity by gender and population group among school learners in South Africa: a cross-sectional study. *BMC Obes*. 2017;4(1):29. DOI: 10.1186/s40608-017-0165-1

5. Mwaikambo SA, Leyna GH, Killewo J, Simba A, Puoane T. Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. *BMC Public Health*. 2015/12/23. 2015;15:1269. DOI: 10.1186/s12889-015-2598-0.

6. Romero-Corral A, Somers VK, Sierra-Johnson J, Korenfeld Y, Boarin S, Korinek J, et al. Normal weight obesity: A risk factor for cardiometabolic dysregulation and cardiovascular mortality. *Eur Heart J*. 2010;31(6):737–46.

7. Nightingale CM, Rudnicka AR, Owen CG, Cook DG, Whincup PH. Patterns of body size and adiposity among UK children of South Asian, black African-Caribbean and white European origin: Child Heart And health Study in England (CHASE Study). *Int J Epidemiol*. 2010/11/04. 2011;40(1):33–44.

8. Hudda MT, Nightingale CM, Donin AS, Fewtrell MS, Haroun D, Lum S, et al. Body mass index adjustments to increase the validity of body fatness assessment in UK Black African and South Asian children. *Int J Obes*. 2017;41(7):1048–55. DOI:10.1038/ijo.2017.75.

9. Mehdad S, Hamrani A, El Kari K, El Hamdouchi A, Barakat A, El Mzibri M, et al. Body mass index, waist circumference, body fat, fasting blood glucose in a sample of Moroccan adolescents aged 11-17 years. *J Nutr Metab*. 2012;2012. DOI:10.1155/2012/510458

10. Friel S, Chopra M, Satcher D. Unequal weight: equity oriented policy responses to the global obesity epidemic. *BMJ*. 2007;335(7632):1241–3.

11. Pérez-Escamilla R, Lutter C, Rabadan-Diehl C, Rubinstein A, Calvillo A, Corvalán C. Prevention of childhood obesity and food policies in Latin America: from research to practice. *Obes Rev*. 2017; Suppl 2:28-38. DOI: 10.1111/obr.12574.

12. Gorski M, Roberto C. Public health policies to encourage healthy eating habits: recent perspectives. *J Healthc Leadersh*. 2015;7(3):81–90.

13. Sadeghirad B, Duhaney T, Motaghipisheh S, Campbell NRC, Johnston BC. Influence of unhealthy food and beverage marketing on children's dietary intake and preference: a systematic review and meta-analysis of randomized trials. *Obes Rev*. 2016;17(10):945–59.

14. Thow AM, Downs S, Jan S. A systematic review of the effectiveness of food taxes and subsidies to improve diets: Understanding the recent evidence. *Nutr Rev*. 2014;72(9):551–65.

15. Cabrera Escobar MA, Veerman JL, Tollman SM, Bertram MY, Hofman KJ. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. *BMC Public Health*. 2013;13(1072). DOI: 10.1186/1471-2458-13-1072.

16. Miller, Soederberg Lisa M. Cassady DL, Applegate EA, Beckett LA, Wilson MD, Gibson TN, Ellwood K. Relationships among Food Label Use, Motivation, and Dietary Quality. *Nutrients*. 2015;7:1068–80.

17. Cecchini M, Warin L. Impact of food labelling systems on food choices and eating

behaviours: A systematic review and meta-analysis of randomized studies. *Obes Rev*. 2016;17(3):201–10.

18. Rees-Punia E, Hathaway ED, Gay JL. Crime, perceived safety, and physical activity: A meta-analysis. *Prev Med (Baltim)*. 2017;(November):0–1.

19. Datar A, Nicosia N, Shier V. Parent perceptions of neighborhood safety and children's physical activity, sedentary behavior, and obesity: Evidence from a national longitudinal study. *Am J Epidemiol*. 2013;177(10):1065–73.

20. Galaviz KI, Zytnick D, Kegler MC, Cunningham SA. Parental Perception of Neighborhood Safety and Children's Physical Activity. *J Phys Act Heal*. 2016;13:1110–6.

21. WHO. Report of the Commission on Ending Childhood Obesity. World Health Organization. 2016. World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

22. Cooksey-Stowers K, Schwartz MB, Brownell KD. Food Swamps Predict Obesity Rates Better Than Food Deserts in the United States. *Int J Environ Res Public Health*. 2017;14: 1366; DOI:10.3390/ijerph14111366.

23. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School Food Environments and Practices Affect Dietary Behaviors of US Public School Children. *J Am Diet Assoc*. 2009;109(2):S91–107. DOI: 10.1016/j.jada.2008.10.059

24. Fox MK, Dodd AH, Wilson A, Gleason PM. Association between School Food Environment and Practices and Body Mass Index of US Public School Children. *J Am Diet Assoc*. 2009;109(2):S108–17. DOI: 10.1016/j.jada.2008.10.065.

25. Van Cauwenberghe E, Maes L, Spittaels H, Van Lenthe FJ, Brug J, Oppert JM, et al. Effectiveness of school-based interventions in Europe to promote healthy nutrition in children and adolescents: Systematic review of published and grey literature. *Br J Nutr*. 2010;103(6):781–97.

26. Sallis JF, Floyd MF, Rodríguez DA, Saelens BE. Role of built environments in physical

activity, obesity, and cardiovascular disease. *Circulation*. 2012;125(5):729–37.

27. Leatherdale ST. A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 to 4 students. *BMC Public Health.* 2013;13:982. http://www.biomedcentral.com/1471-2458/13/982.

28. Lo K-Y, Wu M-C, Tung S-C, Hsieh C, Yao H-H, Ho C-C. Association of School Environment and After-School Physical Activity with Health-Related Physical Fitness among Junior High School Students in Taiwan. *Int J Environ Res Public Health*. 2017;14(1):83. DOI: https://doi.org/10.3390/ijerph14010083

29. Beets MW, Beighle A, Erwin HE, Huberty JL. After-School Program Impact on Physical Activity. *AMEPRE*. 2009;36(6):527–37.

30. Bleich SN, Vercammen KA, Zatz LY, Frelier JM, Ebbeling CB, Peeters A. Interventions to prevent global childhood overweight and obesity: a systematic review. *Lancet Diabetes Endocrinol*. 2018;6(4):332–46. DOI: http://dx.doi.org/10.1016/S2213-8587(17)30358-3

31. Verstraeten R, Roberfroid D, Lachat C, Leroy JL, Holdsworth M, Maes L, et al. Effectiveness of preventive school-based obesity interventions in low- and middle-income countries: a systematic review. *Am J Clin Nutr*. 2012;96(10):415–38.

32. Waters E, de Silva-Sanigorski A, Burford BJ, Brown T, Campbell KJ, Gao Y, et al. Interventions for preventing obesity in children. *Cochrane Database Syst Rev*. 2011;(12). DOI: http://doi.wiley.com/10.1002/14651858.CD001871.pub3

33. Brown EC, Buchan DS, Baker JS, Wyatt FB, Bocalini DS, Kilgore L. A Systematised Review of Primary School Whole Class Child Obesity Interventions: Effectiveness, Characteristics, and Strategies. *Biomed Res Int*. 2016. DOI: http://dx.doi.org/10.1155/2016/4902714.

34. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief*. 2010;127(51):1–8.

35. Ziraba AK, Fotso JC, Ochako R. Overweight and obesity in urban Africa: A problem of the

rich or the poor? *BMC Public Health*. 2009;9(1):465. DOI: https://doi.org/10.1186/1471-2458-9-465

36. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocr Rev*. 2012;33(1):48–70.

37. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. *Clin Obes*. 2016/01/20. 2016;6(1):19–32. DOI: 10.1111/cob.12130.

38. McMinn AM, Griffin SJ, Jones AP, Van Sluijs EMF. Family and home influences on children's after-school and weekend physical activity. *Eur J Public Health*. 2013;23(5):805–10.

39. Bauer KW, Neumark-Sztainer D, Fulkerson JA, Hannan PJ, Story M. Familial correlates of adolescent girls' physical activity, television use, dietary intake, weight, and body composition. *Int J Behav Nutr Phys Act*. 2011;8(1):25. DOI: 10.1186/1479-5868-8-25.

40. Horst K Van Der, Oenema A, Ferreira I, Giskes K, Lenthe F Van, Brug J. A systematic review of environmental correlates of obesity-related dietary behaviors in youth. *Health Educ Res*. 2007;22(2):203–26.

41. Fitzsimons E, Pongiglione B. The impact of maternal employment on children's weight: Evidence from the UK. SSM - *Popul Heal*. 2019;7:100333. https://doi.org/10.1016/j.ssmph.2018.100333.

42. Bezerra IN, Curioni C, Sichieri R. Association between eating out of home and body weight. *Nutr Rev*. 2011;70(2):65–79.

43. Duffey KJ, Gordon-larsen P, Jr DRJ, Williams OD, Popkin BM. Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study 1 – 3. *Am J Clin Nutr*. 2007;85:201–8.

44. Pereira MA, Kartashov AI, Ebbeling CB, Horn L Van, Slattery ML, Jr DRJ, et al. Fast-food

habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet*. 2005;365(January 1):36–42.

45. Meng T, Florkowski WJ, Sarpong DB, Chinnan MS, Resurreccion AVA. Consumer's food shopping choice in Ghana: Supermarket or traditional outlets? *Int Food Agribus Manag Rev*. 2014;17(Special IssueA):107–29.

46. Zecevic CA, Tremblay L, Lovsin T, Michel L. Parental Influence on Young Children's Physical Activity. *Int J Pediatr*. 2010:1–9.

47. Puoane T, Tsolekile L, Steyn N. Perceptions about body image and sizes among Black African girls living in Cape Town. *Ethn Dis*. 2010/02/25. 2010;20(1):29–34.

48. Hart CN, Cairns A, Jelalian E. Sleep and Obesity in Children and Adolescents. *Pediatr Clin North Am*. 2012;58(3):715–33.

49. Katzmarzyk PT, Barreira T V, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11: Results from a 12-country study. *Obes (Silver Spring)*. 2015/07/15. 2015;23(8):1696–702.

50. Li L, Zhang S, Huang Y, Chen K. Sleep duration and obesity in children: A systematic review and meta-analysis of prospective cohort studies. *J Paediatr Child Health*. 2017;53(4):378–85.

51. Touchette É, Petit D, Tremblay RE, Boivin M, Falissard B, Genolini C. Associations Between Sleep Duration Patterns and Overweight/Obesity at Age 6. *Sleep*. 2008;31(11):1507–14.

52. Westerlund L, Ray C, Roos E. Associations between sleeping habits and food consumption patterns among 10-11-year-old children in Finland. *Br J Nutr*. 2009;102(10):1531–7.

53. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. *Sleep*. 2010;33(9):1201–9.

54. Chaput J-P, Tremblay A. Insufficient Sleep as a Contributor to Weight Gain: An Update. *Curr Obes Rep*. 2012;1(4):245–56.

55. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2011;8(1):98. DOI: 10.1186/1479-5868-8-98.

56. Braithwaite I, Stewart AW, Hancox RJ, Beasley R, Murphy R, Mitchell EA. The Worldwide Association between Television Viewing and Obesity in Children and Adolescents: Cross Sectional Study. *PLoS One*. 2013;8(9). e74263. DOI:10.1371/journal.pone.0074263.

57. Watson WL, Lau V, Wellard L, Hughes C, Chapman K. Advertising to children initiatives have not reduced unhealthy food advertising on Australian television. *J Public Heal (United Kingdom)*. 2017;39(4):787–92.

58. Mchiza ZJ, Temple NJ, Steyn NP, Abrahams Z, Clayford M. Content analysis of television food advertisements aimed at adults and children in South Africa. *Public Health Nutr*. 2013;16(12):2213–20.

59. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: Part of a bigger picture. *Lancet*. 2015;385(9986):2510–20. http://dx.doi.org/10.1016/S0140-6736(14)61746-3.

60. Hills AP, Andersen LB, Byrne NM. Physical activity and obesity in children. *Br J Sport Med*. 2011;45:866–70.

61. Dobbins M, Husson H, Decorby K, LaRocca RL. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev*. 2013;(2):Art.No.:CD007651. DOI: 10.1002/14651858.CD007651.p.

62. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: A meta-analysis. *CMAJ*. 2009;180(7):719–26.

63. Larouche R, Saunders TJ, John Faulkner GE, Colley R, Tremblay M. Associations between Active School Transport and Physical Activity, Body Composition, and Cardiovascular Fitness: A Systematic Review of 68 Studies. *J Phys Act Heal*. 2014;11(1):206–27. DOI: http://doi.org/doi/10.1123/jpah.2011-0345.

64. Malhotra R, Hoyo C, Østbye T, Hughes G, Schwartz D, Tsolekile L, et al. Determinants of obesity in an urban township of South Africa. *S Afr J Clin Nutr*. 2008;21(4):315–20.

65. Sarmiento OL, Lemoine P, Gonzalez SA, Broyles ST, Denstel KD, Larouche R, et al. Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries. *Int J Obes Suppl*. 2016/05/07. 2015;5(Suppl 2):S107-14.

66. Larouche R, Lloyd M, Knight E, Tremblay MS. Relationship Between Active School Transport and Body Mass Index in Grades- 4-to-6 Children. *Pediatric Exercise Science*. 2011, 23, 322-330.

APPENDICES

Appendix I: Supplementary materials for prevalence studies

Table S1. Search strategy for PubMed

Search	Search terms	Hits
1	Obesity [tw] OR obese [tw] OR overweight [tw] over weight [tw] OR over-weight [tw] OR weight disorder* [tw] OR body composition [tw] OR body mass index [tw] OR body weight* [tw] OR BMI [tw] OR body fat [tw] OR percent* body fat [tw] OR body fat percent* [tw] OR body fat distribution [tw] OR adiposity [tw] OR skinfold thickness [tw] OR skinfolds [tw]	
2	Obesity [MeSH Terms]	
3	Overweight [MeSH Terms]	
4	# 1 OR # 2 OR # 3	
5	Learners [tw] OR schoolchildren [tw] OR school children [tw] OR school-children [tw] OR school going children [tw] OR school-going children [tw]	
6	# 4 AND # 5	
7	((((("Africa"[MeSH] OR Africa*[tw] OR Algeria[tw] OR Angola[tw] OR Benin[tw] OR Botswana[tw] OR "Burkina Faso"[tw] OR Burundi[tw] OR Cameroon[tw] OR "Canary Islands"[tw] OR "Cape Verde"[tw] OR "Central African Republic"[tw] OR Chad[tw] OR Comoros[tw] OR Congo[tw] OR "Democratic Republic of Congo"[tw] OR Djibouti[tw] OR Egypt[tw] OR "Equatorial Guinea"[tw] OR Eritrea[tw] OR Ethiopia[tw] OR Gabon[tw] OR Gambia[tw] OR Ghana[tw] OR Guinea[tw] OR "Guinea Bissau"[tw] OR "Ivory Coast"[tw] OR "Cote d'Ivoire"[tw] OR Jamahiriya[tw] OR Jamahiryia[tw] OR Kenya[tw] OR Lesotho[tw] OR Liberia[tw] OR Libya[tw] OR Libia[tw] OR Madagascar[tw] OR Malawi[tw] OR Mali[tw] OR Mauritania[tw] OR Mauritius[tw] OR Mayote[tw] OR Morocco[tw] OR Mozambique[tw] OR Mocambique[tw] OR Namibia[tw] OR Niger[tw] OR Nigeria[tw] OR Principe[tw] OR Reunion[tw] OR Rwanda[tw] OR "Sao Tome"[tw] OR Senegal[tw] OR Seychelles[tw] OR "Sierra Leone"[tw] OR Somalia[tw] OR "South Africa"[tw] OR "St Helena"[tw] OR Sudan[tw] OR Swaziland[tw] OR Tanzania[tw] OR Togo[tw] OR Tunisia[tw] OR Uganda[tw] OR "Western Sahara"[tw] OR Zaire[tw] OR Zambia[tw] OR Zimbabwe[tw] OR "Central Africa"[tw] OR "Central African"[tw] OR "West Africa"[tw] OR "West African"[tw] OR "Western Africa"[tw] OR "Western African"[tw] OR "East Africa"[tw] OR "East African"[tw] OR "Eastern Africa"[tw] OR "Eastern African"[tw] OR "North Africa"[tw] OR "North	

	African"[tw] OR "Northern Africa"[tw] OR "Northern African"[tw] OR "South African"[tw] OR "Southern Africa"[tw] OR "Southern African"[tw] OR "sub Saharan Africa"[tw] OR "sub Saharan African"[tw] OR "subSaharan Africa"[tw] OR "subSaharan African"[tw]) NOT ("guinea pig"[tw] OR "guinea pigs"[tw] OR "aspergillus niger"[tw])))))	
8	# 6 AND # 7	
9	# 8 Limits: 1980/01/01 to 2017/02/28	

Table S2: PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3 & 4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4, PROSPERO, # CRD42016035248
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4 & 5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	1
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5 & 6

Table S3: Summary of the quality scores of the included studies

Reference	Is the hypothesis/ aim/ objective of the study clearly described?	Are the main outcomes to be measured clearly described in the Introduction or Methods section?	Are the characteristics of the patients included in the study clearly described?	Are the main findings of the study clearly described?	Does the study provide estimates of the random variability in the data for the main outcome	Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?	Were the subjects asked to participate in the study representative of the entire population from which they were recruited?	Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	Were the statistical tests used to assess the main outcomes appropriate?	Were the main outcome measures used accurate (valid and reliable)?	Total score
Abrahams et al,[82]	1	1	0	1	1	1	0	0	1	1	7
Amidu et al [9]	1	1	1	0	1	1	1	0	1	1	8
Armstrong et al, [83]	1	1	1	1	1	1	1	1	1	1	10
Boukthir, et al [84]	1	1	1	1	1	1	0	0	1	1	8
Caleyachetty, et al [85]	1	1	0	1	1	1	1	1	1	1	9
Chebet et al [86]	1	1	0	1	1	0	0	0	0	1	5
Daboné et al, [87]	1	1	1	1	1	1	0	0	1	1	8
Dekkaki et al, [88]	1	1	0	1	1	1	1	0	1	1	8
El-Sabely et al, [89]	1	1	0	1	1	1	0	0	1	1	7
Fetuga et al [90]	1	1	0	1	1	1	1	0	1	1	8
Hassan et al [91]	1	1	0	1	1	0	0	0	1	1	6
Jinabhai et al, [92]	1	1	1	1	1	0	1	1	1	1	9
Jinabhai et al, [93]	1	1	1	1	1	1	1	0	1	1	9
Kirsten et al [94]	1	1	1	1	0	1	1	0	1	1	8
Kyallo et al, [95]	1	1	1	0	1	1	0	0	1	1	7
Maruf et al, [96]	1	1	1	1	1	1	1	0	1	1	9
McKersie et al [97]	0	1	1	1	1	0	1	0	1	1	7
Mogre et al, [10]	0	1	0	1	1	1	1	0	1	1	7
Mohammed et al, [98]	0	1	1	0	0	1	1	0	1	1	6

Moselakgomo et al [99]	1	1	1	1	1	1	0	0	1	1	8
Mosha et al [100]	1	1	1	1	0	0	0	0	1	1	6
Mpembeni, et al [101]	1	1	1	1	1	1	1	0	1	1	9
Muhihi, et al [102]	1	1	1	1	1	1	1	0	1	1	9
Muthuri et al [103]	1	1	1	1	1	1	0	1	1	1	9
Mwaikambo et al, [104]	0	1	0	1	1	1	1	0	1	1	7
Navti et al, [105]	1	1	0	0	1	1	1	0	1	1	7
Oldewage-Theron et al [106]	1	1	0	1	1	0	0	0	1	1	6
Pangani, et al [107]	1	1	1	0	1	1	1	0	1	1	8
Pedro et al [108]	1	1	1	1	1	1	0	0	1	1	8
Pienaar, 2015 [109]	0	1	0	1	0	1	1	1	1	1	7
Prista et al [110]	1	1	0	1	1	1	0	0	1	1	7
Puckree et al, [111]	1	1	1	0	1	1	0	0	1	1	7
Regaieg, et al [112]	1	1	0	1	1	1	0	0	1	1	7
Salman et al [113]	1	1	0	1	1	0	0	0	1	1	6
Sebbani et al, [114]	1	1	0	0	1	0	1	0	1	1	6
Taleb et al, [115]	1	1	0	0	1	1	0	0	1	1	6
Tathiah et al [116]	1	1	1	1	1	0	0	0	1	1	7
Truter et al [117]	1	1	0	1	1	0	0	1	1	1	7
Van Den Ende, et al [118]	1	1	0	1	1	1	0	0	1	1	7
Wiles et al, [119]	1	0	1	1	1	0	0	0	1	1	6

Table S4. Summary statistics from meta-analyses of prevalence studies of overweight in African school going children using random effects model and arcsine transformations

Group	Subgroup	Criteria	N Studies	N participants	N Cases	Prev (95% CI)	H (95% CI)	I^2 (95% CI)	P-heterogeneity	P-dif criteria	P-dif sub-groups	P- Egger
Overall										0.0027		
		WHO	21	36981	2340	10.5 [7.1-14.3]	8.73 [8.01-9.53]	98.7 [98.4-98.9]	<0.0001			0.003
		IOTF	18	51604	3491	9.5 [6.5-13.0]	11.27 [10.41-12.20]	99.2 [99.1-99.3]	<0.0001			0.020
		CDC	4	2433	283	11.5 [9.6-13.4]	1.39 [1.00-2.41]	48.0 [0.0-82.7]	0.124			0.912
		Unspecified	2	1361	14	0.5 [0.0-4.5]	5.32 [-]	96.5 [90.4-98.7	<0.0001			-
Gender	Overall									0.0028		
		WHO	29	11028	1313	11.4 [8.4-14.9]	5.43 [4.91-6.00]	96.6 [95.9-97.2	<0.0001		0.192	0.557
		IOTF	28	25623	2884	10.3 [8.4-12.3]	5.02 [4.51-5.58]	96.0 [95.1-96.8]	<0.0001		0.175	0.425
		CDC	6	2033	239	11.5 [9.5-13.7]	1.38 [1.00-2.19]	47.6 [0.0-79.2]	0.089		0.293	0.702
		Unspecified	2	1361	14	0.5 [0.0-4.5]						
	Boys									<0.0001		
		WHO	14	4965	462	9.3 [5.6-13.8]	4.89 [4.18-5.71]	95.8 [94.3-96.9]	<0.0001			0.478
		IOTF	14	13316	1267	8.9 [7.0-11.1]	3.81 [3.18-4.57]	93.1 [90.1-95.2]	<0.0001			0.634
		CDC	3	958	104	9.8 [5.8-14.7]	1.88 [1.02-3.46]	71.7 [4.3-91.7]	0.029			0.702
		Unspecified	1	678	14	2.1 [1.1-3.3]	-	-	-			-
	Girls									<0.0001		
		WHO	15	6063	851	13.6 [9.0-19.0]	5.67 [4.94-6.50]	96.9 [95.9-97.6]	<0.0001			0.742
		IOTF	14	12307	1617	11.7 [8.4-15.4]	5.68 [4.93-6.55]	96.9 [95.9-97.7]	<0.0001			0.426
		CDC	3	1075	135	12.5 [10.6-14.6]	1.00 [1.00-1.96]	0.0 [0.0-74.1]	0.669			0.205
		Unspecified	1	683	0	0.0 [0.0-0.01]	-	-	-			-
Setting	Overall									0.115		
		WHO	24	42803	2733	10.3 [7.5-13.6]	8.62 [7.94-9.35]	98.7 [98.4-98.9]	<0.0001		0.051	0.001
		IOTF	21	50863	3315	7.7 [5.1-10.7]	10.59 [9.81-11.42]	99.1 [99.0-99.2]	<0.0001		0.119	0.088
		CDC	4	2433	282	11.5 [9.6-13.4]	1.39 [1.00-2.41]	48.0 [0.0-82.7]	0.124		0.256	0.912
	Rural									0.305		
		WHO	4	3962	256	6.9 [3.3-11.6]	2.98 [1.95-4.55]	88.8 [73.8-95.2]	<0.0001			0.706
		IOTF	7	1532	102	4.0 [1.3-8.2]	5.58 [4.52-6.89]	96.8 [95.1-97.9]	<0.0001			0.149
		CDC	0	-	-	-	-	-	-		-	-
	Urban									0.575		
		WHO	15	10689	1422	12.8 [8.7-17.5]	6.85 [6.06-7.73]	97.3 [97.3-98.3]	<0.0001			0.685

		IOTF	8	9880	964	9.4 [5.2-14.7]	7.87 [6.73-9.20]	98.4 [97.8-98.8]	<0.0001			0.592
		CDC	3	1987	238	12.0 [9.8-14.4]	1.44 [1.00-2.68]	51.8 [0.0-86.1]	0.126			0.924
	Both									0.289		
		WHO	5	30582	1209	6.6 [3.8-10.1]	7.23 [5.82-8.99]	98.1 [97.0-98.8]	<0.0001			0.197
		IOTF	6	37021	2095	10.5 [4.7-18.3]	16.83 [15.07-18.79]	99.6 [99.6-99.7]	<0.0001			0.249
		CDC	1	446	44	9.9 [7.3-12.8]	-	-	-			-
Type												
	Overall									0.177		
		WHO	27	15720	2171	13.3 [10.0-17.0]	6.51 [5.94-7.14]	97.6 [97.2-98.0]	<0.0001		0.013	0.553
		IOTF	20	53689	3656	9.1 [6.3-12.3]	10.86 [10.05-11.72]	99.2 [99.0-99.3]	<0.0001		<0.0001	0.018
		CDC	5	2529	276	10.1 [7.5-13.0]	2.10 [1.35-3.26]	77.3 [45.1-90.6]	0.001		0.107	0.431
	Public									0.499		
		WHO	13	7778	843	11.2 [7.4-15.7]	5.73 [4.94-6.63]	97.0 [95.9-97.7]	<0.0001			0.372
		IOTF	8	7493	776	7.6 [3.7-12.9]	7.57 [6.44-8.88]	98.3 [97.6-98.7]	<0.0001			0.241
		CDC	2	1483	163	8.0 [2.2-17.0]	3.68 [-]	92.6 [75.2-97.8]	0.0002			-
	Private									0.209		
		WHO	5	1648	401	22.6 [16.0-30.0]	3.22 [2.26-4.60]	90.4 [80.5-95.3]	<0.0001			0.611
		IOTF	1	692	126	18.2 [15.4-21.2]	-	-	-			-
		CDC	1	200	30	15.0 [10.4-20.3]	-	-	-			-
	Both									0.783		
		WHO	9	6294	927	11.9 [6.5-18.8]	7.57 [6.52-8.80]	98.3 [97.6-98.7]	<0.0001			0.359
		IOTF	11	45504	2754	9.5 [5.9-13.9]	12.56 [11.41-13.82]	99.4 [99.2-99.5]	<0.0001			0.057
		CDC	2	846	83	9.8 [7.9-11.9]	1.00 [-]	0.0 [-]	0.955			-
Region												
	Overall									0.0027		
		WHO	21	36981	2340	10.5 [7.1-14.3]	8.73 [8.01-9.53]	98.7 [98.4-98.9]	<0.0001		0.155	0.003
		IOTF	18	51604	3491	9.5 [6.5-13.0]	11.27 [10.41-12.20]	99.2 [99.1-99.3]	<0.0001		0.684	0.020
		CDC	4	2433	283	11.5 [9.6-13.4]	1.39 [1.00-2.41]	48.0 [0.0-82.7]	0.124		0.434	0.912
		Unspecified	2	1361	14	0.5 [0.0-4.5]	5.32 [-]	96.5 [90.4-98.7	<0.0001		-	-
	Central									-		
		WHO	1	557	82	14.7 [11.9-17.8	-	-	-			-
		IOTF	0	-	-	-	-	-	-			-
		CDC	0	-	-	-	-	-	-			-
	Eastern									0.740		

		WHO	4	3730	698	16.1 [7.7-26.8]	7.77 [6.11-9.87]	98.3 [97.3-99.0]	<0.0001			0.678
		IOTF	2	2168	260	14.1 [6.8-23.5]	4.65	95.4 [86.4-98.4]	<0.0001			-
		CDC	2	750	89	12.1 [7.7-17.3]	2.03	75.7 [0.0-94.5	0.042			-
	Northern									0.853		
		WHO	3	3276	296	11.4 [5.2-19.5]	6.16 [4.40-8.62]	97.4 [94.8-98.7]	<0.0001			0.444
		IOTF	4	7678	701	10.1 [4.7-17.3]	9.08 [7.31-11.27]	98.8 [98.1-99.2]	<0.0001			0.213
		CDC	1	1283	154	12.0 [10.3-13.8]	-	-	-			-
	Southern									0.014		
		WHO	9	27265	1140	8.7 (4.7-13.8]	6.31 [5.33-7.47]	97.5 [96.5-98.2]	<0.0001			0.032
		IOTF	11	39983	2358	8.5 [4.6-13.5]	12.72 [11.57-13.99]	99.4 [99.3-99.5]	<0.0001			0.179
		CDC	0	-	-	-	-	-	-			
		Undefined	2	1361	14	0.5 [0.0-4.5]	5.52 [-]	96.5 [90.4-98.7]	<0.0001			-
	Western									0.864		
		WHO	4	2153	124	7.7 [2.4-15.7]	5.60 [4.17-7.51]	96.8 [94.2-98.2]	<0.0001			0.136
		IOTF	1	1775	172	9.7 [8.4-11.1]	-	-	-			-
		CDC	1	400	39	9.7 [7.0-12.8]	-	-	-			-
Coverage										0.0027		
	Overall	WHO	21	36981	2340	10.5 [7.1-14.3]	8.73 [8.01-9.53]	98.7 [98.4-98.9]	<0.0001			0.003
		IOTF	18	51604	3491	9.5 [6.5-13.0]	11.27 [10.41-12.20]	99.2 [99.1-99.3]	<0.0001			0.020
		CDC	4	2433	283	11.5 [9.6-13.4]	1.39 [1.00-2.41]	48.0 [0.0-82.7]	0.124			0.912
		Unspecified	2	1361	14	0.5 [0.0-4.5]	5.32 [-]	96.5 [90.4-98.7	<0.0001		-	-
Publication year												
	<2013									0.0013		
		WHO	11	30299	1215	6.6 [4.6-8.9]	4.66 [3.88-5.59]	95.4 [93.4-96.8]	<0.0001		0.0007	0.028
		IOTF	6	40438	2385	10.9 [5.1-18.4]	18.07 [16.28-20.07]	99.7 [99.6-99.8]	<0.0001		0.585	0.180
		CDC	2	1587	199	12.9 [10.5-15.5]	1.29 [-]	39.9 [-]	0.197		0.061	-
		Unspecified	0	-	-	-	-	-			-	
	>=2013									0.0005		
		WHO	10	6682	1125	15.4 [10.6-20.9]	5.70 [4.80-6.75]	96.9 [95.7-97.8]	<0.0001			0.799
		IOTF	12	11166	1106	8.9 [6.4-11.7]	4.92 [4.15-5.82]	95.9 [94.2-97.0]	<0.0001			0.581
		CDC	2	846	83	9.8 [7.9-11.9]	1.00 [-]	0.0 [-]	0.955			-
		Unspecified	2	1361	14	0.5 [0.0-4.5]	5.32 [-]	96.5 [90.4-98.7]	<0.0001			-
Sample size										0.0027		
	<638									0.578		

	WHO	13	4555	544	11.3 [7.9-15.2]	3.93 [3.27-4.73]	93.5 [90.6-95.5]	<0.0001		0.571	0.869
	IOTF	6	2699	240	7.8 [3.1-14.3]	5.56 [4.42-7.01]	96.8 [94.9-98.0]	<0.0001		0.566	0.959
	CDC	3	1150	128	11.2 [8.4-14.4]	1.62 [1.00-3.02]	61.7 [0.0-89.1]	0.074		0.667	0.198
	Unspecified	0	-	-	-					-	
>=638									0.0016		
	WHO	8	32426	1796	9.2 [4.3-15.7]	12.62 [11.26-14.14]	99.4 [99.2-99.5]	<0.0001			0.087
	IOTF	12	48905	3251	10.4 [6.6-15.0]	13.44 [12.32-14.67]	99.4 [99.4-99.5]	<0.0001			0.017
	CDC	1	1283	154	12.0 [10.3-13.8]	-	-	-			-
	Unspecified	2	1361	14	0.5 [0.0-4.5]	5.32 [-]	96.5 [90.4-98.7]	<0.0001			-

Note: - not computable

Table S5. Summary statistics from meta-analyses of prevalence studies of obesity in African school going children using random effects model and arcsine transformations

Group	Subgroup	Criteria	N studies	N participants	N Cases	Prev (95% CI)	H (95% CI)	I^2 (95% CI)	P-heterogeneity	P-dif criteria	P-dif sub-groups	P- Egger
Overall										<0.0001		
		WHO	18	34895	979	6.1 [3.4-9.7]	9.12 [8.32-9.99]	98.8 [98.6-99.0]	<0.0001			0.0019
		IOTF	16	50779	1120	4.0 [2.5-5.9]	8.56 [7.74-9.47]	98.6 [98.3-98.9]	<0.0001			0.003
		CDC	4	2433	158	6.9 [5.0-9.0]	1.82 [1.07-3.09]	69.8 [13.2-89.5]	0.019			0.320
		Unspecified	2	1361	8	0.5 [0.01-1.7]	2.34 [-]	81.8 [22.9-95.7]	0.019			-
Gender	Overall									<0.0001		
		WHO	25	8942	696	7.0 [4.5-10.1]	5.20 [4.65-5.81]	96.3 [95.4-97.0]	<0.0001		0.212	0.475
		IOTF	26	24798	907	4.3 [3.4-5.3]	3.53 [3.08-4.05]	92.0 [89.5-93.9]	<0.0001		0.295	0.047
		CDC	6	2033	126	6.2 [4.7-8.0]	1.44 [1.00-2.28]	51.7 [0.0-80.8]	0.066		0.128	0.743
		Unspecified	2	1361	8	0.5 [0.0-1.7]	2.34 [-]	81.8 [22.9-95.7]	0.019		0.019	-
	Boys									<0.0001		
		WHO	12	4011	241	5.3 [2.3-9.3]	4.83 [4.08-5.73]	95.7 [94.0-97.0]	<0.0001			0.655
		IOTF	13	12895	384	3.8 [2.7-5.0]	3.8 [2.7-5.0]	88.8 [82.8-92.8]	<0.0001			0.034
		CDC	3	958	49	5.1 [3.8-6.6]	1.00 [1.00-2.22]	0.0 [0.0-79.8]	0.598			0.823
		Unspecified	1	678	7	1.0 [0.4-1.9]	-	-	-			-
	Girls									<0.0001		
		WHO	13	4931	455	8.9 [4.9-13.8]	5.42 [4.66-6.32]	96.6 [95.4-97.5]	<0.0001			0.515
		IOTF	13	11903	523	4.8 [3.3-6.5]	3.81 [3.15-4.60]	93.1 [89.9-95.3]	<0.0001			0.435
		CDC	3	1075	77	7.5 [4.8-10.6]	1.72 [1.00-3.20]	66.1 [0.0-90.2]	0.052			0.540
		Unspecified	1	683	1	0.1 [0.0-0.6]	-	-	-			-
Setting	Overall									0.0.041		
		WHO	21	40717	1106	5.6 [3.4-8.3]	8.83 [8.10-9.62]	98.7 [98.5-98.9]	<0.0001		<0.0001	0.001
		IOTF	19	50038	1085	3.7 [2.3-5.4]	7.74 [7.01-8.55]	98.3 [98.0-98.6]	<0.0001		0.082	0.0056
		CDC	4	2433	158	6.9 [5.0-9.0]	1.82 [1.07-3.09]	69.8 [13.2-89.5]	0.0191		0.163	0.320
	Rural									0.757		
		WHO	4	1532	22	1.5 [0.6-2.9]	1.69 [1.00-2.91]	65.2 [0.0-88.2]	0.035			0.360
		IOTF	5	3137	70	1.8 [0.6-3.7]	3.24 [2.28-4.62]	90.5 [80.7-95.3]	<0.0001			0.880
		CDC	0	-	-			-	-		-	-
	Urban									0.076		
		WHO	12	8603	783	9.8 [6.0-14.6]	6.61 [5.74-7.60]	97.7 [97.0-98.3]	<0.0001			0.214

		IOTF	8	9880	375	4.9 [3.0-7.2]	4.73 [3.81-5.87]	95.5 [93.1-97.1]	<0.0001			0.035
		CDC	3	1987	135	7.5 [5.1-10.5]	2.05 [1.13-3.71]	76.1 [21.5-92.7]	0.015			0.207
	Both									0.013		
		WHO	5	30582	301	1.9 [0.9-3.1]	4.69 [3.52-6.24]	95.4 [91.9-97.4]	<0.0001			0.187
		IOTF	6	37021	640	4.0 [1.5-7.7]	11.92 [10.36-13.71]	99.3 [99.1-99.5]	<0.0001			0.186
		CDC	1	446	23	5.2 [3.3-7.4]	-	-	-			-
Type												
	Overall									0.009		
		WHO	24	13634	1183	8.7 [5.8-12.0]	6.47 [5.87-7.14]	97.6 [97.1-98.0]	<0.0001		0.018	0.228
		IOTF	28	52864	1212	3.7 [2.3-5.4]	8.50 [7.72-9.35]	98.6 [98.3-98.9]	<0.0001		0.003	0.004
		CDC	5	2529	156	6.2 [4.1-8.7]	2.18 [1.41-3.36]	78.9 [49.6-91.1]	0.0008		0.008	0.767
	Public									0.675		
		WHO	12	6762	807	6.2 [3.1-10.3]	5.95 [5.13-6.92]	97.2 [96.2-97.9]	<0.0001			0.446
		IOTF	6	6668	764	4.9 [2.5-8.1]	5.36 [4.23-6.78]	96.5 [94.4-97.8]	<0.0001			0.955
		CDC	2	1483	163	4.2 [1.6-7.9]	2.16 [-]	78.6 [6.8-95.1]	0.031			-
	Private									<0.0001		
		WHO	5	1648	255	16.6 [10.4-23.8]	3.49 [2.49-4.90]	91.8 [83.8-95.8]	<0.0001			0.539
		IOTF	1	692	8	1.2 [0.5-2.1]	-	-	-			-
		CDC	1	200	25	12.5 [8.3-17.4]	-	-	-			-
	Both									0.069		
		WHO	7	5224	487	8.3 [3.2-15.4]	7.93 [6.70-9.38]	98.4 [98.4-98.9]	<0.0001			0.905
		IOTF	11	45504	841	3.3 [1.8-5.3]	9.08 [8.06-10.23]	98.8 [98.5-99.0]	<0.0001			0.044
		CDC	2	846	52	6.2 [4.1-8.7]	1.40 [-]	49.2 [-]	0.160			-
Region												
	Overall									<0.0001		
		WHO	18	34895	979	6.1 [3.4-9.7]	9.12 [8.32-9.99]	98.8 [98.6-99.0]	<0.0001		0.115	0.0019
		IOTF	16	50779	1120	4.0 [2.5-5.9]	8.56 [7.74-9.47]	98.6 [98.3-98.9]	<0.0001		<0.0001	0.003
		CDC	4	2433	158	6.9 [5.0-9.0]	1.82 [1.07-3.09]	69.8 [13.2-89.5]	0.019		0.379	0.320
		Unspecified	2	1361	8	0.5 [0.01-1.7]	2.34 [-]	81.8 [22.9-95.7]	0.019		-	-
	Central									-		
		WHO	1			2.9 [1.6-4.4]	-	-	-			-
		IOTF	0	-	-	-	-	-	-			-
		CDC	0	-	-	-	-	-	-			-
	Eastern									0.125		

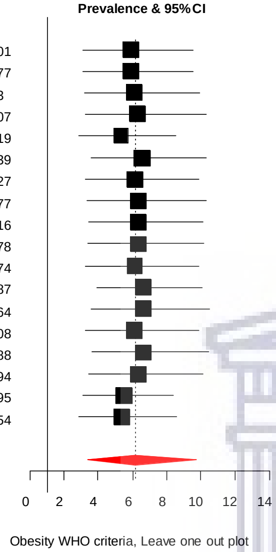
		WHO	4	3730	390	9.6 [3.8-17.6]	6.95 [5.38-8.99]	97.9 [96.5-98.8]	<0.0001			0.976
		IOTF	2	2168	101	4.6 [3.8-5.6]	1.00 [-]	0.0 [-]	0.428			-
		CDC	2	750	55	7.6 [3.2-13.6]	2.72 [-]	86.5 [46.6-96.6]	0.042			-
	Northern									0.219		
		WHO	3	3276	177	8.7 [2.2-19.2]	8.27 [6.25-10.94]	98.5 [97.4-99.2]	<0.0001			0.092
		IOTF	4	7678	239	3.5 [1.5-6.1]	5.43 [4.02-7.33]	96.6 [93.8-98.1]	<0.0001			0.111
		CDC	1	1283	73	5.7 [4.5-7.0]	-	-	-			-
	Southern									0.0044		
		WHO	7	26195	339	4.1 [0.7-9.9]	7.52 [6.32-8.95]	98.2 [97.5-98.8]	<0.0001			0.123
		IOTF	9	39158	766	4.6 [2.2-7.8]	10.41 [9.22-11.76]	99.1 [98.8-99.3]	<0.0001			0.043
		CDC	0	-	-	-	-	-	-			-
		Undefined	2	1361	8	0.5 [0.0-1.7]	2.34 [-]	81.8 [22.9-95.7]	0.019			-
	Western									<0.0001		
		WHO	3	1137	57	6.1 [0.4-18.0]	6.07 [4.32-8.53]	97.3 [94.7-98.6]	<0.0001			0.108
		IOTF	1	1775	14	0.8 [0.4-1.2]	-	-	-			-
		CDC	1	400	30	7.5 [5.1-10.3]	-	-	-			-
Coverage										<0.0001		
	Overall	WHO	18	34895	979	6.1 [3.4-9.7]	9.12 [8.32-9.99]	98.8 [98.6-99.0]	<0.0001			0.0019
		IOTF	16	50779	1120	4.0 [2.5-5.9]	8.56 [7.74-9.47]	98.6 [98.3-98.9]	<0.0001			0.003
		CDC	4	2433	158	6.9 [5.0-9.0]	1.82 [1.07-3.09]	69.8 [13.2-89.5]	0.019			0.320
		Unspecified	2	1361	8	0.5 [0.01-1.7]	2.34 [-]	81.8 [22.9-95.7]	0.019			-
Publication year												
	<2013									0.154		
		WHO	8	28213	360	3.3 [1.4-6.1]	5.76 [4.76-6.97]	97.0 [95.6-97.9]	<0.0001		0.037	0.039
		IOTF	6	40438	691	3.3 [1.2-6.3]	11.95 [10.39-13.74]	99.3 [99.1-99.5]	<0.0001		0.488	0.201
		CDC	2	1587	105	6.2 [4.1-8.7]	2.81 [-]	87.3 [50.5-96.8]	0.005		0.560	-
		Unspecified	0	-	-	-	-	-	-		-	-
	>=2013									<0.0001		
		WHO	10	6682	619	8.9 [4.4-14.8]	7.34 [6.36-8.49]	98.1 [97.5-98.6]	<0.0001			0.572
		IOTF	10	10341	429	4.4 [2.9-6.3]	4.25 [3.46-5.21]	94.5 [91.7-96.3]	<0.0001			0.087
		CDC	2	846	53	7.7 [3.7-13.0]	1.40 [-]	49.2 [-]	0.160			-
		Unspecified	2	1361	8	0.5 [0.0-1.7]	2.34 [-]	81.8 [22.9-95.7]	<0.0001			-
Sample size										<0.0001		
	<638									0.532		

	WHO	11	3485	310	7.1 [3.2-12.4]	5.37 [4.54-6.34]	96.5 [95.1-97.5]	<0.0001		0.461	0.952
	IOTF	12	1874	110	3.5 [1.9-5.6]	1.21 [1.00-2.02]	31.8 [0.0-75.6]	0.221		0.050	0.859
	CDC	3	1150	85	7.5 [4.8-10.7]	1.93 [1.06-3.54]	73.3 [10.3-92.0]	0.074		0.255	0.161
	Unspecified	0	-	-	-	-	-	-		-	
>=638									<0.0001		
	WHO	7	31410	669	4.8 [1.5-9.8]	11.88 [10.45-13.50]	99.3 [99.1-99.5]	<0.0001			0.053
	IOTF	4	48905	1010	5.8 [4.6-7.2]	9.51 [8.52-10.62]	98.9 [98.6-99.1]	<0.0001			0.017
	CDC	1	1283	73	5.7 [4.5-7.0]	-	-	-			-
	Unspecified	2	1361	8	0.5 [0.0-4.5]	2.34 [-]	81.8 [22.9-95.7]	0.019			-

Note: - not computable

Figure S1: Forest plot showing the effect of omitting one study at a time on pooled prevalence and heterogeneity statistics from studies that used World]Health Organisation (WHO) criteria to diagnose prevalent obesity (first panel) and overweight (second panel) in African school learners

Omitted study	Tau square	I square	Prevalence	95% CI
Omitting Mohammed, 2012	0.140624850434694	0.988333602972501	5.9	[3.1; 9.5]
Omitting Mogre, 2013	0.140647113821633	0.988389149307377	5.9	[3.1; 9.5]
Omitting Pangani, 2016	0.146648332365404	0.98768744166603	6.1	[3.2; 9.9]
Omitting Dekkaki et al, 2011	0.150443651566329	0.988525455180707	6.3	[3.3; 10.3]
Omitting Wiles et al, 2013	0.131683194199342	0.986670353752219	5.3	[2.8; 8.6]
Omitting Puckree et al, 2011	0.141787592395396	0.988668244442939	6.6	[3.6; 10.4]
Omitting Mosha & Fungo, 2010	0.142561151019588	0.988488733153527	6.1	[3.3; 9.8]
Omitting Sebanni et al, 2013	0.149945984217527	0.988613132358777	6.4	[3.3; 10.3]
Omitting Oldewage-Theron 2010	0.141949829567598	0.988672640977016	6.4	[3.4; 10.1]
Omitting Navti et al, 2014	0.144455598987201	0.988658385291178	6.4	[3.4; 10.2]
Omitting Muthuri 2014	0.142977134304633	0.988419257388174	6.1	[3.2; 9.9]
Omitting Jinabhai et al, 2003	0.127909910429771	0.974868246971087	6.6	[3.9; 10.0]
Omitting Daboné et al, 2011	0.144673089325608	0.988600260394364	6.6	[3.6; 10.5]
Omitting Abrahams et al, 2011	0.143050813623124	0.988349428843908	6.1	[3.2; 9.8]
Omitting Pedro 2014	0.142715019141337	0.988647524070888	6.6	[3.6; 10.4]
Omitting Pedro 2014	0.142843681480844	0.988663831553294	6.4	[3.4; 10.1]
Omitting Chebet 2014	0.119758077390724	0.982990688060695	5.5	[3.1; 8.4]
Omitting El-Sabely, 2013	0.132779444390472	0.986912573696054	5.4	[2.8; 8.6]
Random effects model			**6.1**	**[3.4; 9.7]**



Omitted study	Tau square	I square	Prevalence	95% CI
Omitting Fetuga, 2011	0.139970651216673	0.987471431952188	10.9	[7.3; 15.1]
Omitting Mohammed, 2012	0.135154780134591	0.987272953619674	10.2	[6.9; 14.1]
Omitting Mogre, 2013	0.135259134729546	0.987338629476145	10.2	[6.9; 14.2]
Omitting Pangani, 2016	0.133268841151511	0.985390339783631	10.2	[6.9; 14.1]
Omitting Dekkaki et al, 2011	0.143325327699025	0.987543528857501	10.8	[7.1; 15.0]
Omitting Wiles et al, 2013	0.131399966397211	0.986506292397173	9.8	[6.6; 13.6]
Omitting Puckree et al, 2011	0.135929081581194	0.987547212595855	10.7	[7.3; 14.8]
Omitting Mosha & Fungo, 2010	0.137425725261507	0.987546872923286	10.7	[7.2; 14.8]
Omitting Sebanni et al, 2013	0.139619010246153	0.987030381851853	10.4	[6.9; 14.5]
Omitting Oldewage-Theron 2010	0.135685866584892	0.987483881346472	10.4	[7.0; 14.3]
Omitting Navti et al, 2014	0.1354818964701	0.987073642788591	10.3	[6.9; 14.2]
Omitting Muthuri 2014	0.135639534859542	0.987097766293894	10.3	[6.9; 14.2]
Omitting Jinabhai et al, 2003	0.127821734618399	0.975572079365681	10.9	[7.6; 14.7]
Omitting Daboné et al, 2011	0.137159967729499	0.987300821003202	11.1	[7.5; 15.2]
Omitting Abrahams et al, 2011	0.135714472591578	0.987037958067733	10.3	[6.9; 14.2]
Omitting Pedro 2014	0.136304138501495	0.987464630634985	11.0	[7.5; 15.1]
Omitting Pedro 2014	0.136313414238164	0.987462786606585	10.4	[7.0; 14.4]
Omitting Chebet 2014	0.112732480295542	0.980896317051032	9.6	[6.8; 12.8]
Omitting Prista 2003	0.137662438614095	0.987547685709672	10.7	[7.2; 14.8]
Omitting Prista 2003	0.137890848977392	0.987481849523155	10.6	[7.1; 14.6]
Omitting El-Sabely, 2013	0.133740211486703	0.986989369040468	10.0	[6.7; 13.9]
Random effects model			**10.5**	**[7.1; 14.3]**

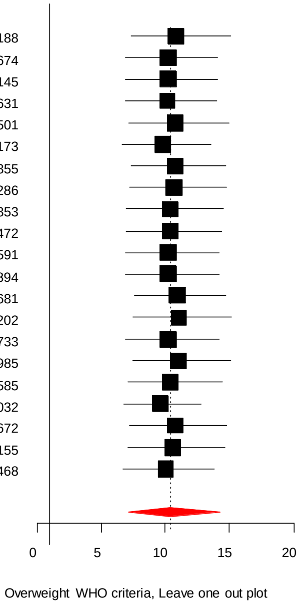


Figure S2: Forest plot showing the effect of omitting one study at a time on pooled prevalence and heterogeneity statistics from studies that used International Obesity Task Force (IOTF, upper panels) and Centers for Disease Control and Prevention (CDC, lower panels) criteria to diagnose prevalent obesity (left panels) and overweight (right panels) in African school learners

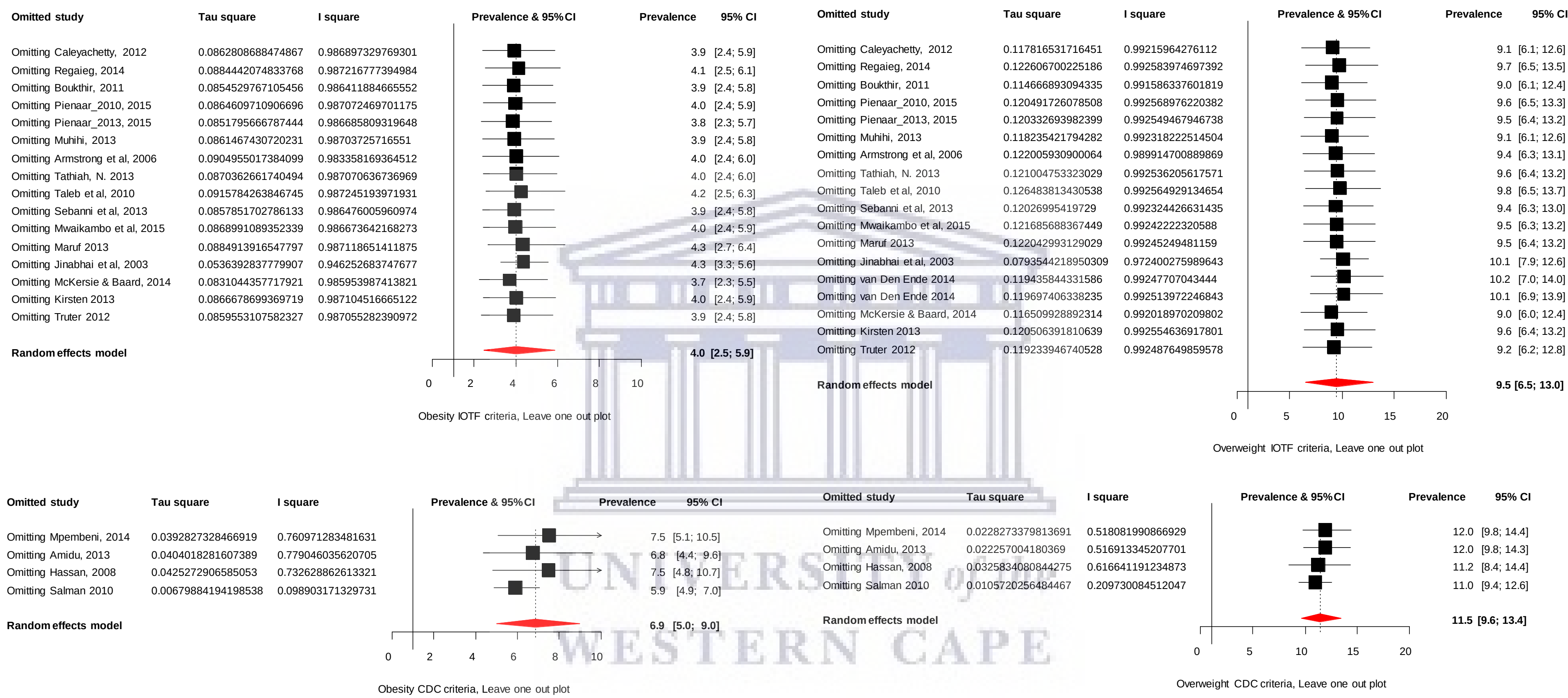


Figure S3: Funnel plots for the assessment of publication bias in studies of prevalent overweight (upper panels) and obesity (lower panels) by the World Health Organization (left column), International Obesity Task Force (middle column) and Centers for Disease Control and Prevention (right column) criteria, in African school going children, after implementation of the trim & fill methods to correct for publication bias.

For each figure panel, the dots are the arcsine transformed prevalence estimates of individual studies (horizontal axis) plotted against their standard error (vertical exist). The dotted vertical blue line is for the observed pooled prevalence estimates after imputation of missing studies. The p-value from the egger test of bias is also shown.

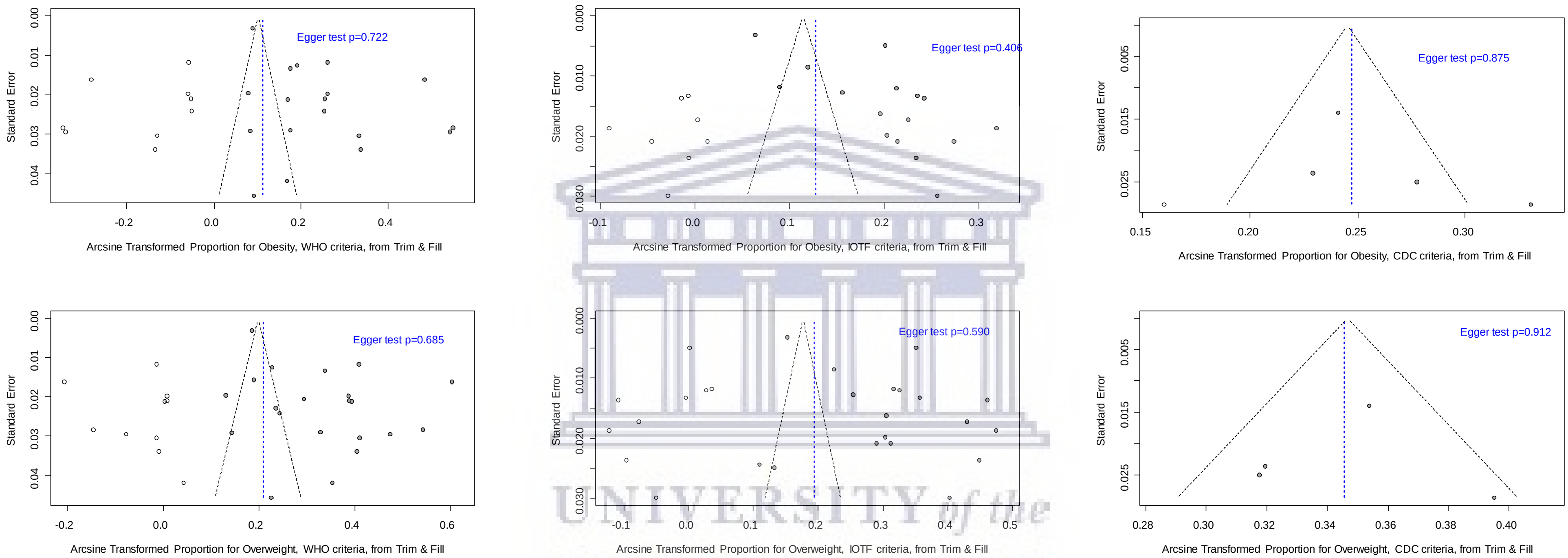
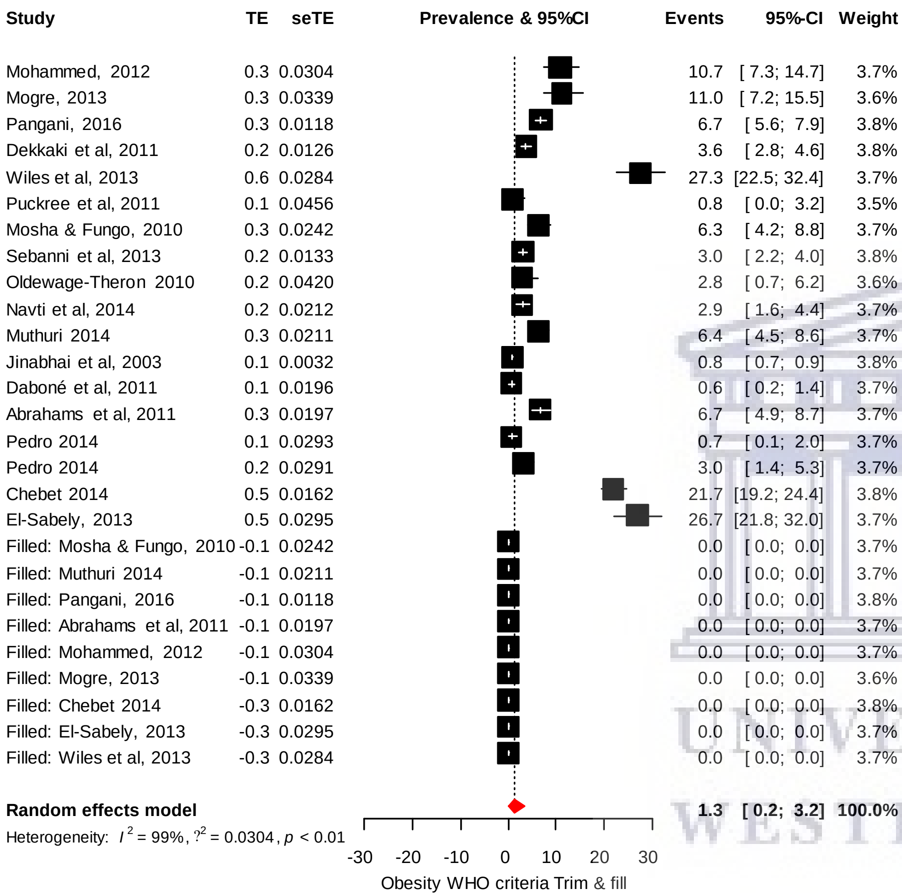


Figure S4: Forest plots showing the effect of studies imputations on pooled prevalence estimates from trim and fill methods, for studies that used the World Health Organization (WHO) criteria to diagnose obesity (first panel) or overweight (second panel) in African school going children



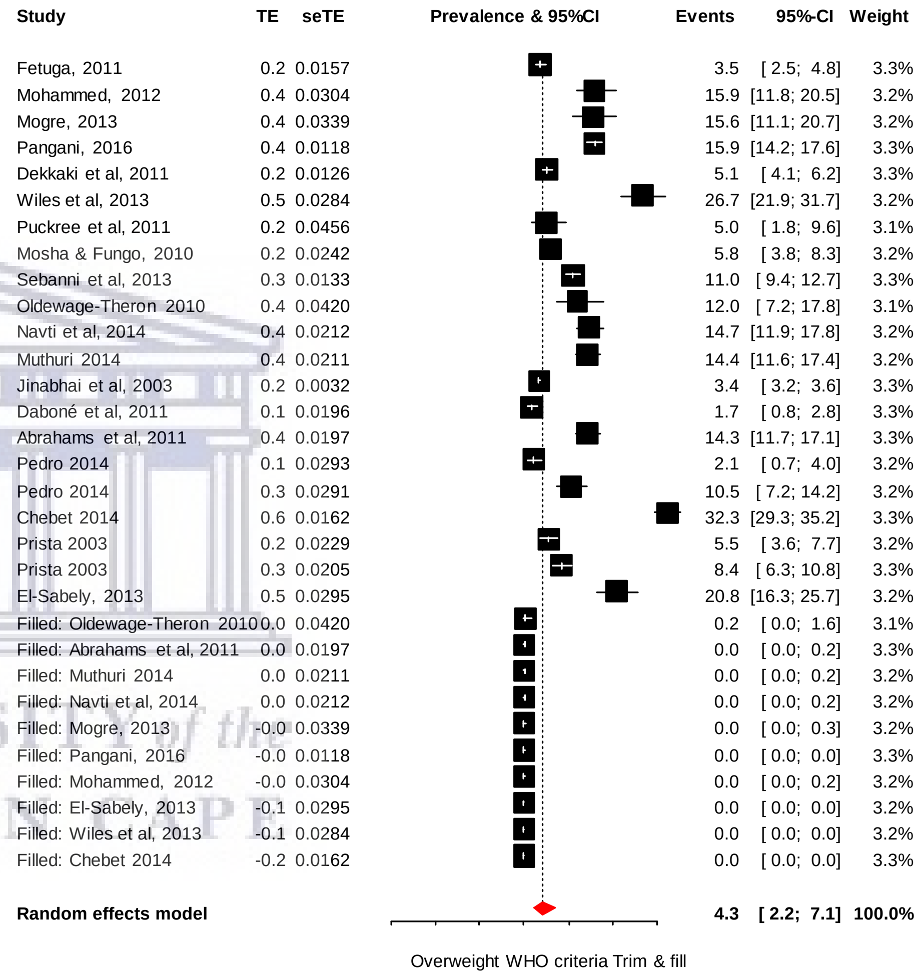
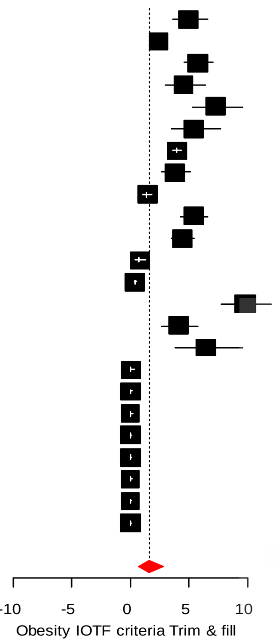


Figure S5: Forest plots showing the effect of studies imputations on pooled prevalence estimates from trim and fill methods, for studies that used the International Obesity Task Force (IOTF, upper panels) or Centers for Disease Control and Prevention (CDC, lower panels) criteria to diagnose obesity (left panels) or overweight (right panels) in African school going children

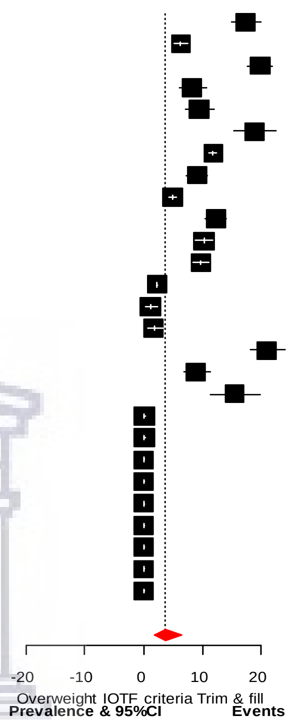
Study	TE	seTE	Events	95%-CI	Weight
Caleyachetty, 2012	0.2	0.0172	5.0	[3.6; 6.6]	4.2%
Regaieg, 2014	0.2	0.0128	2.4	[1.7; 3.2]	4.2%
Boukthir, 2011	0.2	0.0137	5.8	[4.6; 7.1]	4.2%
Pienaar_2010, 2015	0.2	0.0209	4.5	[3.0; 6.4]	4.1%
Pienaar_2013, 2015	0.3	0.0209	7.3	[5.3; 9.6]	4.1%
Muhihi, 2013	0.2	0.0237	5.4	[3.5; 7.7]	4.1%
Armstrong et al, 2006	0.2	0.0050	4.0	[3.6; 4.4]	4.3%
Tathiah, N. 2013	0.2	0.0162	3.8	[2.7; 5.1]	4.2%
Taleb et al, 2010	0.1	0.0086	1.4	[1.0; 1.8]	4.3%
Sebanni et al, 2013	0.2	0.0133	5.4	[4.3; 6.7]	4.2%
Mwaikambo et al, 2015	0.2	0.0120	4.5	[3.5; 5.5]	4.2%
Maruf 2013	0.1	0.0119	0.8	[0.4; 1.3]	4.2%
Jinabhai et al, 2003	0.1	0.0032	0.4	[0.3; 0.5]	4.3%
McKersie & Baard, 2014	0.3	0.0187	9.8	[7.7; 12.1]	4.2%
Kirsten 2013	0.2	0.0198	4.1	[2.7; 5.7]	4.1%
Truter 2012	0.3	0.0299	6.4	[3.9; 9.6]	3.9%
Filled: Pienaar_2010, 2015	0.0	0.0209	0.0	[0.0; 0.3]	4.1%
Filled: Caleyachetty, 2012	0.0	0.0172	0.0	[0.0; 0.1]	4.2%
Filled: Muhihi, 2013	-0.0	0.0237	0.0	[0.0; 0.2]	4.1%
Filled: Sebanni et al, 2013	-0.0	0.0133	0.0	[0.0; 0.0]	4.2%
Filled: Boukthir, 2011	-0.0	0.0137	0.0	[0.0; 0.0]	4.2%
Filled: Truter 2012	-0.0	0.0299	0.0	[0.0; 0.1]	3.9%
Filled: Pienaar_2013, 2015	-0.0	0.0209	0.0	[0.0; 0.0]	4.1%
Filled: McKersie & Baard, 2014	-0.1	0.0187	0.0	[0.0; 0.0]	4.2%
Random effects model			**1.6**	**[0.8; 2.7]**	**100.0%**

Heterogeneity: $I^2 = 99\%$, $?^2 = 0.009$, $p < 0.01$



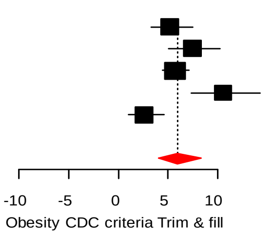
Study	TE	seTE	Events	95%-CI	Weight
Caleyachetty, 2012	0.4	0.0172	17.4	[14.9; 20.0]	3.7%
Regaieg, 2014	0.3	0.0128	6.3	[5.1; 7.5]	3.7%
Boukthir, 2011	0.5	0.0137	19.8	[17.7; 22.0]	3.7%
Pienaar_2010, 2015	0.3	0.0209	8.2	[6.1; 10.6]	3.7%
Pienaar_2013, 2015	0.3	0.0209	9.4	[7.2; 11.9]	3.7%
Muhihi, 2013	0.4	0.0237	18.8	[15.3; 22.6]	3.7%
Armstrong et al, 2006	0.4	0.0050	11.8	[11.2; 12.4]	3.7%
Tathiah, N. 2013	0.3	0.0162	9.0	[7.3; 10.9]	3.7%
Taleb et al, 2010	0.2	0.0086	4.9	[4.2; 5.7]	3.7%
Sebanni et al, 2013	0.4	0.0133	12.2	[10.5; 14.0]	3.7%
Mwaikambo et al, 2015	0.3	0.0120	10.2	[8.8; 11.7]	3.7%
Maruf 2013	0.3	0.0119	9.7	[8.4; 11.1]	3.7%
Jinabhai et al, 2003	0.2	0.0032	2.3	[2.1; 2.5]	3.7%
van Den Ende 2014	0.1	0.0244	1.2	[0.4; 2.4]	3.7%
van Den Ende 2014	0.1	0.0249	1.7	[0.7; 3.2]	3.7%
McKersie & Baard, 2014	0.5	0.0187	20.9	[18.0; 24.0]	3.7%
Kirsten 2013	0.3	0.0198	8.9	[6.8; 11.3]	3.7%
Truter 2012	0.4	0.0299	15.4	[11.4; 19.8]	3.6%
Filled: Maruf 2013	0.0	0.0119	0.1	[0.0; 0.3]	3.7%
Filled: Mwaikambo et al, 2015	0.0	0.0120	0.1	[0.0; 0.3]	3.7%
Filled: Armstrong et al, 2006	0.0	0.0050	0.0	[0.0; 0.0]	3.7%
Filled: Sebanni et al, 2013	-0.0	0.0133	0.0	[0.0; 0.0]	3.7%
Filled: Truter 2012	-0.1	0.0299	0.0	[0.0; 0.0]	3.6%
Filled: Caleyachetty, 2012	-0.1	0.0172	0.0	[0.0; 0.0]	3.7%
Filled: Muhihi, 2013	-0.1	0.0237	0.0	[0.0; 0.0]	3.7%
Filled: Boukthir, 2011	-0.1	0.0137	0.0	[0.0; 0.0]	3.7%
Filled: McKersie & Baard, 2014	-0.1	0.0187	0.0	[0.0; 0.0]	3.7%
Random effects model			**3.7**	**[1.8; 6.4]**	**100.0%**

Heterogeneity: $I^2 = 100\%$, $?^2 = 0.0253$, $p < 0.01$



Study	TE	seTE	Events	95%-CI	Weight
Mpembeni, 2014	0.2	0.0237	5.2	[3.3; 7.4]	20.2%
Amidu, 2013	0.3	0.0250	7.5	[5.1; 10.3]	19.7%
Hassan, 2008	0.2	0.0140	5.7	[4.5; 7.0]	23.5%
Salman 2010	0.3	0.0287	10.5	[7.3; 14.2]	18.3%
Filled: Salman 2010	0.2	0.0287	2.5	[1.1; 4.6]	18.3%
Random effects model			**6.0**	**[4.0; 8.3]**	**100.0%**

Heterogeneity: $I^2 = 80\%$, $?^2 = 0.002$, $p < 0.01$



Study	TE	seTE	Events	95%-CI	Weight
Mpembeni, 2014	0.3	0.0237	9.9	[7.3; 12.8]	23.2%
Amidu, 2013	0.3	0.0250	9.8	[7.0; 12.8]	21.8%
Hassan, 2008	0.4	0.0140	12.0	[10.3; 13.8]	36.6%
Salman 2010	0.4	0.0287	14.8	[11.0; 19.0]	18.4%
Random effects model			**11.5**	**[9.6; 13.4]**	**100.0%**

Heterogeneity: $I^2 = 48\%$, $?^2 = 0.0004$, $p = 0.12$

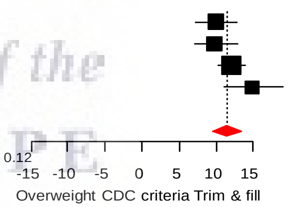


Figure S6: Prevalence of overweight by major diagnostic criteria in boys.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

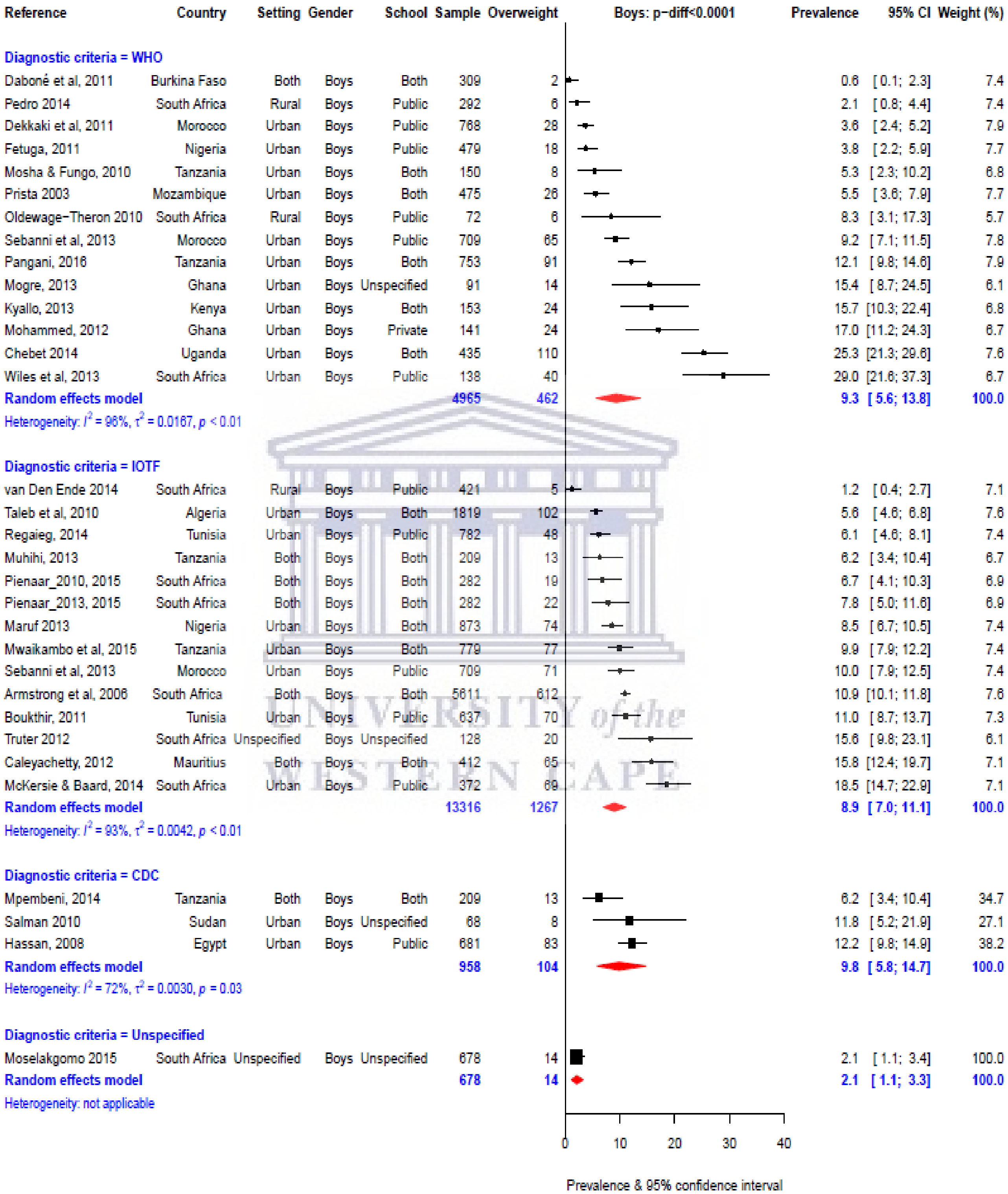


Figure S7: Prevalence of overweight by major diagnostic criteria in girls.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

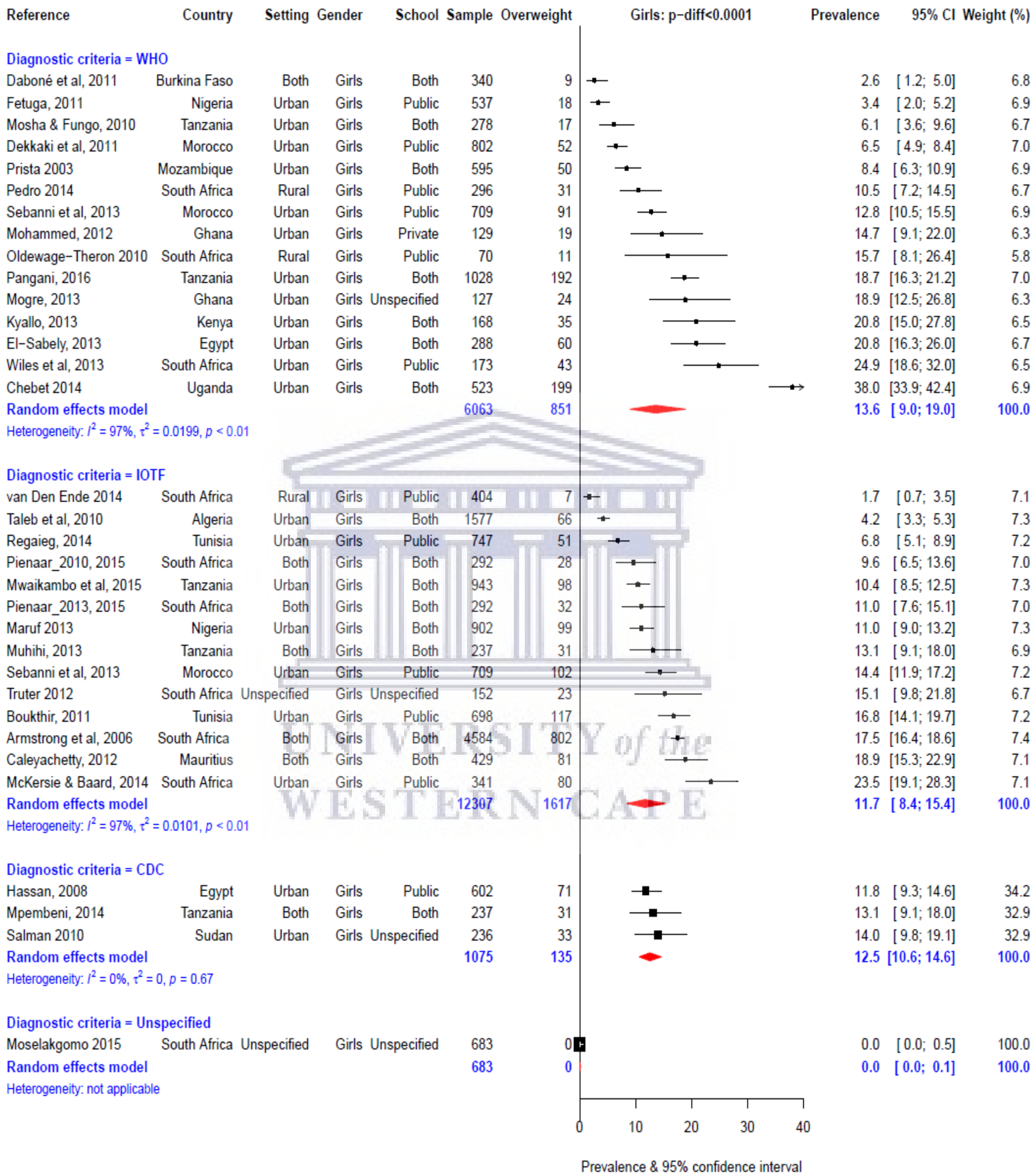


Figure S8: Prevalence of obesity by major diagnostic criteria in boys.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

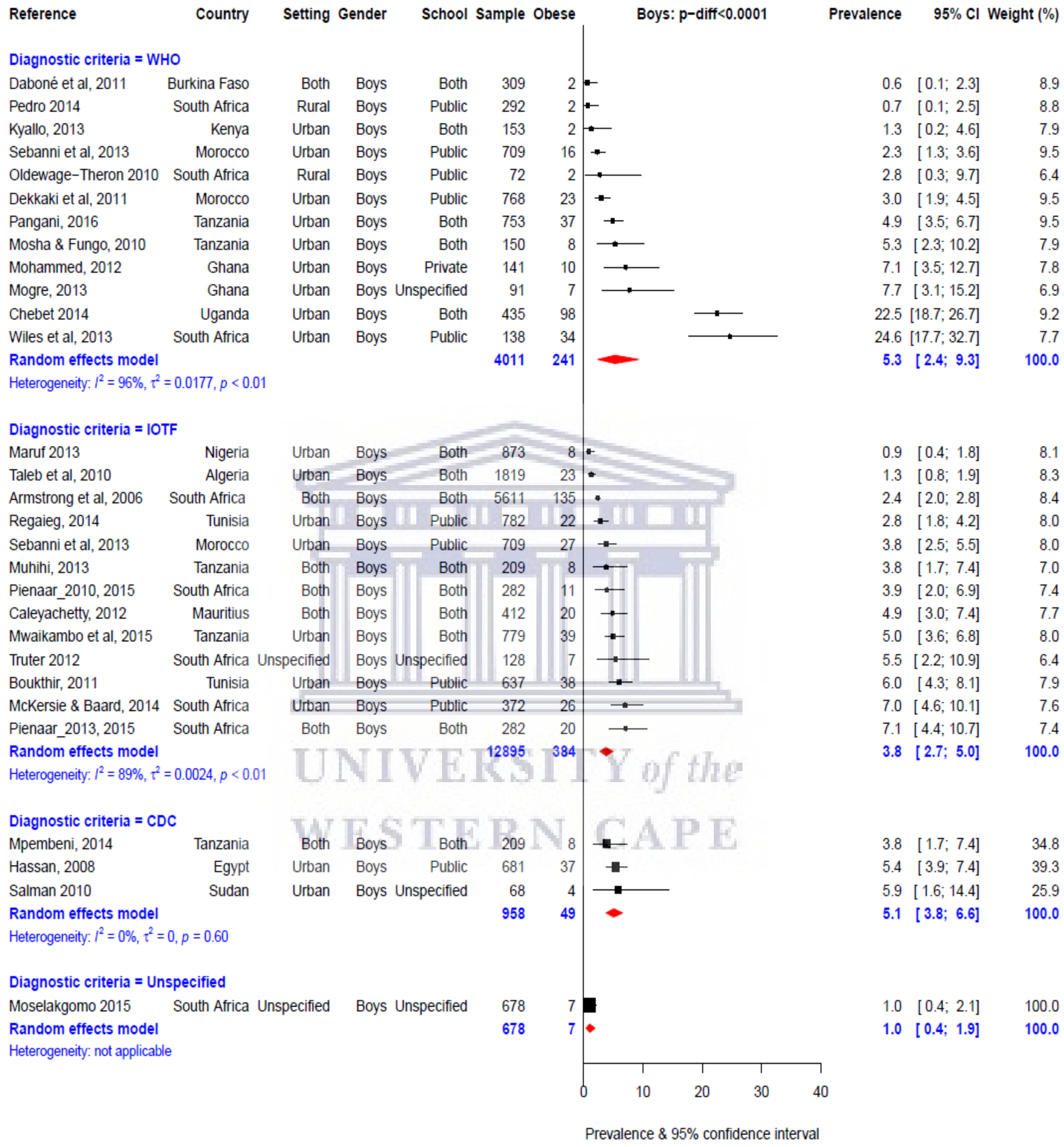


Figure S9: Prevalence of obesity by major diagnostic criteria in girls.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

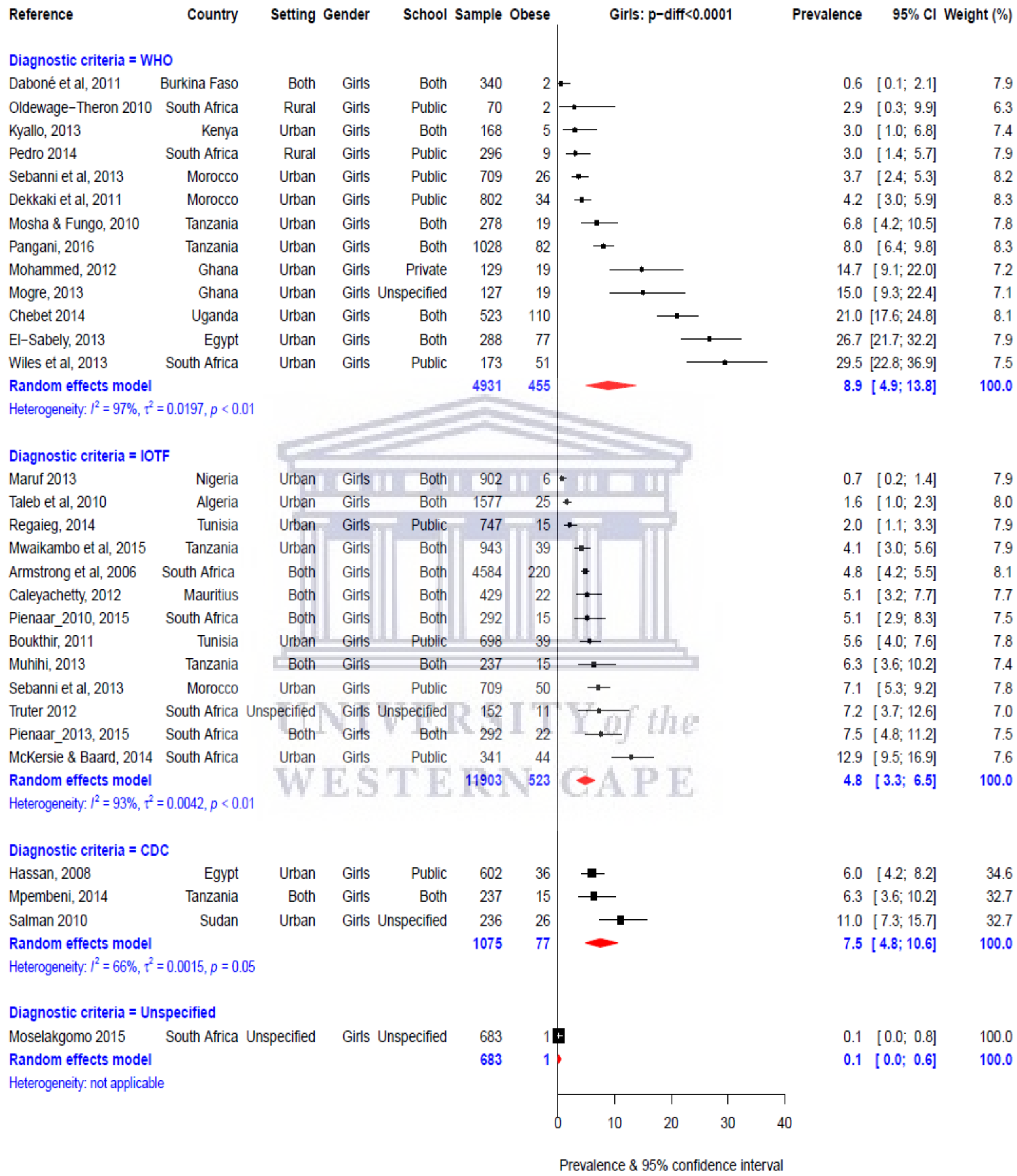


Figure S10: Prevalence of overweight by major diagnostic criteria in urban studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Overweight	Prevalence	95% CI	Weight (%)
Diagnostic criteria = WHO									
Fetuga, 2011	Nigeria	Urban	Both	Public	1016	36	3.5	[2.5; 4.9]	6.8
Puckree et al, 2011	South Africa	Urban	Both	Public	120	6	5.0	[1.9; 10.6]	6.0
Dekkaki et al, 2011	Morocco	Urban	Both	Public	1570	80	5.1	[4.1; 6.3]	6.9
Prista 2003	Mozambique	Urban	Boys	Both	475	26	5.5	[3.6; 7.9]	6.7
Mosha & Fungo, 2010	Tanzania	Urban	Both	Both	428	25	5.8	[3.8; 8.5]	6.7
Prista 2003	Mozambique	Urban	Girls	Both	595	50	8.4	[6.3; 10.9]	6.8
Sebanni et al, 2013	Morocco	Urban	Both	Public	1418	156	11.0	[9.4; 12.7]	6.9
Muthuri 2014	Kenya	Urban	Both	Both	563	81	14.4	[11.6; 17.6]	6.7
Mogre, 2013	Ghana	Urban	Both	Unspecified	218	34	15.6	[11.0; 21.1]	6.4
Pangani, 2016	Tanzania	Urban	Both	Both	1781	283	15.9	[14.2; 17.7]	6.9
Mohammed, 2012	Ghana	Urban	Both	Private	270	43	15.9	[11.8; 20.8]	6.5
El-Sabely, 2013	Egypt	Urban	Girls	Both	288	60	20.8	[16.3; 26.0]	6.5
Pangani, 2016	Tanzania	Urban	Both	Private	678	150	22.1	[19.1; 25.4]	6.8
Wiles et al, 2013	South Africa	Urban	Both	Public	311	83	26.7	[21.9; 32.0]	6.6
Chebet 2014	Uganda	Urban	Both	Both	958	309	32.3	[29.3; 35.3]	6.8
Random effects model					**10689**	**1422**	**12.8**	**[8.7; 17.5]**	**100.0**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0167$, $p < 0.01$									
Diagnostic criteria = IOTF									
Muhihi, 2013	Tanzania	Urban	Both	Both	249	0	0.0	[0.0; 1.5]	12.0
Taleb et al, 2010	Algeria	Urban	Both	Both	3396	168	4.9	[4.2; 5.7]	12.8
Regaieg, 2014	Tunisia	Urban	Both	Public	1529	96	6.3	[5.1; 7.6]	12.7
Kirsten 2013	South Africa	Urban	Both	Both	638	57	8.9	[6.8; 11.4]	12.5
Mwaikambo et al, 2015	Tanzania	Urban	Both	Both	1722	176	10.2	[8.8; 11.7]	12.7
Caleyachetty, 2012	Mauritius	Urban	Both	Both	298	54	18.1	[13.9; 23.0]	12.1
Boukthir, 2011	Tunisia	Urban	Both	Public	1335	264	19.8	[17.7; 22.0]	12.7
McKersie & Baard, 2014	South Africa	Urban	Both	Public	713	149	20.9	[18.0; 24.1]	12.5
Random effects model					**9880**	**964**	**9.4**	**[5.2; 14.7]**	**100.0**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0135$, $p < 0.01$									
Diagnostic criteria = CDC									
Amidu, 2013	Ghana	Urban	Both	Both	400	39	9.8	[7.0; 13.1]	33.1
Hassan, 2008	Egypt	Urban	Both	Public	1283	154	12.0	[10.3; 13.9]	34.2
Salman 2010	Sudan	Urban	Both	Unspecified	304	45	14.8	[11.0; 19.3]	32.7
Random effects model					**1987**	**238**	**12.0**	**[9.8; 14.4]**	**100.0**
Heterogeneity: $I^2 = 52\%$, $\tau^2 = 0.0005$, $p = 0.13$									

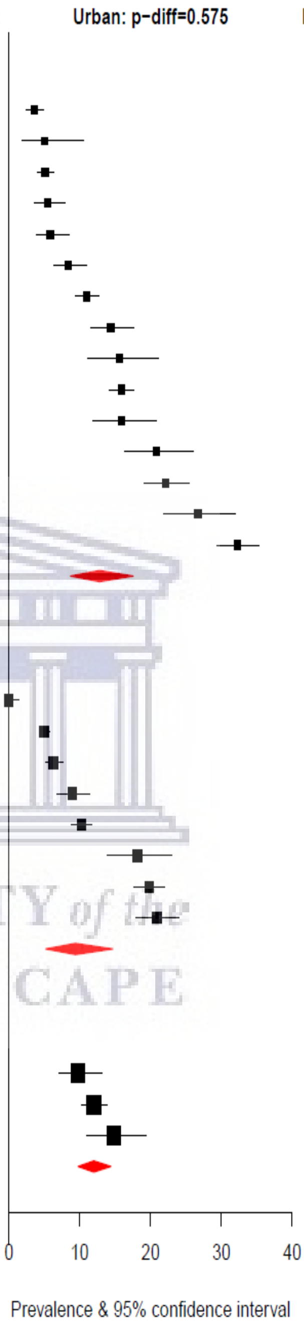


Figure S11: Prevalence of overweight by major diagnostic criteria in rural studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Overweight	Prevalence	95% CI	Weight (%)
Diagnostic criteria = IOTF									
Muhihi, 2013	Tanzania	Rural	Both	Both	197	0	0.0	[0.0; 1.9]	13.4
van Den Ende 2014	South Africa	Rural	Boys	Public	421	5	1.2	[0.4; 2.7]	14.2
van Den Ende 2014	South Africa	Rural	Girls	Public	404	7	1.7	[0.7; 3.5]	14.2
Jinabhai et al, 2003	South Africa	Rural	Both	Public	802	33	4.1	[2.8; 5.7]	14.6
Jinabhai et al, 2005	South Africa	Rural	Both	Public	643	33	5.1	[3.6; 7.1]	14.5
Tathiah, N. 2013	South Africa	Rural	Both	Both	952	86	9.0	[7.3; 11.0]	14.7
Caleyachetty, 2012	Mauritius	Rural	Both	Both	543	92	16.9	[13.9; 20.4]	14.4
Random effects model					**3962**	**256**	**4.0**	**[1.3; 8.2]**	**100.0**
Heterogeneity: $I^2 = 97\%$, $?^2 = 0.0137$, $p < 0.01$									
Diagnostic criteria = WHO									
Pedro 2014	South Africa	Rural	Boys	Public	292	6	2.1	[0.8; 4.4]	25.1
Jinabhai et al, 2003	South Africa	Rural	Both	Public	802	48	6.0	[4.4; 7.9]	26.4
Pedro 2014	South Africa	Rural	Girls	Public	296	31	10.5	[7.2; 14.5]	25.2
Oldewage-Theron 2010	South Africa	Rural	Both	Public	142	17	12.0	[7.1; 18.5]	23.3
Random effects model					**1532**	**102**	**6.9**	**[3.4; 11.6]**	**100.0**
Heterogeneity: $I^2 = 89\%$, $?^2 = 0.0060$, $p < 0.01$									

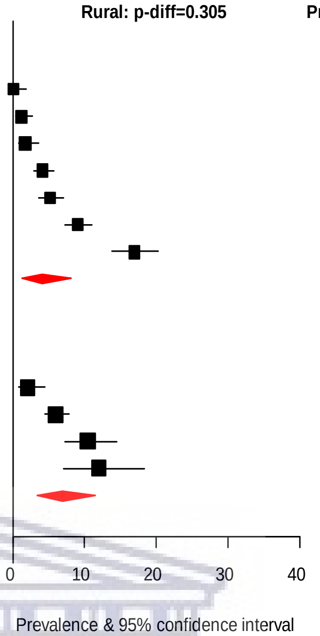


Figure S12: Prevalence of overweight by major diagnostic criteria in urban and rural studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Overweight	Prevalence	95% CI	Weight (%)
Diagnostic criteria = WHO									
Daboné et al, 2011	Burkina Faso	Both	Both	Both	649	11	1.7	[0.8; 3.0]	19.7
Jinabhai et al, 2003	South Africa	Both	Both	Both	24391	829	3.4	[3.2; 3.6]	20.6
Jinabhai et al, 2003	South Africa	Both	Both	Both	4342	195	4.5	[3.9; 5.1]	20.5
Abrahams et al, 2011	South Africa	Both	Both	Public	643	92	14.3	[11.7; 17.3]	19.7
Navti et al, 2014	Cameroon	Both	Both	Both	557	82	14.7	[11.9; 17.9]	19.6
Random effects model					**30582**	**1209**	**6.6**	**[3.8; 10.1]**	**100.0**
Heterogeneity: I^2 = 98%, ?^{2} = 0.0049, p < 0.01									
Diagnostic criteria = IOTF									
Jinabhai et al, 2003	South Africa	Both	Both	Both	24391	561	2.3	[2.1; 2.5]	17.2
Pienaar_2010, 2015	South Africa	Both	Both	Both	574	47	8.2	[6.1; 10.7]	16.4
Pienaar_2013, 2015	South Africa	Both	Both	Both	574	54	9.4	[7.1; 12.1]	16.4
Armstrong et al, 2006	South Africa	Both	Both	Both	10195	1203	11.8	[11.2; 12.4]	17.2
Caleyachetty, 2012	Mauritius	Both	Both	Both	841	146	17.4	[14.9; 20.1]	16.7
Muhihi, 2013	Tanzania	Both	Both	Both	446	84	18.8	[15.3; 22.8]	16.2
Random effects model					**37021**	**2095**	**10.5**	**[4.7; 18.3]**	**100.0**
Heterogeneity: I^2 = 100%, ?^{2} = 0.0195, p < 0.01									
Diagnostic criteria = CDC									
Mpembeni, 2014	Tanzania	Both	Both	Both	446	44	9.9	[7.3; 13.0]	100.0
Random effects model					**446**	**44**	**9.9**	**[7.3; 12.8]**	**100.0**
Heterogeneity: not applicable									

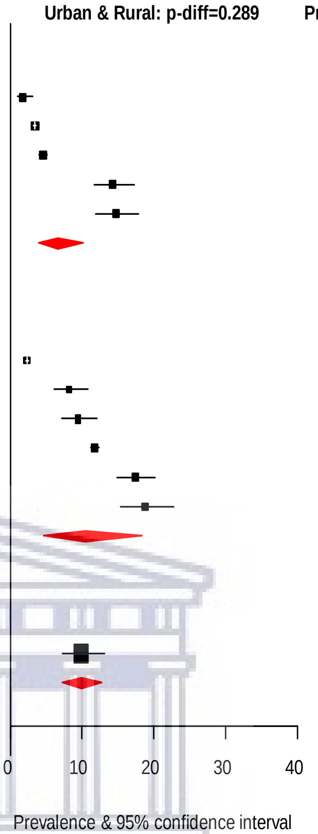


Figure S13: Prevalence of obesity by major diagnostic criteria in urban studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Obese	Prevalence	95% CI	Weight (%)
Diagnostic criteria = WHO									
Puckree et al, 2011	South Africa	Urban	Both	Public	120	1	0.8	[0.0; 4.6]	7.4
Sebanni et al, 2013	Morocco	Urban	Both	Public	1418	43	3.0	[2.2; 4.1]	8.7
Dekkaki et al, 2011	Morocco	Urban	Both	Public	1570	57	3.6	[2.8; 4.7]	8.7
Mosha & Fungo, 2010	Tanzania	Urban	Both	Both	428	27	6.3	[4.2; 9.0]	8.4
Muthuri 2014	Kenya	Urban	Both	Both	563	36	6.4	[4.5; 8.7]	8.5
Pangani, 2016	Tanzania	Urban	Both	Both	1781	119	6.7	[5.6; 7.9]	8.7
Mohammed, 2012	Ghana	Urban	Both	Private	270	29	10.7	[7.3; 15.1]	8.1
Mogre, 2013	Ghana	Urban	Both	Unspecified	218	24	11.0	[7.2; 15.9]	8.0
Pangani, 2016	Tanzania	Urban	Both	Private	678	77	11.4	[9.1; 14.0]	8.5
Chebet 2014	Uganda	Urban	Both	Both	958	208	21.7	[19.1; 24.5]	8.6
El-Sabely, 2013	Egypt	Urban	Girls	Both	288	77	26.7	[21.7; 32.2]	8.2
Wiles et al, 2013	South Africa	Urban	Both	Public	311	85	27.3	[22.5; 32.6]	8.2
Random effects model					**8603**	**783**	**9.8**	**[6.0; 14.6]**	**100.0**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0157$, $p < 0.01$									
Diagnostic criteria = IOTF									
Taleb et al, 2010	Algeria	Urban	Both	Both	3396	48	1.4	[1.0; 1.9]	12.9
Regaieg, 2014	Tunisia	Urban	Both	Public	1529	37	2.4	[1.7; 3.3]	12.8
Kirsten 2013	South Africa	Urban	Both	Both	638	26	4.1	[2.7; 5.9]	12.5
Mwaikambo et al, 2015	Tanzania	Urban	Both	Both	1722	77	4.5	[3.5; 5.6]	12.8
Boukthir, 2011	Tunisia	Urban	Both	Public	1335	77	5.8	[4.6; 7.2]	12.7
Caleyachetty, 2012	Mauritius	Urban	Both	Both	298	20	6.7	[4.1; 10.2]	12.0
Muhihi, 2013	Tanzania	Urban	Both	Both	249	20	8.0	[5.0; 12.1]	11.8
McKersie & Baard, 2014	South Africa	Urban	Both	Public	713	70	9.8	[7.7; 12.2]	12.5
Random effects model					**9880**	**375**	**4.9**	**[3.0; 7.2]**	**100.0**
Heterogeneity: $I^2 = 96\%$, $\tau^2 = 0.0047$, $p < 0.01$									
Diagnostic criteria = CDC									
Hassan, 2008	Egypt	Urban	Both	Public	1283	73	5.7	[4.5; 7.1]	34.4
Amidu, 2013	Ghana	Urban	Both	Both	400	30	7.5	[5.1; 10.5]	33.1
Salman 2010	Sudan	Urban	Both	Unspecified	304	32	10.5	[7.3; 14.5]	32.5
Random effects model					**1987**	**135**	**7.5**	**[5.1; 10.5]**	**100.0**
Heterogeneity: $I^2 = 76\%$, $\tau^2 = 0.0015$, $p = 0.02$									

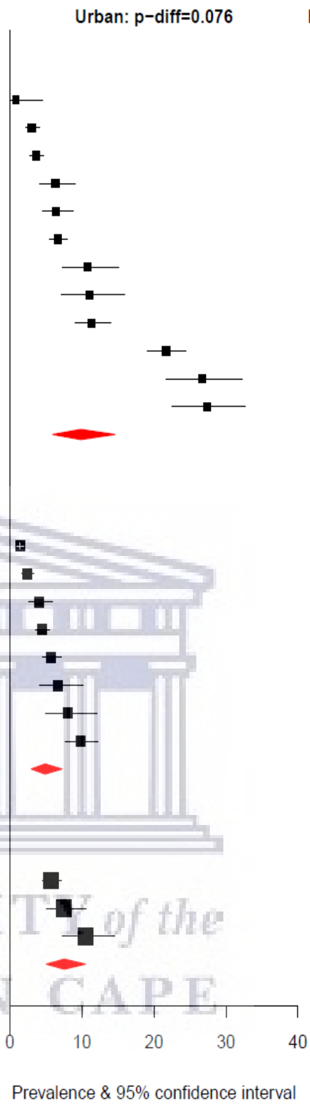


Figure S14: Prevalence of obesity by major diagnostic criteria in rural studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Obese	Rural: p-diff=0.757	Prevalence	95% CI	Weight (%)
Diagnostic criteria = IOTF										
Jinabhai et al, 2005	South Africa	Rural	Both	Public	643	4		0.6	[0.2; 1.6]	20.7
Jinabhai et al, 2003	South Africa	Rural	Both	Public	802	5		0.6	[0.2; 1.4]	21.2
Muhihi, 2013	Tanzania	Rural	Both	Both	197	3		1.5	[0.3; 4.4]	16.3
Tathiah, N. 2013	South Africa	Rural	Both	Both	952	36		3.8	[2.7; 5.2]	21.6
Caleyachetty, 2012	Mauritius	Rural	Both	Both	543	22		4.1	[2.6; 6.1]	20.3
Random effects model					**3137**	**70**		**1.8**	**[0.6; 3.8]**	**100.0**
Heterogeneity: $I^2 = 90\%$, ?^{2} = 0.0040, $p < 0.01$										
Diagnostic criteria = WHO										
Pedro 2014	South Africa	Rural	Boys	Public	292	2		0.7	[0.1; 2.5]	25.1
Jinabhai et al, 2003	South Africa	Rural	Both	Public	802	7		0.9	[0.4; 1.8]	29.5
Oldewage-Theron 2010	South Africa	Rural	Both	Public	142	4		2.8	[0.8; 7.1]	20.2
Pedro 2014	South Africa	Rural	Girls	Public	296	9		3.0	[1.4; 5.7]	25.2
Random effects model					**1532**	**22**		**1.5**	**[0.6; 2.9]**	**100.0**
Heterogeneity: $I^2 = 65\%$, ?^{2} = 0.0014, $p = 0.03$										

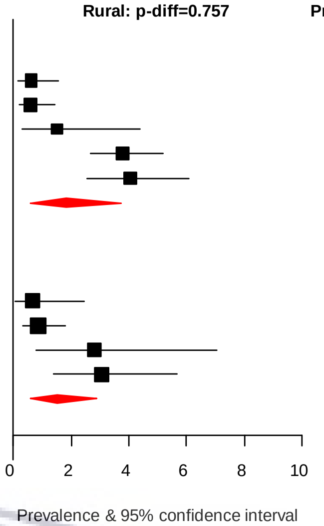


Figure S15: Prevalence of overweight by major diagnostic criteria in public schools studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

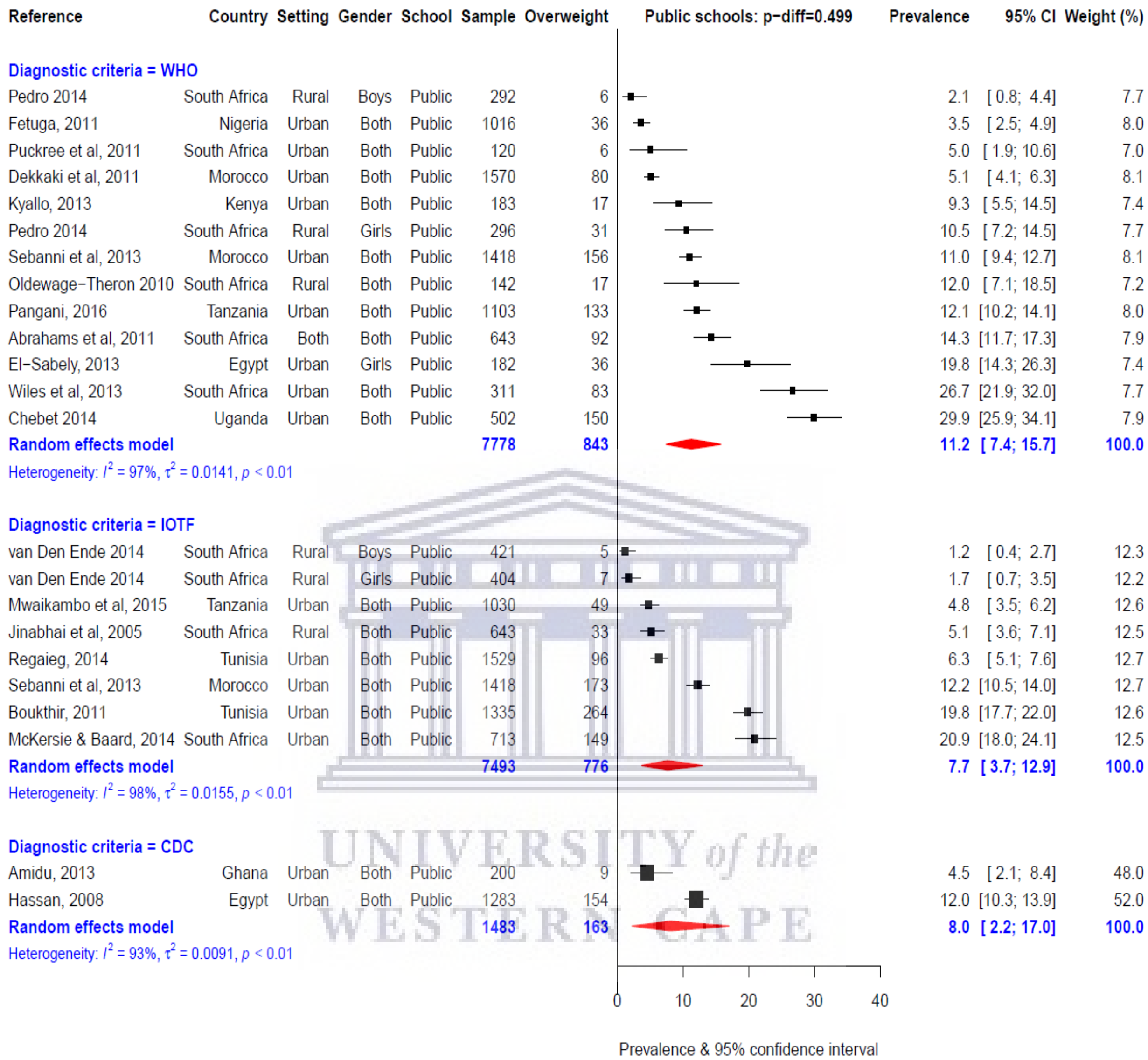


Figure S16: Prevalence of overweight by major diagnostic criteria in private schools studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Overweight	Private schools: p-diff=0.209	Prevalence	95% CI	Weight (%)
Diagnostic criteria = WHO										
Mohammed, 2012	Ghana	Urban	Both	Private	270	43		15.9	[11.8; 20.8]	20.6
Kyallo, 2013	Kenya	Urban	Both	Private	138	25		18.1	[12.1; 25.6]	18.3
Pangani, 2016	Tanzania	Urban	Both	Private	678	150		22.1	[19.1; 25.4]	22.2
El-Sabely, 2013	Egypt	Urban	Girls	Private	106	24		22.6	[15.1; 31.8]	17.2
Chebet 2014	Uganda	Urban	Both	Private	456	159		34.9	[30.5; 39.4]	21.7
Random effects model					**1648**	**401**		**22.6**	**[16.0; 30.0]**	**100.0**
Heterogeneity: I^2 = 90%, ?^{2} = 0.0080, p < 0.01										
Diagnostic criteria = IOTF										
Mwaikambo et al, 2015	Tanzania	Urban	Both	Private	692	126		18.2	[15.4; 21.3]	100.0
Random effects model					**692**	**126**		**18.2**	**[15.4; 21.2]**	**100.0**
Heterogeneity: not applicable										
Diagnostic criteria = CDC										
Amidu, 2013	Ghana	Urban	Both	Private	200	30		15.0	[10.4; 20.7]	100.0
Random effects model					**200**	**30**		**15.0**	**[10.4; 20.3]**	**100.0**
Heterogeneity: not applicable										

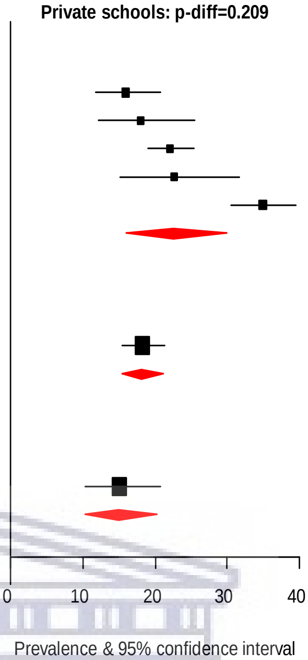


Figure S17: Prevalence of obesity by major diagnostic criteria in public schools studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Reference	Country	Setting	Gender	School	Sample	Obese	Prevalence	95% CI	Weight (%)
Diagnostic criteria = WHO									
Pedro 2014	South Africa	Rural	Boys	Public	292	6	2.1	[0.8; 4.4]	8.3
Puckree et al, 2011	South Africa	Urban	Both	Public	120	6	5.0	[1.9; 10.6]	7.5
Dekkaki et al, 2011	Morocco	Urban	Both	Public	1570	80	5.1	[4.1; 6.3]	8.9
Kyallo, 2013	Kenya	Urban	Both	Public	183	17	9.3	[5.5; 14.5]	8.0
Pedro 2014	South Africa	Rural	Girls	Public	296	31	10.5	[7.2; 14.5]	8.3
Sebanni et al, 2013	Morocco	Urban	Both	Public	1418	156	11.0	[9.4; 12.7]	8.9
Oldewage−Theron 2010	South Africa	Rural	Both	Public	142	17	12.0	[7.1; 18.5]	7.7
Pangani, 2016	Tanzania	Urban	Both	Public	1103	133	12.1	[10.2; 14.1]	8.8
Abrahams et al, 2011	South Africa	Both	Both	Public	643	92	14.3	[11.7; 17.3]	8.7
El−Sabely, 2013	Egypt	Urban	Girls	Public	182	36	19.8	[14.3; 26.3]	8.0
Wiles et al, 2013	South Africa	Urban	Both	Public	311	83	26.7	[21.9; 32.0]	8.4
Chebet 2014	Uganda	Urban	Both	Public	502	150	29.9	[25.9; 34.1]	8.6
Random effects model					**6762**	**807**	**12.1**	**[8.1; 16.8]**	**100.0**
Heterogeneity: $I^2 = 96\%$, $\tau^2 = 0.0131$, $p < 0.01$									
Diagnostic criteria = IOTF									
Mwaikambo et al, 2015	Tanzania	Urban	Both	Public	1030	49	4.8	[3.5; 6.2]	16.7
Jinabhai et al, 2005	South Africa	Rural	Both	Public	643	33	5.1	[3.6; 7.1]	16.5
Regaieg, 2014	Tunisia	Urban	Both	Public	1529	96	6.3	[5.1; 7.6]	16.8
Sebanni et al, 2013	Morocco	Urban	Both	Public	1418	173	12.2	[10.5; 14.0]	16.8
Boukthir, 2011	Tunisia	Urban	Both	Public	1335	264	19.8	[17.7; 22.0]	16.8
McKersie & Baard, 2014	South Africa	Urban	Both	Public	713	149	20.9	[18.0; 24.1]	16.5
Random effects model					**6668**	**764**	**10.6**	**[5.8; 16.7]**	**100.0**
Heterogeneity: $I^2 = 98\%$, $\tau^2 = 0.0120$, $p < 0.01$									
Diagnostic criteria = CDC									
Amidu, 2013	Ghana	Urban	Both	Public	200	9	4.5	[2.1; 8.4]	47.6
Hassan, 2008	Egypt	Urban	Both	Public	1283	154	12.0	[10.3; 13.9]	52.4
Random effects model					**1483**	**163**	**8.0**	**[2.2; 17.0]**	**100.0**
Heterogeneity: $I^2 = 93\%$, $\tau^2 = 0.0091$, $p < 0.01$									

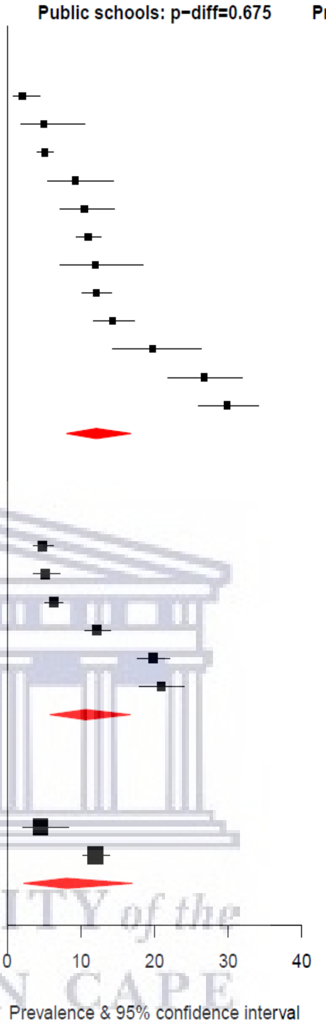
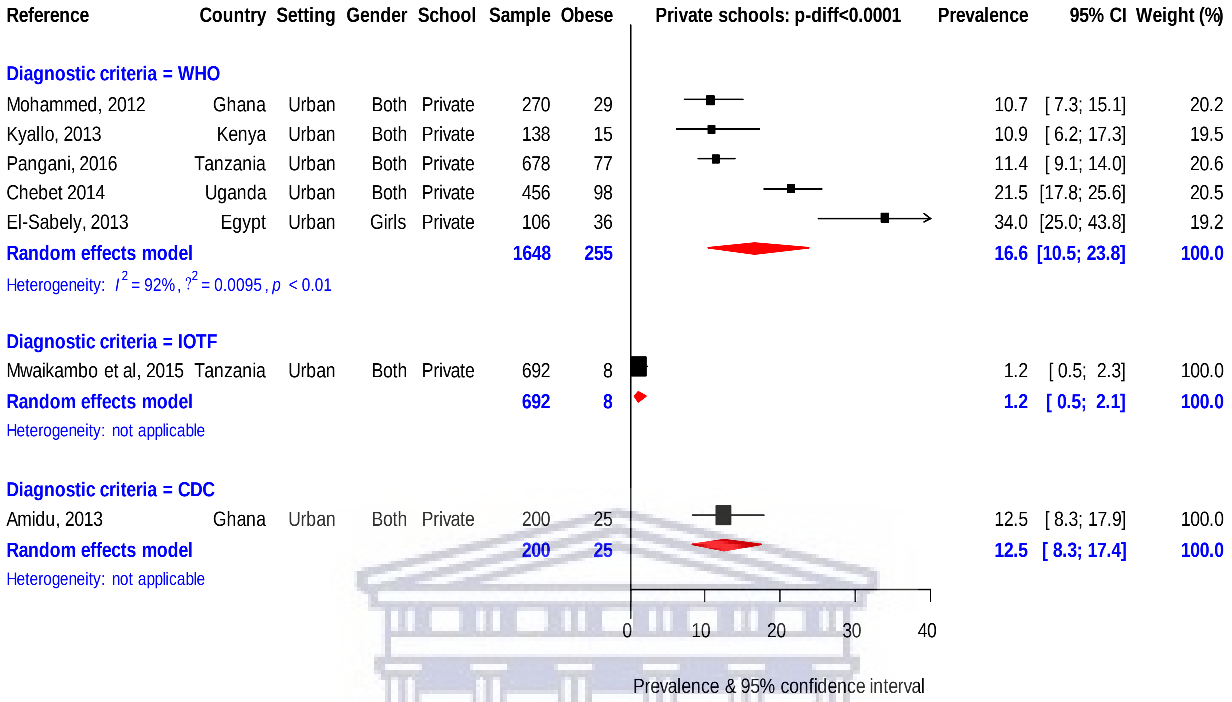


Figure S18: Prevalence of obesity by major diagnostic criteria in private schools studies.

Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.



Appendix II: Supplementary materials for school-based intervention studies

Table S1: Search strategy PubMed: Protocol for systematic review of school-based interventions targeting nutrition and physical activity behaviours, and body weight status of African learners

Search	Search terms	Hits
1	Weight [tw] OR height [tw] OR BMI [tw] OR BMI z-scores [tw]	
2	Obesity, Overweight [MeSH Terms]	
3	Obesity prevention [tw] OR obesity treatment [tw] OR obesity management [tw] OR health promotion [tw] OR health education [tw] OR physical activity [tw] recreation* [tw] OR sports [tw] OR exerci* [tw] OR fitness [tw] OR nutrition intervention [tw] OR diet* intervention [tw]	
4	School programme [tw] OR school intervention [tw] OR school-based study [tw]	
5	# 1 OR # 2 OR # 3 OR # 4	
6	Learner* [tw] OR school* children [tw] OR school* going children [tw]	
7	# 5 AND # 6	
8	((((("Africa"[MeSH] OR Africa*[tw] OR Algeria[tw] OR Angola[tw] OR Benin[tw] OR Botswana[tw] OR "Burkina Faso"[tw] OR Burundi[tw] OR Cameroon[tw] OR "Canary Islands"[tw] OR "Cape Verde"[tw] OR "Central African Republic"[tw] OR Chad[tw] OR Comoros[tw] OR Congo[tw] OR "Democratic Republic of Congo"[tw] OR Djibouti[tw] OR Egypt[tw] OR "Equatorial Guinea"[tw] OR Eritrea[tw] OR Ethiopia[tw] OR Gabon[tw] OR Gambia[tw] OR Ghana[tw] OR Guinea[tw] OR "Guinea Bissau"[tw] OR "Ivory Coast"[tw] OR "Cote d'Ivoire"[tw] OR Jamahiriya[tw] OR Jamahiryia[tw] OR Kenya[tw] OR Lesotho[tw] OR Liberia[tw] OR Libya[tw] OR Libia[tw] OR Madagascar[tw] OR Malawi[tw] OR Mali[tw] OR Mauritania[tw] OR Mauritius[tw] OR Mayote[tw] OR Morocco[tw] OR Mozambique[tw] OR Mocambique[tw] OR Namibia[tw] OR Niger[tw] OR Nigeria[tw] OR Principe[tw] OR Reunion[tw] OR Rwanda[tw] OR "Sao Tome"[tw] OR Senegal[tw] OR Seychelles[tw] OR "Sierra Leone"[tw] OR Somalia[tw] OR "South Africa"[tw] OR "St Helena"[tw] OR Sudan[tw] OR Swaziland[tw] OR Tanzania[tw] OR Togo[tw] OR Tunisia[tw] OR Uganda[tw] OR "Western Sahara"[tw] OR Zaire[tw] OR Zambia[tw] OR Zimbabwe[tw] OR "Central Africa"[tw] OR "Central African"[tw] OR "West Africa"[tw] OR "West African"[tw] OR "Western Africa"[tw] OR "Western African"[tw] OR "East Africa"[tw] OR "East African"[tw] OR "Eastern Africa"[tw] OR "Eastern African"[tw] OR "North Africa"[tw] OR "North African"[tw] OR "Northern Africa"[tw] OR "Northern African"[tw] OR "South African"[tw] OR "Southern Africa"[tw] OR "Southern African"[tw] OR "sub Saharan Africa"[tw] OR "sub Saharan African"[tw] OR "subSaharan Africa"[tw] OR "subSaharan African"[tw]) NOT ("guinea pig"[tw] OR "guinea pigs"[tw] OR "aspergillus niger"[tw])))))	
9	# 7 AND # 8	
10	# 9 Limits: 2000/01/01 to 2018/06/30	

Table S2: PRISMA checklist for systematic review of school-based interventions targeting nutrition and physical activity behaviours, and body weight status of African learners

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1 & 2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	2
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2, PROSPERO, # CRD42016035248
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	2 & 3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Table S1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	3
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	3
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	3
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	3
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	3 & 4
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	3 & 4

Table S3: Methodological Quality of included studies

Reference	Selection bias *Likelihood of bias due to the allocation process in an experimental study Participants are more likely to be representative of the target population*	Study design *Was the study described as randomized? Was the method of randomization described?*	Confounders *The authors should indicate if confounders were controlled in the design (by stratification or matching) or in the analysis. If the allocation to intervention and control groups is randomized, the authors must report that the groups were balanced at baseline with respect to confounders.*	Blinding *Assessors should be described as blinded to which participants were in the control and intervention groups. Study participants should not be aware of (i.e. blinded to) the research question*	Data collection methods *Tools for primary outcome measures must be described as reliable and valid*	Withdrawals and drop-outs *Numbers and reasons for withdrawals and drop-outs must be described*	Overall rating
Naidoo et al, 2009 [19]	Weak	Moderate	Weak	Weak	Moderate	Moderate	Weak
Draper et al, 2010 [20]	Weak	Moderate	Weak	Weak	Moderate	Weak	Weak
Harrabi et al, 2010 [22]	Moderate	Moderate	Weak	Weak	Moderate	Strong	Weak
Jemmott et al, 2011 [21]	Moderate	Strong	Strong	Strong	Strong	Strong	Strong
Monyeki 2012 [15]	Weak	Weak	Weak	Weak	Moderate	Weak	Weak
Regaieg 2013 [25]	Weak	Strong	Strong	Weak	Moderate	Strong	Weak
Maatoug et al, 2015 [23]	Weak	Moderate	Weak	Weak	Moderate	Moderate	Weak
De Villiers et al, 2016 [18]	Moderate	Strong	Weak	Moderate	Moderate	Weak	Weak
Uys 2016 [17]	Moderate	Strong	Moderate	Weak	Strong	Weak	Weak
Ghammam 2017 [24]	Moderate	Moderate	Weak	Weak	Strong	Weak	Weak

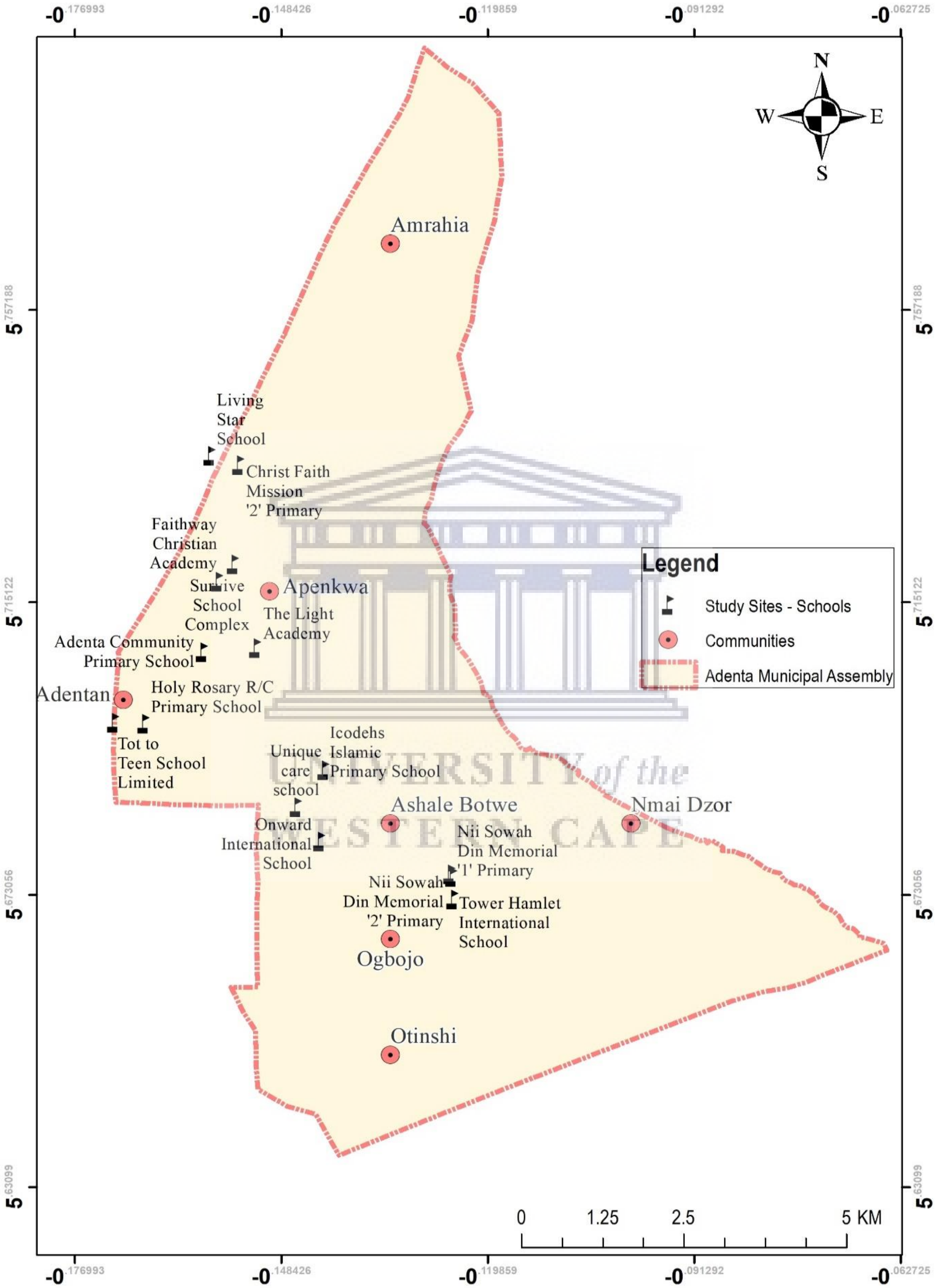
Appendix III: National policy, actions, programmes, and strategies on diet and physical activity to prevent obesity/non-communicable diseases in African countries

Country	**Title and type of document**	**Year**
Algeria	Multi-sectoral Integrated Strategic Plan for Control of Risk Factors of Non-Communicable Diseases	2015-2019
Angola	Health Development Plan	2012-2025
Benin	Integrated Strategic Plan for the Control of Non-communicable Diseases	2014-2018
Botswana	Multi-sectoral Strategy for the Prevention and Control of Non-Communicable Diseases	2017-2022
Burkina Faso	Integrated Strategic Plan for Control of Non-communicable Diseases Nutrition Policy	2016-2020* 2016
Burundi	Multi-sectoral Strategic Plan for Food Safety and Nutrition Health Development Plan	2014-2017* 2011-2015*
Cameroon	Health Development Plan Food and Nutrition Policy	2016-2020 2007-2011
Cape Verde	Health Development Plan	2012-2016*
Central African Republic	Policy for the Prevention and Control of Non-communicable Diseases	2014
Chad	Multi-sectoral Plan to fight and control non-communicable Diseases	2017-2021
Comoros	Strategic Document for Prevention and Control of Non-communicable Diseases	2013*
Congo	Integrated Plan for Control of Non-communicable Diseases	2013-2017
Cote d'Ivoire (Ivory Coast)	Integrated Strategic Plan for Prevention and Management of Non-communicable Diseases	2015-2019
DR of the Congo	Health Development Plan	2014*
Djibouti	Health Development Plan	2013-2017*
Egypt	Multi-sectoral Action Plan For Non-communicable Diseases Prevention and Control	2018-2022
Ethiopia	Strategic Action Plan for Prevention and Control of Non-communicable Diseases	2014-2016
Eritrea	Non-communicable Diseases Policy	2008*
Gabon	Policy on Food Security and Nutrition	2017-2025
Gambia	Health Sector Strategic Plan Nutrition Policy	2014-2020* 2010-2020
Ghana	Strategy for the Management, Prevention and Control of Chronic Non-Communicable Diseases in Ghana	2012-2016
Guinea-Bissau	National Nutrition Policy	2008-2017
Guinea	Integrated Programme for the Prevention and Control of Non-communicable Diseases	2011-2015
Kenya	Strategy for the Prevention and Control of Non Communicable Diseases	2015-2020
Lesotho	Multi-sectoral Integrated Strategic Plan for the Prevention and Control of Non-communicable Diseases	2014-2020
Liberia	Policy and Strategic Plan on Health Promotion	2016-2021

	Food Security and Nutrition Strategy	2008
Madagascar	National Policy for Prevention and fight against Integrated non-communicable chronic Diseases Action Plan for Nutrition	 2017-2021*
Malawi	Health Sector Strategic Plan II Multi-sector Nutrition Policy	2017-2022* 2018-2022
Mali	Policy to fight against non-Communicable Diseases	2013*
Mauritania	Health Development Plan	2012-2020
Mauritius	Health Sector Strategy Plan of Action for Nutrition Final Action Plan on Physical Activity	2017-2021 2009-2010 2011-2014
Morocco	Multi-sectoral Integrated Strategic Plan for the Prevention and Control of Non-communicable Diseases	2016-2025
Mozambique	Strategic Plan for Prevention and Control of Non-communicable Diseases	2008-2014
Namibia	Health Policy Framework Strategic Plan for Nutrition	2010-2020* 2011-2015
Niger	Integrated Strategic Plan for Prevention and Control of Chronic Non-communicable Diseases	2012
Nigeria	Policy and Strategic Plan of Action On Non-communicable Diseases	2013
Rwanda	Non-communicable Diseases Policy Food and Nutrition Policy	2015 2013-2018
Sao Tome and Principe	Health Development Plan	2017-20218
Senegal	Health Development Plan	2009-2018*
Seychelles	Strategy for the Prevention and Control of Non-Communicable Diseases	2016-2025
Sierra Leone	Non-communicable Diseases Strategic Plan Food and Nutrition Security Policy	2013-2017 2012–2016*
Somaliland	National Health Policy Health Sector Strategic Plan	2011* 2013-20168
South Africa	Strategy for the Prevention and Control of Obesity	2015-2020
South Sudan	Health Policy Framework and Work Plan	2013-2016*
Sudan	25 years Strategic Plan for Health Sector	2003-2027*
Swaziland	Non-communicable Diseases Prevention and Control Policy	2016
Tanzania	Strategic and Action Plan for the Prevention and Control of Non-communicable Diseases	2016-2020
Togo	Integrated Policy and Strategic Plan to fight against non-communicable diseases	2012-2015
Tunisia	Strategy for Prevention and Control of Obesity	2013-2017
Uganda	Health Sector Development Plan Nutrition Action Plan	2015/16 -* 2019/20 2011-2016*
Zambia	Strategic Plan Non-communicable Diseases and their risk factors	2013-2016
Zimbabwe	National Health Strategy	2016-2020

DR: Democratic Republic; * denotes documents that were excluded from the review

Appendix IV: Map of Adentan Municipality showing the selected schools



Appendix V: Child Questionnaire

TITLE: INDIVIDUAL AND ENVIRONMENTAL FACTORS ASSOCIATED WITH OVERWEIGHT AMONG CHILDREN IN PRIMARY SCHOOLS IN THE ADENTAN MUNICIPALITY

Name of school ______________________ School Number __________

Name of interviewer ___________________ Date___________(dd/mm/yyyy)

Questionnaire 4-digit ID ________________ Class/Grade ____________

SECTION A: Tell us about you and your family

We would like to learn more about you and your family. Please answer all questions. Remember that there are no right or wrong answers, and that every person is different. We will not share any of your personal information with anyone else, and all of your answers will remain private.

1. Name ____
2. Are you a boy or a girl? *(tick one)* 1= Boy 2 = Girl
3. How old are you? _______ (in completed years)
4. Date of birth ___________________ (dd/mm/yyyy)
5. Girls only: Have you started menstruating (bleeding every month/period)? 1 = Yes 2 = No
6. Including yourself, how many people currently live in your home? ________
7. How many rooms are there in your house? ________ rooms

8. In your home, what is the main source of water? (Circle *one*)

1 = Indoor tap water 2 = Outside tap water 3 = Other water source

9. What kind of toilet do you usually use at home? (*Circle one*)

1 = Flush toilet inside the house 2 = Flush toilet outside the house

3 = Pit latrine/bucket 4 = Other type, Specify ______________________

10. Tick all items that you have in your home now?

Household items	✓ if Yes
Electricity	
Television	
Radio	
Car/motorbike	
Bicycle	
Fridge/refrigerator	
Washing machine	
Telephone/Cell phone	

Computer	
Satellite dish/cable	
Microwave oven	

11. What is used for cooking in your home? (*You can circle more than one)*.

1 = Gas 2 = Electricity 3 = Wood 4 = Charcoal

5 = Paraffin stove 6 = Other, specify ___________________________

12. Does your mother/guardian work? (*Tick one*) 1 = Yes 2 = No

12.1 If yes, what type of work does she do?

1 = Artisan (hairdresser, tailor, etc.)

2 = Professionals (doctor, teacher, lawyer, accountant, nurse, etc.)

3 = Trading 4 = Other, specify ___________________________

13. Does your father/guardian work? (*Tick one*) 1 = Yes 2 = No

13.1 If yes, what type of work does he do?

1 = Artisan (carpenter, hairdresser, tailor, etc.)

2 = Professionals (doctor, teacher, lawyer, accountant, nurse, etc.)

3 = Trading 4 = Other, specify ___________________________

SECTION B: KNOWLEDGE (*Circle appropriate response)*

1. Do you have school lessons where you talk about healthy eating? 1 = Yes 2 = No
2. Is eating fruit and vegetables every day good for our bodies to fight against illnesses like colds and flu?

   1 = Yes 2 = No 3 = I don't know
3. Eating a lot of sugar, sweets and sweet food…

3.1 Is good for health 1 = Yes 2 = No 3 = I don't know
3.2 Can make you fat 1 = Yes 2 = No 3 = I don't know
3.3 Is bad for your teeth 1 = Yes 2 = No 3 = I don't know

4. When you eat too much fat you can…….

4.1 become fat (overweight) 1 = Agree 2 = Neutral 3 = Disagree

4.2 get high blood pressure when you are older 1 = Agree 2 = Neutral 3 = Disagree

4.3 have a heart attack when you are older 1 = Agree 2 = Neutral 3 = Disagree

4.4 develop diabetes as you get older 1 = Agree 2 = Neutral 3 = Disagree

5. Fruits are a healthy snack

   1 = Agree 2 = Neutral 3 = Disagree

6. I do not have to worry about the kind of foods I eat because I am still young

1 = Agree 2 = Neutral 3 = Disagree

7. Are you doing physical activity when you play games, e.g. skipping, soccer?

   1 = Agree 2 = Neutral 3 = Disagree

8. Are you doing physical activity when you are walking, e.g. walking to school?

   1 = Agree 2 = Neutral 3 = Disagree

9. I do not like sport

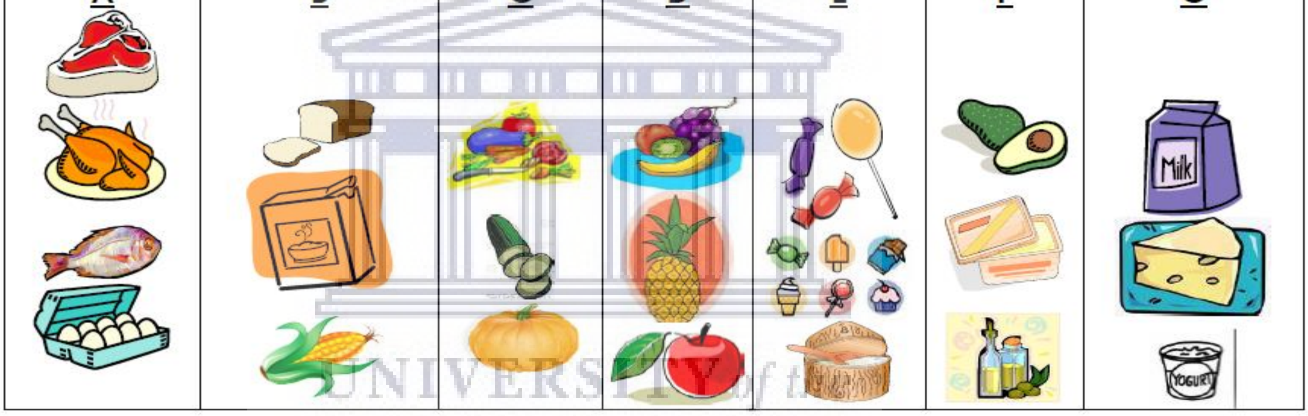
   1 = Agree 2 = Neutral 3 = Disagree

10. It is important to do sport/exercise every day in order to keep your body healthy

   1 = Agree 2 = Neutral 3 = Disagree

11. Look at the following pictures and fill in the LETTER (A, B, C, D, E, F or G) of the food group you think best fits the answer to the questions below (You can choose a group more than once)

Meat, Chicken, Fish, Eggs	Brown Bread, Rice, Samp, Mealie meal	Vegetables	Fruit	Sugar, Sweets	Fats, oils	Milk, Maas, Yoghurt, Cheese
A	B	C	D	E	F	G



11.1 Choose the food group that you should eat the MOST of every day ☐

11.2 Choose the food group that you should eat the LEAST of every day ☐

11.3 Choose the food group that gives your body the best ENERGY ☐

11.4 Choose the food group that your BODY uses to BUILD MUSCLES ☐

11.5 Choose the food group that best PROTECTS THE BODY AGAINST ILLNESSES ☐

11.6 Choose a food group that contains foods with LOTS OF FIBRE (roughage) ☐

SECTION C: LIFESTYLE AND HEALTH

1. In the last 7 days, did you eat in front of the television/computer?

Yes	No	Sometimes

2. In the last 7 days did you eat your main meal with your family?

Yes	No	Sometimes

3. In the past 7 days did you eat breakfast before school?

Yes	No	Sometimes

4. Is it difficult for you to eat breakfast at home because:

4.1 the people at home do not eat breakfast?

Yes		No	

4.2 there is no food in the house to eat for breakfast?

Yes		No	

5. In the past 7 days did you bring a lunchbox to school?

Yes	No	Sometimes	Not allowed lunchboxes at school

5.1. Is it difficult for you to take a lunchbox to school because other children will want your food?

Yes	No	Sometimes

5.2. Is it difficult for you to take a lunchbox to school because there is nothing at home to put in your lunchbox?

Yes	No	Sometimes

5.3 Is it difficult for you to take a lunchbox to school because no one at home can help you to make a lunchbox?

Yes	No	Sometimes

5.4 Do you share or exchange what you have in your lunchbox with friends?

Yes	No	Sometimes

6. Do you bring money to school? 1 = Yes 2 = No

6.1 If yes, how many days in the last 7 days did you bring money to school?

Every day (5 days)	2-3 times/wk

7. In the past 7 days did you buy anything from the tuck shop/school canteen/vendor?

Yes	No	Sometimes

7.1 Do you participate in the school feeding scheme?/ Do you receive lunch (a meal) from your school every day?

Yes	No	Sometimes	Daily

8. In the past 7 days did you eat fruit?

Yes	No

8.1 If you do eat fruit, why do you eat them?

8.2 because you like the taste?

Yes	No	Sometimes

8.3 because people at home eat fruit

Yes	No	Sometimes

8.4 because you are told to eat them

Yes	No	Sometimes

9. In the past 7 days did you eat vegetables?

Yes	No	Sometimes

9.1 If you do eat vegetables, why do you eat them?

9.2 Because you like the taste

Yes	No	Sometimes

9.3 because people at home eat vegetables

Yes	No	Sometimes

9.4 because you are told to eat them

Yes	No	Sometimes

10. When you feel like a snack, what do you eat?

10.1 Chips

Yes	No	Sometimes

10.2 Sweets

Yes	No	Sometimes

10.3 Fruit

Yes	No	Sometimes

10.4 Sandwich or cereal

Yes	No	Sometimes

10.5 Chocolate

Yes	No	Sometimes

10.6 Other

Yes	No	Sometimes	Food snacked	

11. In the past 7 days, did you consume sweetened beverages (cold drinks, fizzy drinks, squash, soft drinks, sweet drink)?

Yes	No	Sometimes

12 In the past 7 days have you eaten fast foods (e.g. hot chips, potato chips (French fries), burger, hotdog, pizza, fried rice)?

Yes	No	Sometimes

13. In the last 7 days have you ever gone to bed hungry because there was no food? If yes, how many times?

Never	1-2 days	>3 days

14. Do you think you can make changes to your diet by:

1 = Yes 2 = No 3 = Not sure

14.1 putting less margarine on your bread?

1 = Yes 2 = No 3 = Not sure

14.2 eating fewer chips?

1 = Yes 2 = No 3 = Not sure

14.3 buying fruit instead of chips?

1 = Yes 2 = No 3 = Not sure

14.4 putting less sugar in your tea?

1 = Yes 2 = No 3 = Not sure

14.4 putting less sugar on your cereal/porridge?

1 = Yes 2 = No 3 = Not sure

14.6 eating sweets less often?

1 = Yes 2 = No 3 = Not sure

14.7 drinking cold drinks less often?

1 = Yes 2 = No 3 = Not sure

14.8 eating more fruits?

1 = Yes 2 = No 3 = Not sure

14.9 eating more vegetables?

1 = Yes 2 = No 3 = Not sure

14.10 eating brown bread instead of white bread?

1 = Yes 2 = No 3 = Not sure

SECTION D: PHYSICAL ACTIVITY

We are trying to find out about your level of physical activity from the last 7 days (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Have you done any of the following activities in the past 7 days (last week) in your spare time when you are not at school? If yes, how many times? Only mark one box per row.

	1	**2**	**3**	**4**	**5**
	No	1-2	3-4	5-6	7 times or more
Walking for exercise					
Skipping rope					
Skateboarding					
Tag					
Judo					
Dodge ball					
Karate					
Jumping/ampe/tuumatu					
Table tennis					
Lawn tennis					
Bicycling					
Jogging or running					
Aerobics					
Stair climbing					
Swimming					
Dance					
Soccer/football					
Handball					
Gardening					
Volleyball					
Hockey					
Basketball					
Other, specify					

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? *(Check one only)*

1 = I don't do PE 2 = Hardly ever 3 = Sometimes 4 = Quite often 5 = Always

3. In the last 7 days, what did you do most of the time **at break**? *(Check one only)*

1 = Sat down (talking, reading, doing schoolwork) 2 = Stood around or walked around

3 = Ran or played a little bit 4 = Ran around and played quite a bit

5 = Ran and played hard most of the time

4. In the last 7 days, what did you normally do **at lunch** (besides eating lunch)? *(Check one only)*

1 = Sat down (talking, reading, doing schoolwork)   2 = Stood around or walked around

3 = Ran or played a little bit   4 = Ran around and played quite a bit

5 = Ran and played hard most of the time

5. In the last 7 days, on how many days **right after school**, did you do sports, dance, or play games in which you were very active? (*This includes any of the activities in Table 1. Check one only)*

1 = None   2 = 1 time last week   3 = 2 or 3 times last week

4 = 4 times last week   5 = 5 times last week

6. In the last 7 days, on how many **evenings** did you do sports, dance, or play games in which you were very active? (*This includes any of the activities in Table 1. Circle one only)*

1 = None   2 = 1 time last week   3 = 2 or 3 times last week

4 = 4 or 5 last week   5 = 6 or 7 times last week

7. On the **last weekend**, how many times did you do sports, dance, or play games in which you were very active? (*This includes any of the activities in Table 1. Check one only)*

1 = None   2 = 1 time   3 = 2 - 3 times   4 = 4 - 5 times   5 = 6 or more times

8. Which one of the following describes you best for the last 7 days? Read all five statements before deciding on the one answer that describes you.

1 = All or most of my free time was spent doing things that involve little physical effort

2 = I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics)

3 = I often (3 — 4 times last week) did physical things in my free time

4 = I quite often (5 — 6 times last week) did physical things in my free time

5 = I very often (7 or more times last week) did physical things in my free time

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity or any of the activities listed in Table 1).

	1 = None	2 = Little bit	3 = Medium	4 = Often	5 = Very often
Monday					

Tuesday					
Wednesday					
Thursday					
Friday					
Saturday					
Sunday					

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? *(Remember to check only one.)*

1 = Yes 2 = No

10.1 If yes, what prevented you? ___________________________________

11. Do your teachers encourage you to do physical activity?

Yes	No	Sometimes

12. Does your family encourage you to do physical activity?

Yes	No	Sometimes

13. Do you go out with your family to physical activity events at your school or in your neighbourhood e.g. fun run/walk?

Yes	No	Sometimes

14. My parents do not allow me to do sports

Yes	No	Sometimes

15 My friends do not do sports

Yes	No	Sometimes

16. I am not good enough to be on a sports team

Yes	No	Sometimes

17. I do not know how to play sports and games very well, I am sometimes chosen last for games

Yes	No	Sometimes

18. Sometimes my friends make fun of me when I play sports and games outdoors with them

Yes	No	Sometimes

19. How do you travel to and from school? *(Check only one)*

1= By bus, car, van

2 = I walk

3 = Both

20. Do you participate in after school/weekend classes?

1 = Yes 2 = No

20.1. If yes, how many days per week do you participate?

20.2. On the average, how much time do you spend per day?

21. Look at the pictures provided below, and fill in the LETTER (A, B, C or D) of the activities which BEST answers each question

TV watching, reading and computers	Eating with family and friends	Doing things outside e.g. playing games, gardening	Organised/team sports
A 	B 	C 	D 

21.1 Choose the activities that YOU like the most ☐

21.2 Choose the activities that your FRIENDS like the most ☐

21.3 Choose the activities that are BEST for your health ☐

SECTION E: MEDIA USE

1. Do you watch TV with your family?

1 = Yes 2 = No

1.1. If yes, how often do you watch TV with your family?

1 = Everyday 2 = Most days 3 = Only on weekends

2. How easy is it for you to watch TV at home?

1= Quite easy 2= Easily 3= Not easily/not with difficulty 4= With difficulty 5= Very difficult

3. How many days per week do you watch TV?

0= I don't watch TV 1= 1 day per week 2= 2 days per week 3= 3 days per week
4= 4 days per week 5= 5 days per week 6= 6 days per week 7= Every day

4. How many hours on average do you watch TV each day?

1= One hour 2 = Two hours 3 = Three hours 4 = Four hours 5 = Five hours

6 = More than five hours 7 = N/A 8 = Other (specify)

____

5. Do you play computer games/video games/play station? (Circle the appropriate answer)

1 = Yes 2 = No

5.1 If yes, how often do you play computer/video games/play station? (Circle the appropriate answer)

0= I don't play computer/video games/play station 2= Everyday

3 = Most days 4 = Only on weekends

SECTION F: SLEEP PATTERNS

1. What time do you go to bed on school night? ___________________________________
2. What time do you go to bed on a non-school night (on a weekend or on holiday)? _________
3. What time do you wake up on a school morning? ___________________________________
4. What time do you wake up on a non-school morning (on a weekend or on holiday)? _________

SECTION G: MEASUREMENTS

1. CHILD'S AGE: ________ years
2. CHILD'S DATE OF BIRTH (d/m/y) ________________ (*verify by school records*)
3. CHILD'S ANTHROPOMETRY:
   a) WEIGHT (kg.):1st:________ 2nd:________ mean:_______
   b) HEIGHT (cm.): 1st:________ 2nd:________ mean:________
   c) WAIST CIRCUMFERENCE (cm):
      1st:________ 2nd:________ mean:________
   d) MUAC
      1st:________ 2nd:________ mean:________
4. BLOOD PRESSURE (mm/Hg):

   First reading: systolic: ________ diastolic:________

   Second reading: systolic:_________ diastolic:________

   Third reading: systolic:_________ diastolic:________

   Mean (2nd and 3rd): systolic: _________ diastolic:________

5. FASTING BLOOD SUGAR (mmol/L) ________

Appendix VI: School Questionnaire

TITLE: INDIVIDUAL AND ENVIRONMENTAL FACTORS ASSOCIATED WITH OVERWEIGHT AMONG CHILDREN IN PRIMARY SCHOOLS IN THE ADENTAN MUNICIPALITY

SCHOOL ENVIRONMENT QUESTIONNAIRE

Name of school ______________________ School Number: ____________

School type (private/public) ______________________

Name of interviewer ___________________ Date___________ (dd/mm/yyyy)

Position of person being interviewed at the school: _______________________

Date of Consent: ___________ (dd/mm/yyyy)

A: SCHOOL DEMOGRAPHICS AND NEIGHBOURHOOD ENVIRONMENT

We would like to learn more about your school, the pupils and community that your school serves. All answers will remain confidential, and your school will never be mentioned by name or area in any communication or publications emanating from this project.

1. Grade levels in your school: From Grade/Class ____ to Grade/Class _____
2. Number of classes: _______
3. Number of pupils in your school: ________
4. Number of teachers: ________
5. The socioeconomic status of the pupils within the school and the community that it serves may best be described as:
   1 = lowest socioeconomic status in relation to the region
   2 = low to moderate socioeconomic status in relation to the region
   3 = mixed low, moderate or high socioeconomic status in relation to the region
   4 = upper middle income groups in relation to the region
   5 = do not know
6. How do **MOST** pupils travel to your school?
   1 = car or private vehicle 2 = walk 3 = ride bicycles
   4 = public transport 5 = other, specify ______________________________
7. Which best describes the area or community surrounding your school?
   1= mostly residential urban or suburban
   2 = mixed land use, (residential and business or commercial)
   3 = mostly commercial or business or industrial
   4 = informal settlements urban
   5 = other _________________________________

8. Please answer the following questions as they best describe the physical environment of the neighbourhood surrounding the school:

	Strongly disagree	Somewhat disagree	Not applicable	Somewhat agree	Strongly agree
8.1 There are facilities to bicycle or walk near school, such as separate paths or shared use paths					
8.2 There are many shops, markets or other places to buy things within easy walking distance of the school					
8.3 In the neighborhood, there are several free/low cost facilities, like recreation centres, parks, & playgrounds.					
8.4 There is so much traffic on the street that it makes it difficult or unpleasant to walk or cycle in this neighbourhood					
8.5 The neighbourhood near the school is relatively free from litter, rubbish and graffiti.					
8.6 There are transit stops (bus, taxi) within a 10-15 minute walk from the school.					
8.7 The crime rate in the neighbourhood near the school makes it unsafe to go walking at night.					

B. POLICIES AND PRACTICES

For the following section, "policies" refers to any mandates issued by the state, the local school board, or any other agency, including policies developed by your school or (district/diocese), that affects your school environment and that have been officially adopted by your school or district. This section also asks about practices (what your students and staff are allowed to do on a regular basis) that you might follow to promote the health and well-being of students.

9. Does your school have written policies or practices concerning physical activity?

1 = Yes, existing written policies 2 = Yes, written policies still under development

3 = Yes, practices 4 = No 5 = N/A

10. Does your school have written policies or practices concerning healthy eating?

1 = Yes, existing written policies 2 = Yes, written policies still under development

3 = Yes, practices 4 = No 5 = N/A

11. Does your school have a committee that oversees or offers guidance on the development of policies and practices concerning physical activity and healthy eating at your school (e.g., health action team, school health or wellness council)?

1 = Yes, both physical activity and healthy eating 2 = Yes, physical activity only

3 = Yes, healthy eating only

C. PHYSICAL ACTIVITY

12. What percent of pupils participate in the following extracurricular activities offered by your school? (Please estimate)

	Not available	Less than 10%	10-24%	25-49%	More than 50%
a. Interschool athletics					
b. Intramural athletics or physical activity clubs (including dance, playing)					
d. Academic/hobby clubs (e.g., chess, cooking, sewing)					
e. Arts-based clubs (e.g., drama, music, photography)					

13. Does your school offer late bus/transportation service to pupils who participate in extra-curricular activities?

1. Yes 2. No

14. From the following list, please indicate which sports are offered in your interschool or intramural athletics programmers available to pupils?

a. Not applicable, school does not offer interschool or intramural athletics to pupils			
		Interschool	Intramural
B	Basketball		
C	Volleyball		
D	Soccer/football		
E	Hockey		
F	Karate		
G	Judo		
H	Wrestling		
I	Swimming		
J	Track and field		
K	Other, specify		

15. Is structured **physical activity** currently in the weekly timetable for the pupils?

1 Yes 2. No

15.1 If yes;

a. How many sessions per week? _______ Sessions/week

b. How long is each physical activity session? _______ Minutes/session

16. Is structured **physical education** currently in the weekly timetable?

1 Yes 2 No

16.1 If yes;

a. How many sessions per week? _______ Sessions/week

b. How long is each physical activity session? _______ Minutes/session

17. Does your school promote **active transport** to and from school in any of the following ways?

	No	Don't know	**Yes**
a. Identify safe routes to use for walking and cycling to and from school (e.g., with signs, in newsletters, etc.)			
b. Provide crossing guards at intersections to encourage safe walk-to-school routes			
c. Allow pupils to bring bicycles on school property			

d. Allow pupils to bring small wheel vehicles (e.g., rollerblades, scooters, skateboards) on school property			
e. Encourage the use of helmets and safety gear for those who use bicycles and small wheel vehicles to get to school			
f. Designate a 'car free zone' to provide safe walking areas around the school			

D. SCHOOL FACILITIES

18. Do the majority of pupils at your school have regular access to any of the following during school hours*? *(*During school hours means from the first bell to the last bell, including both instructional and non-instructional time (e.g., lunch).*

	Yes, on grounds only	Yes, off grounds only	Yes, both on and off grounds	No	Don't know
a. Gymnasium					
b. Other large room suitable for physical activity (e.g. auditorium, cafeteria, dance studio)					
c. Fitness room for aerobic					
d. Running track					
e. Outdoor sports field (e.g. football or soccer)					
f. Outdoor paved area (e.g. tennis courts, basketball courts, any paved area that can be used for active games like skipping)					
g. Secure change room lockers available for use during physical activity					
h. Change rooms available for use before and after physical activity					
i. Grassy playground area					
j. Playground equipment (e.g., climbing structures, swings)					

k. Equipment (e.g., basketballs, skipping ropes, footballs, netballs, etc)					
l. Art room					
m. Music room					

19. Do pupils have access to the following facilities where they can buy foods or drinks?

	Yes	No
a. Cafeteria		
b. School shop		
c. Shops/fast food restaurants close to school		
d. Food vendors close to school		

20. If yes, which of the following items are available?

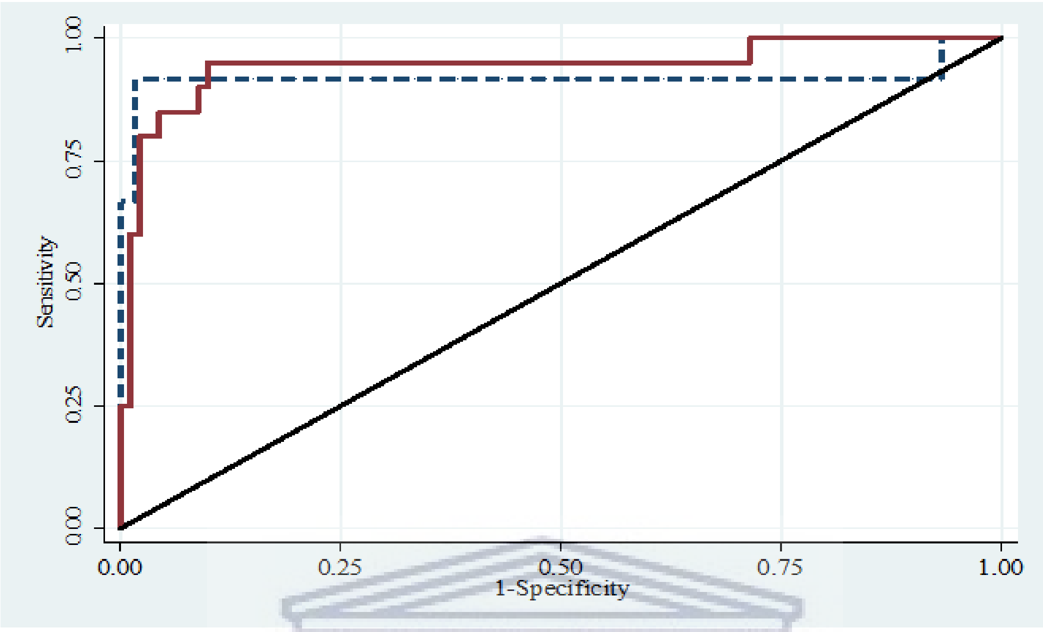
	Yes	No
Chocolate		
Sweets/toffees		
Raw fruits (e.g. orange, watermelon)		
Cooked meals		
Fruit juices (fresh)		
Fruit juices (e.g. ceres, kalypo etc.)		
Soft drinks or minerals (e.g. Fanta, coke, sprite, malt, etc)		
Cakes, cookies, biscuits		
Chips		
Sausage rolls, doughnuts, pies		
Popcorn		
Regular chips, crackers		
Diet sodas (e.g. diet coke)		
Ice cream		
Others		

21. Outside of school hours*, does your school permit regular student access to the following? (**Outside of school hours means before and/or after school, evenings and weekends. Access may occur via school-led, community-led or informal use).*

	Yes	No	Don't know	N/A
a. Gymnasium				
b. indoor facilities				
c. Outdoor facilities (e.g., playing fields, paved activity areas				
d. Equipment (e.g., basketballs, skipping ropes, footballs,)				

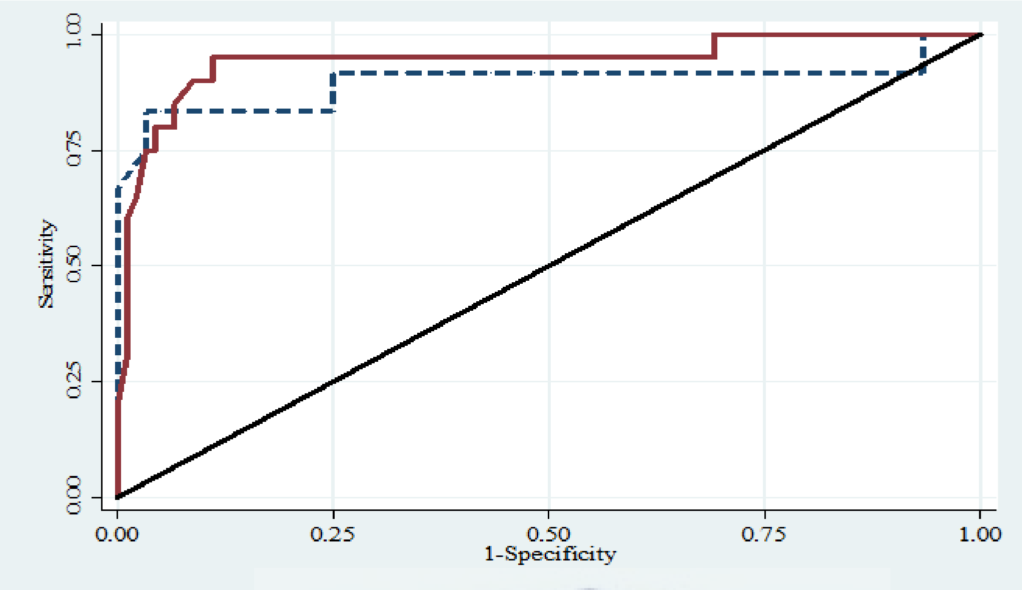
THANK YOU VERY MUCH FOR TAKING TIME TO COMPLETE QUESTIONNAIRE

Appendix VII: Supplementary Figures from Chapter 6



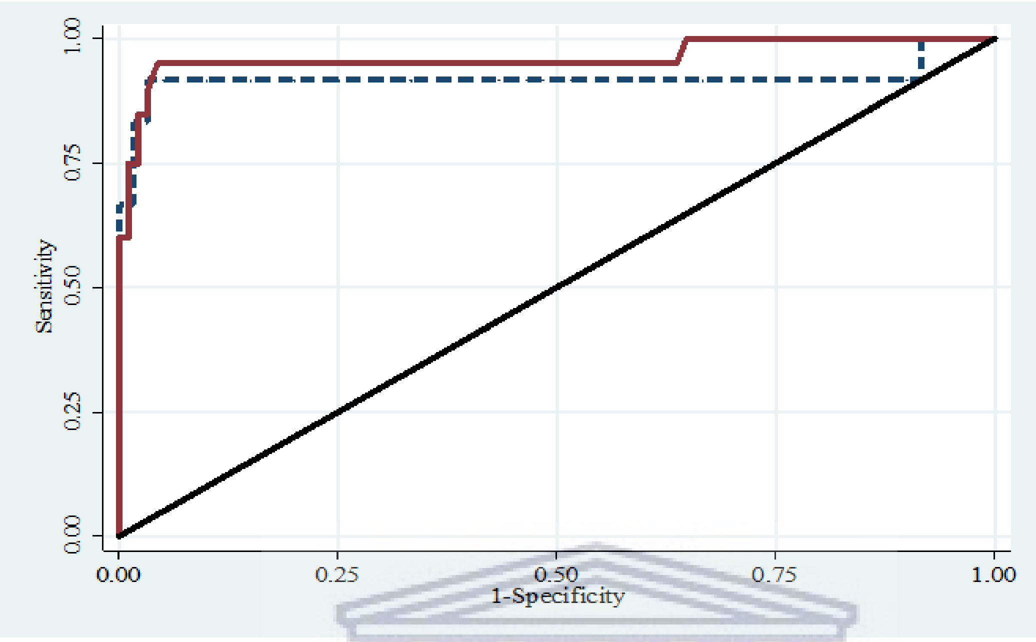
Supplementary Figure A1: Receiver operating characteristics curves for WHO, stratified by gender

Legend: Solid maroon line: ROC area for girls, AUC = 0.944. Broken navy line: ROC area for boys, AUC = 0.918. Diagonal line: ROC area for reference, AUC = 0.500.



Supplementary Figure A2: Receiver operating characteristics curves for CDC, stratified by gender.

Legend: Solid maroon line: ROC area for girls, AUC = 0.943. Broken navy line: ROC area for boys, AUC = 0.897. Diagonal line: ROC area for reference, AUC = 0.500.



Supplementary Figure A3: Receiver operating characteristics curves for IOTF, stratified by gender

Legend: Solid maroon line: ROC area for girls, AUC = 0.960. Broken navy line: ROC area for boys, AUC = 0.918. Diagonal line: ROC area for reference, AUC = 0.500.

Appendix VIII: Ethics approval

Ethics approval from University of the Western Cape

Ethics approval from Ghana Health Service Ethical Review Committee

Appendix 8.1

OFFICE OF THE DEAN
DEPARTMENT OF RESEARCH DEVELOPMENT

UNIVERSITY *of the* WESTERN CAPE

18 August 2015

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:
Ms T Adom (School of Public Health)

Research Project:	Individual and environmental factors associated with obesity among young children in primary schools in Ghana.
Registration no:	15/5/5

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

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a place to grow, from hope
to action through knowledge

Appendix 8.2

GHANA HEALTH SERVICE ETHICAL REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

My Ref. :GHS-ERC: 3
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Tel: +233-302-681109
Fax + 233-302-685424
Email: nitadzy@yahoo.com

25th November, 2013

Theodosia Adom
Radiocological and Medical Sciences Research Institute
Ghana Atomic Energy Commission
Accra

ETHICAL APPROVAL - ID NO: GHS-ERC: 01/07/13

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol titled:

"Applying nuclear techniques to design and evaluation interventions to reduce obesity and health related risks"

This approval requires that you inform the Ethical Review Committee (ERC) when the study begins and provide Mid-term reports of the study to the Ethical Review Committee (ERC) for continuous review. The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Please note that any modification without ERC approval is rendered invalid.

You are also required to report all serious adverse events related to this study to the ERC within seven days verbally and fourteen days in writing.

You are requested to submit a final report on the study to assure the ERC that the project was implemented as per approved protocol. You are also to inform the ERC and your sponsor before any publication of the research findings.

Please always quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED...

PROF. FRED BINKA
(GHS-ERC CHAIRPERSON)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra

Appendix IX: Informed consent

9.1 Participants' Information Sheet and Informed Consent

9.2 Parental Permission Form

9.2 Child Assent Form

UNIVERSITY OF THE WESTERN CAPE
Private Bag X 17, Bellville 7535, South Africa

Tel: +27 21-959 2809, Fax: 27 21-959 2872
E-mail: soph-comm@uwc.ac.za

9.1 PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT

Title: Individual and Environmental Factors Associated with Obesity among Children in Primary Schools in Ghana

What is this study about?
This is a research project being conducted by Theodosia Adom of the School of Public Health at the Faculty of Community and Health Sciences at the University of the Western Cape. We are seeking your consent for your child to participate in this research project because his/her school has been selected. Your child/ward will also be asked for their permission to participate. The purpose of this research project is to learn more about obesity, physical activity and the causes among children aged 8-11 years in primary schools. The information obtained from this research project will help the pupil, parents and community to manage and prevent obesity and related health risks.

What will I be asked to do if I agree to participate?
You and your child will be asked questions about your household, child behaviours like eating patterns, food intake, and physical activity which will take about 40 minutes. Your child's weight, height and waist circumference will be measured. In addition saliva samples will be collected from your child before and after drinking a little heavy water on the same day. Blood pressure will also be measured and your child given an accelerometer (a small device) to wear to monitor his/her activity for 7 days. Samples collected will be stored and used only for the duration and purpose of the research. The study will be conducted in the school and your home.

Would my participation in this study be kept confidential?
The researchers undertake to protect your identity and the nature of your contribution. if applicable (1) your name will not be included on the surveys and other collected data; (2) a code will be placed on the survey and other collected data; (3) through the use of an identification key, the researcher will be able to link your survey to your identity; and (4) only the researcher will have access to the identification key.
To ensure your confidentiality, data entry forms will be locked in filing cabinets and storage areas. Unique identification codes will be assigned and will be used on all data entry forms

instead of your name. If we write a report or article about this research project, your identity will be protected.

What are the risks of this research?
There may be some risks from participating in this research study. All human interactions and talking about self or others carry some amount of risks. We will nevertheless minimise such risks and act promptly to assist you if you experience any discomfort, psychological or otherwise during the process of your participation in this study. Where necessary, an appropriate referral will be made to a suitable professional for further assistance or intervention.

What are the benefits of this research?
This research is not designed to help you or your child personally; but the results may help the investigator learn more about prevalence of obesity, physical activity levels and risk factors in school children in the Adentan Municipality. We hope that, in the future, other people might benefit from this study through improved understanding of the potential risk factors of childhood obesity in Ghana and this will help in designing effective interventions to address the problem.

Do I have to be in this research and may I stop participating at any time?
Your child/ward's participation in the research is not a course requirement. It is completely voluntary. You may choose not to grant permission for your child/ward to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

What if I have questions?
This research is being conducted by Theodosia Adom (Ms), a PhD candidate of the School of Public Health at the University of the Western Cape. If you have any questions about the research study itself, please contact Theodosia Adom at: Nutrition Research Centre, Radiological and Medical Sciences Research Institute, Ghana Atomic Energy Commission; +233 262 806512; theo.adom@gmail.com.

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

Prof Helene Schneider
Director of the School of Public Health
Head of Department
University of the Western Cape
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Prof José Frantz
Dean of the Faculty of Community and Health Sciences
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This research has been approved by the University of the Western Cape's Senate Research Committee. (REFERENCE NUMBER: 15/5/5)

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9.2 PARENTAL PERMISSION FORM

Title: Individual and Environmental Factors Associated with Obesity among Children in Primary Schools in Ghana

The study has been described to me in language that I understand. My questions about the study have been answered. I understand what my child/ward's participation will involve and I agree of my own choice and free will that my child/ward participate. I understand that my child/ward's identity will not be disclosed to anyone. I understand that I may withdraw my child/ward from the study at any time without giving a reason and without fear of negative consequences or loss of benefits.

Parent/guardian's name………………………..

Parent/guardian's signature………………………………

Date………………………

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9.3 CHILD ASSENT FORM

Title: Individual and Environmental Factors Associated with Overweight among Children in Primary Schools in Ghana

The study has been described to me in language that I understand. I understand what I have to do and I agree to participate in the study. I understand that my identity will not be disclosed to anyone. I understand that I may withdraw from the study at any time without giving a reason and without fear of negative consequences or loss of benefits

Participant's name………………………..

Date………………………

Appendix X: Publications

BMJ Open

Prevalence of obesity and overweight in African learners: a protocol for systematic review and meta-analysis

Theodosia Adom,[1,2] Thandi Puoane,[2] Anniza De Villiers,[3] André Pascal Kengne[3,4]

To cite: Adom T, Puoane T, De Villiers A, *et al*. Prevalence of obesity and overweight in African learners: a protocol for systematic review and meta-analysis. *BMJ Open* 2017;7:e013538. doi:10.1136/bmjopen-2016-013538

► Prepublication history and additional material is available. To view please visit the journal (http://dx.doi.org/10.1136/bmjopen-2016-013538).

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For numbered affiliations see end of article.

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ABSTRACT

Introduction: Obesity and overweight are an emerging problem in Africa. Obese children are at increased risk of developing hypertension, high cholesterol, orthopaedic problems and type 2 diabetes as well as increased risk of adult obesity. Prevention of childhood overweight and obesity therefore needs high priority. The review approach is particularly useful in establishing whether research findings are consistent and can be generalised across populations and settings. This systematic review aims to assess the magnitude and distribution of overweight and obesity among primary school learners within populations in Africa.

Methods and analysis: A comprehensive search of key bibliographic databases including MEDLINE (PubMed), MEDLINE (EbscoHost), CINAHL (EbscoHost), Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index) will be conducted for published literature. Grey literature will be also be obtained. Full-text articles of eligible studies will be obtained and screened following predefined inclusion criteria. The quality of reporting as well as risk of bias of included studies will be assessed, data extracted and synthesised. The results will be summarised and presented by country and major regional groupings. Meta-analysis will be conducted for identical variables across studies. This review will be reported following the MOOSE Guidelines for Meta-Analysis and Systematic Reviews of Observational Studies.

Ethics and dissemination: Ethics is not a requirement since no primary data will be collected. All data that will be presented in this review are based on published articles. The findings of this systematic review will be submitted for publication in peer-reviewed journals and disseminated in national and international conferences and also in policy documents to appropriate bodies for decision-making, where needed. It is expected that the findings will identify some research gaps for further studies.

Strengths and limitations of this study

- The use of reference methodologies to guide the study design from study selection to synthesis.
- All eligible studies of all languages will be included.
- The inclusiveness of studies conducted in all countries within the continent.
- Including only studies that used recognised body mass index cut-offs may eliminate some relevant studies that used other measures of body composition.
- The inclusion of only school-based surveys may exclude other relevant studies.

INTRODUCTION

Childhood obesity continues to be a serious public health problem across the globe. The prevalence is increasing to public health proportions among preschool children.[1] According to estimates by the International Obesity Task Force, 155 million school-going children worldwide are either overweight or obese.[2] Obesity/overweight is an emerging problem in Africa. In some cultures, women who are fat or 'rounded' are considered a sign of wealth, fertility and beauty while lean individuals are considered malnourished or a sign of ill health[3 4]

Overweight and obesity are terms used to describe an excess of adiposity (or fatness) above the ideal for good health. According to the WHO, overweight and obesity are the fifth leading cause of mortality globally and a major risk factor for non-communicable diseases including cardiovascular diseases, diabetes and some cancers.[5] Obese children are at increased risk of developing hypertension, high cholesterol, orthopaedic problems and type 2 diabetes.[6] There is also a considerable wealth of evidence that overweight and obesity in childhood present an increased risk of adult obesity[7 8] with associated health risks in adulthood. In addition to the health consequences of overweight and obesity in childhood, there is some evidence to suggest that weight status may affect school performance in children, which may negatively affect long-term career development.[9 10] There is, however, limited evidence in some other studies on the negative association between weight status and academic achievement.[11–13]

Prevention of childhood overweight and obesity therefore needs high priority. Schools are effective for implementing behaviour change in children[14 15] which will have a long-term impact. For effective intervention among learners, however, there is the need for evidence of overweight and obesity prevalence. Some systematic reviews on prevalence combined the findings of children and adolescents/youth.[16 17] No systematic review has been conducted that involved populations of primary school learners residing in all countries within Africa until now, to support the need for intervention programmes across the continent. Moreover, a more recent attempt among school-aged children in Africa was limited to sub-Saharan Africa.[16] The current review, to the best of our knowledge, is the first effort to systematically review the existing literature on overweight and obesity among primary school learners in Africa to identify gaps in the literature for further research.

This protocol is developed following the guidelines of PRIMSA-P 2015.[18]

Objectives

To conduct systematic review and meta-analysis to assess the magnitude and distribution of overweight and obesity among primary school learners aged 6–12 years of both sexes within countries in Africa, using any of the internationally accepted body mass index cut-offs: (Centers for Disease Control and Prevention,[19] International Obesity Task Force,[20] WHO).[21]

Review question

What is the prevalence of overweight and obesity among primary school learners within countries in Africa as reported in studies published between 1980 and 2016?

METHODS

The MOOSE Guidelines for Meta-Analyses and Systematic Reviews of Observational Studies[22] will guide the methods for this systematic review.

Inclusion criteria

Studies that will meet the following criteria will be included in the review:

1. Cross-sectional school-based surveys or the cross-sectional evaluation in longitudinal school-based surveys, involving primary school learners aged between 6–12 years of African populations residing in African countries and reporting a prevalence of overweight and obesity.
2. Any objective measure of body composition, that is, body weight, height, body mass index, sum of skinfolds and body fat
3. All published and unpublished studies between 1 January 1980 and 30 June 2016.
4. No language limitations will be set.

Exclusion criteria

1. Studies that are not school-based
2. Intervention studies
3. Studies conducted in African populations but residing outside Africa.
4. Studies carried out on learners who are suffering from critical illness or with chronic conditions.

Search strategy

Search strategy will involve a series of complementary search methods including a comprehensive search of key bibliographic databases and manual search of reference lists or citations follow-up of identified eligible articles and relevant reviews which will not be captured through the bibliographic databases search. Using relevant search terms that will be developed from Medical Subject Headings (MeSH), keywords generated from the subject headings and the names of the 54 African countries and the five African subregions (African search filter),[23] a systematic search of MEDLINE (PubMed), MEDLINE (EbscoHost) CINAHL (EbscoHost), Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index) will be carried out for published literature on overweight and obesity in learners in Africa. Examples of search terms to be used include the following: 'obese', 'obesity', 'overweight', 'over weight', 'over-weight', 'weight disorder', 'body composition', 'body mass index', 'body weight', 'BMI', 'body fat', 'adiposity', 'percent body fat', 'body fat distribution'. These various combinations will be used to suit each database. A search strategy for the PubMed-MEDLINE database is attached (see online supplementary appendix 1).

Grey literature (including reports and conference proceedings) will be searched through the Google scholar search engine and key relevant websites such as Opengrey, WHO and African Index Medicus. Key individuals in the field will be contacted for any unpublished work and research papers that are under preparation. References will be exported and duplicates will be removed using citation management software.

Selection of studies

The titles and abstracts of potentially relevant identified articles will be independently screened by two researchers for eligibility. Full-text copies of articles that will meet the eligibility criteria will be obtained. These full-text articles will then be assessed by two independent researchers for inclusion in the review. Any disagreement about the eligibility will be resolved through discussion with a third assessor. A short questionnaire was developed and will be used to guide the selection of relevant studies (see online supplementary appendix 2).

Quality assessment of included studies

The quality of full-text articles that will be included in the study will be assessed by a modified version of the Downs and Black assessment tool.[24] All questions on randomised controlled trials and intervention study designs will be eliminated. This checklist provides scores for the quality of reporting, internal validity (bias) and external validity (see online supplementary appendix 3).

Data extraction

This will be carried out independently by two researchers. The following relevant data will be extracted on all included studies using a standardised data form: study details (author, year of publication, year of beginning of study, country of study, type of publications), study characteristics (study design, mean/median age and range, sampling method (random vs non-random), sample size, criteria for classification of overweight and obesity, study setting (urban and rural), type of sample (national vs subnational and local), gender distribution, distribution by location, African region where the study country is located), prevalence of overweight and obesity (overall and by gender and location).

Data synthesis, assessing heterogeneity and publication bias

Data extracted will be summarised by country and regional prevalence (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa) and, where possible, by gender and location. Meta-analysis and meta-regression analysis will be conducted for identical variables across studies. Pooled estimates for the meta-analysis and their 95% CIs will be obtained using the random-effects model of DerSimonian-Laird.[25] Studies will be weighted by the inverse of their variances. To minimise the effect of studies with extreme prevalence rates on pooled estimates, variance stabilisation will be achieved through arc-sine transformation of the estimates before pooling.[26]

Heterogeneity of studies will be assessed with Cochran's Q statistic.[27] This index is, however, limited in that it gives only the statistical significance but not the true extent of heterogeneity. To determine the degree of heterogeneity between studies, the I^2 statistic[28] will be used. I^2 values of 25%, 50% and 75% would represent mean low, medium and high heterogeneity, respectively.

To assess the potential sources of heterogeneity, subgroup analyses using sex, age, sample size, setting (rural–urban; private–public school), year of beginning of study, criteria for classification of overweight and obesity, and geographical region (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa) will be performed. Heterogeneity will also be tested by conducting meta-regression analysis. Funnel plots and Egger's test of bias[29] will be used to assess publication bias. The inter-rater agreement for study inclusion will be assessed using Cohen's κ coefficient.[30]

Data analysis will be performed using the R statistical software (The R Foundation for statistical computing, Vienna, Austria).

Presenting and reporting the review results

A PRISMA flow chart of search and study selection with included and excluded studies will be presented. Reasons for exclusion of studies will be given. Extracted data will be presented in tables. Summary statistics of quantitative data will be complemented with narrative syntheses. Quantitative data will be presented in tables of individual studies, summary tables and forest plots where appropriate. Prevalence will be examined by country (all 54 countries), region (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa), sex and settings (urban–rural; private–public school). The quality assessment and risk of bias scores determined for each included study will be presented in tables.

CONCLUSION

It is expected that this systematic review will provide relevant evidence on the magnitude and distribution of overweight and obesity in schoolgoing children residing in Africa, thereby supporting the need for appropriate intervention strategies to control the increasing prevalence. It is also expected that more information on the criteria commonly used in African countries to classify overweight and obesity in children will be obtained. This review will hopefully identify some research gaps for further studies.

Ethics and dissemination

Ethics is not a requirement since no primary data will be collected. All data that will be presented in this review are based on published articles. The findings of this systematic review will be submitted for publication in a peer-reviewed journal. This will also form a chapter of a PhD thesis. In addition, this will be disseminated in conferences and policy documents to appropriate bodies for decision-making where needed. It is expected that this systematic review will provide relevant evidence on the magnitude and distribution of overweight and obesity in schoolchildren residing in Africa, thereby supporting the need for appropriate intervention strategies to control the increasing prevalence. This review will hopefully identify some research gaps for further studies.

Protocol registration

Details of the protocol for this systematic review were registered on PROSPERO and can be accessed at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016035248.

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Contributors APK and TA conceived the review approach. APK provided general guidance for the drafting of the protocol. TA drafted the manuscript. APK, TA, ADV and TP reviewed and revised the manuscripts. All authors have read and approved the final version of the manuscript.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. de Onis M, Blossner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr* 2010;92:1257–64.
2. Lobstein T, Baur L, Uauy R, IASO International Obesity Task Force. Obesity in children and young people: a crisis in public health. *Obes Rev* 2004;5(Suppl 1):4–85.
3. Mokhtar N, Elati J, Chabir R, *et al*. Diet culture and obesity in Northern Africa. *J Nutr* 2001;131:887S–2S.
4. Steyn K, Damasceno A. Lifestyle and related risk factors for chronic diseases. In: Jamison DT, Feachem RG, Makgoba MW, *et al*, eds. *Disease and mortality in Sub-Saharan Africa*. 2nd edn. Washington DC: World Bank.
5. World Health Organization. *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva, World Health Organization, 2009.
6. Reilly JJ, Methven E, McDowell ZC, *et al*. Health consequences of obesity. *Arch Dis Child* 2003;88:748–52.
7. Parsons TJ, Power C, Logan S, *et al*. Childhood predictors of adult obesity: a systematic review. *Int J Obes* 1999;23(Suppl. 12):S1–S10.
8. Singh AS, Mulder C, Twisk JWR, *et al*. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* 2008;9:474–88.
9. Carey FR, Singh GK, Brown HS, *et al*. Educational outcomes associated with childhood obesity in the United States: cross-sectional results from the 2011–2012 National Survey of Children's Health. *Int J Behav Nutr Phys Act* 2015;12(Suppl 1):S3.
10. Taras H, Potts-Datema W. Obesity and student performance at school. *J Sch Health* 2005;75:291–5.
11. Abdelalim A, Ajaj N, Al-Tmimy A, *et al*. Childhood obesity and academic achievement among male students in public primary schools in Kuwait. *Med Princ Pract* 2012;21:14–9.
12. Martin A, Saunders DH, Shenkin SD, *et al*. Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. *Cochrane Database Syst Rev* 2014;(3):CD009728.
13. Chen LJ, Fox KR, Ku PW, *et al*. A longitudinal study of childhood obesity, weight status change, and subsequent academic performance in Taiwanese children. *J Sch Health* 2012;82:424–31.
14. Waters E, de Silva-Sanigorski A, Hall BJ, *et al*. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2011;(12):CD001871.
15. Oude Luttikhuis H, Baur L, Jansen H, *et al*. Interventions for treating obesity in children. *Cochrane Database Syst Rev* 2009;(1):CD001872.
16. Muthuri SK, Wachira LJ, Leblanc AG, *et al*. Evidence of an overweight/obesity transition among school-aged children and youth in Sub-Saharan Africa: a systematic review. *Int J Environ Res Public Health* 2014;11:3327–59.
17. Ejike CE. Child and adolescent obesity in Nigeria: a narrative review of prevalence data from three decades (1983-2013). *J Obes Metab Res*. 2014;1:171–9.
18. Moher D, Shamseer L, Clarke M, *et al*., PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015;4:1.
19. Kuczmarski RJ, Ogden CL, Guo SS, *et al*. CDC Growth Charts for the United States: methods and development. *Vital Health Stat* 2002;246:1–190.
20. Cole TJ, Bellizzi MC, Flegal KM, *et al*. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;320:1240–3.
21. de Onis M, Onyango AW, Borghi E, *et al*. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007;85:660–7.
22. Stroup DF, Berlin JA, Morton SC, *et al*. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* 2000;283:2008–12.
23. Siegfried N, Clarke M, Volmink J. Randomized controlled trials in Africa of HIV and AIDS: descriptive study and spatial distribution. *BMJ* 2005;331:742–6.
24. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of healthcare interventions. *J Epidemiol Community Health* 1998;52:377–84.
25. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986;7:177–88.
26. Barendregt JJ, Doi SA, Lee YY, *et al*. Meta-analysis of prevalence. *J Epidemiol Community Health* 2013;67:974–8.
27. Cochran WG. The combination of estimates from different experiments. *Biometrics* 1954;10:101–29.
28. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21:1539–58.
29. Egger M, Davey Smith G, Schneider M, *et al*. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;315:629–34.
30. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.

BMJ Open

Protocol for systematic review of school-based interventions to prevent and control obesity in African learners

Theodosia Adom,[1,2] Thandi Puoane,[2] Anniza De Villiers,[3] André Pascal Kengne[3,4]

To cite: Adom T, Puoane T, De Villiers A, *et al*. Protocol for systematic review of school-based interventions to prevent and control obesity in African learners. *BMJ Open* 2017;7:e013540. doi:10.1136/bmjopen-2016-013540

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ABSTRACT

Introduction: The increasing prevalence of obesity and overweight in childhood in developing countries is a public health concern to many governments. Schools play a significant role in the obesity epidemic as well as provide favourable environments for change in behaviours in childhood which can be carried on into adulthood. There is dearth of information on intervention studies in poor-resource settings. This review will summarise the available evidence on school-based interventions that focused on promoting healthy eating and physical activity among learners aged 6–15 years in Africa and to identify factors that lead to successful interventions or potential barriers to success of these programmes within the African context.

Methods and analysis: This protocol is developed following the guidelines of PRIMSA-P 2015. Relevant search terms and keywords generated from the subject headings and the African search filter will be used to conduct a comprehensive search of MEDLINE (PubMed), MEDLINE (EbscoHost), CINAHL (EbscoHost), Register Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index) for published literature on school-based interventions to prevent and control obesity in learners in Africa. Grey literature will be also be obtained. The searches will cover 1 January 2000 to 30 June 2016. No language limitations will be applied. Full-text articles of eligible studies will be screened. Risk of bias and quality of reporting will be assessed. Data will be extracted, synthesised and presented by country and major regional groupings. Meta-analysis will be conducted for identical variables across studies, where data allow. This protocol is developed following the guidelines of PRISMA-P 2015.

Ethics and dissemination: No primary data will be collected hence ethics is not a requirement. The findings will be submitted for publication in peer-reviewed journals, in conferences and in policy documents for decision-making, where needed.

Strengths and limitations of this study

- The systematic approach will summarise the current available evidence on characteristics, outcomes and effectiveness of school-based interventions in Africa.
- The findings could identify potential factors that lead to successful interventions or barriers to the successful implementation of these programmes within the African context as well as serve as a policy guide to the design and implementation of effective strategies.
- Application of the GRADE approach in rating the quality of evidence will strengthen the review.
- Since only studies that used body mass index and/weight changes as body composition changes will be included, some potentially relevant studies that used other measures of body composition are likely to be excluded.

INTRODUCTION

The increasing prevalence of obesity and overweight in childhood in developing countries is a public health concern to many governments. Childhood obesity is not only a major risk factor for obesity in adulthood,[1 2] but also increases the risk of developing hypertension, high cholesterol, orthopaedic problems and type 2 diabetes even in young children.[3] Obese children suffer from negative psychological consequences including poor self-esteem, depression, anxiety and stigmatisation.[4]

The aetiology of obesity is multifactorial, involving individual and environmental factors. Among the individual determinants are energy expenditure and energy intake. Obesity occurs when energy intake exceeds energy expenditure over a prolonged period of time.[5] The environmental factors also present the opportunity to engage in healthy or unhealthy behaviours. Interventions to prevent and control obesity in childhood should therefore be multicomponent targeting modifiable individual factors as well as the settings in which the interventions are implemented. In general, most interventions have focused on health education and promotion to increase knowledge, attitudes and behaviours. These interventions target the individuals by focusing on nutrition or physical activity either separately or combined, with modest effects on behavioural change and body mass index (BMI).[6] In recent years, interventions have been directed at changing the environments related to nutrition and physical activity so as to improve healthy behaviours.[7]

Schools play a significant role in the obesity epidemic[8–10] as well as provide favourable environments for change in behaviours in childhood which can be carried on into adulthood.[11–13] This is because schools offer continuous and intensive contact with children coupled with the schools' organisational structures through which these interventions could be effectively delivered.[14 15] Although considerable scientific literature exists on the importance of school-based interventions to address childhood obesity in developed countries,[12 15] there is dearth of information in poor-resource countries mostly attributed to lack of funds to effectively conduct and evaluate such intervention studies. Should there be funding, competing interests in investing into other areas of health promotion instead of promoting physical activity and healthy eating might also play a role. Some studies highlight inconclusive and conflicting results while others report minimal positive weight-related outcomes and modest behaviour changes.[11 15 16] These inconsistencies may be mostly due to the variability of methods used.

The increasing prevalence of obesity in African learners calls for interventions. Evidence-based strategies are critical to the success of intervention programmes; therefore, the need to synthesise available evidence in the African context. This systematic review will summarise the evidence on school-based interventions targeted at improving diet and physical activity, to gain better understanding of what intervention programmes work in the prevention and control of childhood obesity among African learners and to identify gaps in the literature for further research.

OBJECTIVE

To conduct a systematic review of the published literature to identify and characterise school-based interventions that focused on promoting healthy eating and physical activity among learners aged 6–15 years in Africa to prevent childhood obesity, as well as to identify factors that lead to successful interventions or potential barriers to success of these programmes within the African context, as reported in studies published between January 2000 and June 2016.

REVIEW QUESTIONS

1. What are the characteristics of school-based interventions targeted at the prevention and control of childhood obesity among learners in Africa?
2. What school-based programmes are effective in promoting healthy eating and physical activity behaviours of learners?
3. What factors influence the success of these school-based programmes and what are the potential barriers to their successful implementation?

METHODS

This protocol is developed following the guidelines of PRISMA-P 2015.[17]

Inclusion criteria

To guide selection of studies, the Population, Intervention, Comparison and Outcome (PICO) protocol[18] will be used as outlined below:

1. *Population*: Studies involving learners aged 6–15 years of both sexes of African populations residing in African countries, or studies presenting data specifically for the subgroup of participants within 6–15 years age range.
2. *Intervention*: Primary research evaluating dietary/nutrition interventions alone, physical activity interventions alone, combined dietary and physical activity interventions, school environment.
3. *Outcome*: Studies reporting changes in nutrition and physical activity knowledge, attitude and self-efficacy, increased participation in physical activity, increased intake of fruits and vegetables, decreased consumption of high fat diets and sugar-sweetened beverages, changes in body weight or BMI-for-age and reporting a baseline and a postintervention measurements.
4. *Context*: The primary focus of interventions must be the school setting. However, school-based studies with community-based or family-based components in addition will be included.
5. *Study design*: Obesity prevention and treatment interventions that used a controlled study design with or without randomisation, pre-experimental, quasi-experiment, experimental pre-test/post-test design, cohort study design, of at least 12 weeks duration.
6. All published and unpublished studies between 1 January 2000 and 30 June 2016. The focus of research in African children had been and is still on malnutrition. Post-2000 studies are more likely presentative of the contemporary pictures as obesity and overweight are emerging public health problems in childhood which may occur alongside undernutrition, the issue of double burden of nutrition.
7. Interventions involving human participants.
8. No language limitations will be applied.

Exclusion criteria

1. Studies that are clinic-based or have no school-based components.
2. Interventions in African populations but residing outside Africa.
3. Interventions in learners with eating disorders, critical illness or chronic conditions.
4. Interventions in learners with physical and mental disabilities.

Adom T, et al. BMJ Open 2017;7:e013540. doi:10.1136/bmjopen-2016-013540

Search strategy

A systematic search of the following electronic databases of peer-reviewed journal articles and online search registers will be conducted using the African search filter:[19] MEDLINE (PubMed), MEDLINE (EbscoHost) CINAHL (EbscoHost), Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index). Search terms will include key words relating to population (learners, 'schoolchildren', 'school going children'); interventions: (diet-related, physical activity-related, school environment-related); geographical settings (African search filter) and outcomes (changes in nutritional and physical activity knowledge, attitude and self-efficacy, increased participation in physical activity, increased intake of fruits and vegetables, decreased consumption of high fat diets and sugar-sweetened beverages, changes in body weight or BMI-for-age). The search terms will be combined to suit each database. A search strategy for PubMed database is attached (see online supplementary appendix 1). Grey literature (including reports, conference and workshop proceedings) will be searched through Google scholar search engine and key relevant websites such as WHO African Index Medicus and African Journals Online (AJOL). Key individuals in the field will be contacted for any unpublished work and research papers that are under preparation. References will be exported and duplicates will be removed using any citation management software.

Selection of studies

The titles and abstracts of potentially relevant identified articles will be independently screened by two researchers for eligibility. Full-text copies of articles that will meet the eligibility criteria will be obtained. These full text articles will then be assessed by two independent researchers for inclusion in the review. Any disagreement about the eligibility will be resolved through discussion. A short questionnaire has been developed and used to guide the selection of relevant studies (see online supplementary appendix 2).

Quality assessment of included studies

The quality of all papers that will be included in the review will be assessed using the "Effective Public Health Practice Project quality assessment tool for quantitative studies".[20] Components assessed by the selected tool are selection bias, study design, confounders, blinding, data collection methods, withdrawals and attrition, intervention integrity and analyses (see online supplementary appendix 3). Quality assessment will be performed independently by two authors. Each paper will be carefully assessed and rated for selection bias, study design, confounders, blinding, data collection method and withdrawals and dropouts. A paper will be categorised as STRONG when there is no weak ratings for any of the listed components. A paper with one weak rating will be classified as MODERATE while with two or more weak ratings will be classified as WEAK. Discrepancies in rating between reviewers will be resolved by consensus.

Data extraction

This will be performed independently by two researchers. The following review characteristics and outcome data will be extracted from included studies using a standardised data form: study details (author, year of publication, country of study); study population (sample size, age range, sex distribution, number of children in intervention and control groups); intervention type, intervention characteristics (type, content, duration of study, follow-up time points, mode of delivery, intervention provider); study design; setting (urban–rural; private–public school); outcome data (changes in nutritional and physical activity knowledge, attitude and self-efficacy, increased intake of fruits and vegetables, lower consumption of high fat diets and sugar-sweetened beverages, increased participation in physical activity, changes in body weight or BMI-for-age); theoretical basis of intervention, potential confounders and key limitations of the study as specified by the authors. Additional information will be requested from authors where necessary.

Data synthesis, assessing heterogeneity and publication bias

Data extracted will be summarised by country and region (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa). Narrative synthesis will be used to summarise and explain the evidence for data that cannot be analysed using quantitative synthesis. This will be performed by grouping studies into thematic areas such as study designs, intervention characteristics and types and factors that influenced outcomes and programme implementation (facilitators and barriers). Summary statistics will be presented as frequencies, percentages, means, confident intervals and p values. Differences and similarities will be highlighted.

Estimates of effect sizes will be generated for each outcome across studies. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach[21] will be used to assess the overall quality and strength of evidence across studies. This will be performed by downgrading scores for a number of factors: study limitations, inconsistency of results, imprecision, reporting or publication bias and indirectness of evidence. Scores will be upgraded for studies with large effect sizes, dose–response gradient and confounders that are likely to minimise the effects. Final ratings for the quality of evidence of each outcome will be categorised as high, moderate, low or very low. The overall quality of the evidence will then be rated. Recommendations of the evidence on which school-based intervention programmes are effective in promoting healthy eating and physical activity behaviours of learners will be made considering the direction and strength of the evidence. The results will be summarised and presented in summary of findings tables.

Statistical heterogeneity across studies will be assessed with Cochran's Q statistic,[22] and the I^2 statistic[23] will be used to determine the degree of heterogeneity between studies. To assess the potential sources of heterogeneity, subgroup analyses will be performed using the following variables: sex, age group, study setting (rural, peri-urban, urban; private–public school), criteria for classification of overweight and obesity, intervention types, intervention characteristics, geographical region (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa), where data allow. Heterogeneity will also be tested by conducting meta-regression analysis. Funnel plots and Egger test of bias[24] will be used to assess publication bias. Meta-analysis will be conducted for identical variables across studies such as study designs, data collection tools and intervention types, where data allow. Pooled estimates for the meta-analysis and their 95% CIs will be obtained using the random-effects model of DerSimonian–Laird.[25] Studies will be weighted by the inverse of their variances. Where data allow, sensitivity analysis will be performed to assess robustness of the results by removing a study at a time and assessing the impact of I^2 on the summary estimate. The inter-rater agreement for study inclusion and data extraction will be assessed using the Cohen's κ coefficient.[26]

Data analysis will be performed using the R statistical software (The R Foundation for statistical computing, Vienna, Austria).

PRESENTING AND REPORTING THE REVIEW RESULTS

A PRISMA flow chart of search and study selection with included and excluded studies will be presented. Reasons for exclusion of studies will be given. Extracted data will be presented in tables. Summary statistics of quantitative data will be complemented with narrative syntheses. Quantitative data will be presented in tables of individual studies, summary tables and forest plots where appropriate. Outcome data will be examined by country (all 54 countries), region (Central Africa, Eastern Africa, Southern Africa, Northern Africa and Western Africa), sex, settings (urban, peri-urban, rural; private–public school), type and characteristics of intervention, study design and duration of study. The quality assessment and risk of bias scores determined for each included study will be presented in tables.

CONCLUSIONS

This systematic review will summarise the current available evidence on characteristics, outcomes and effectiveness of school-based interventions targeted at improving diet and physical activity with the overall aim of reducing obesity prevalence and improving health. This attempt could identify potential factors that lead to successful interventions or barriers to the successful implementation of these programmes within the African context. This will inform the development of evidence-based interventions in the prevention and control of childhood obesity among African learners in African countries and to identify research gaps in the literature for further studies. These findings may also serve as a policy document to governments in designing effective programmes to curb the increasing prevalence of obesity and its associated health consequences. Moreover, application of the GRADE approach in rating the quality of evidence will strengthen the review. A limitation of this review is the likely exclusion of some potentially relevant studies that used other measures of body composition since only studies that using BMI and/weight changes as body composition changes will be included.

DISSEMINATION

All data that will be presented in this review are based on published articles. The findings of this systematic review will be submitted for publication in peer-reviewed journals and a chapter of a thesis. In addition, this will be disseminated in conferences and policy document to appropriate bodies for decision-making where needed.

Protocol registration Details of the protocol for this systematic review were registered on PROSPERO and can be accessed at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016041614.

Contributors APK and TA conceived the review approach. APK provided general guidance to the drafting of the protocol. TA drafted the manuscript. APK, TA, ADV and TP reviewed and revised the manuscripts. All authors have read and approved the final version of the manuscript.

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REFERENCES

1. Singh AS, Mulder C, Twisk JWR, *et al*. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* 2008;9:474–88.
2. Parsons TJ, Power C, Logan S, *et al*. Childhood predictors of adult obesity: a systematic review. *Int J Obes* 1999;23(Suppl 12):S1–10.
3. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. *Int J Obes (Lond)* 2011;35:891–8.
4. French SA, Story M, Perry CL. Self-esteem and obesity in children and adolescents: a literature review. *Obes Res* 1995;3:479–90.
5. Hill JO. Understanding and addressing the epidemic of obesity: an energy balance perspective. *Endocr Rev* 2006;27:750–61.
6. Kamath CC, Vickers KS, Ehrlich A, *et al*. Clinical review: behavioural interventions to prevent childhood obesity: a systematic review and metaanalyses of randomized trials. *J Clin Endocrinol Metab* 2008;93:4606–15.
7. De Bourdeaudhuij I, Van Cauwenberghe E, Spittaels H, *et al*. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. *Obes Rev* 2011;12: 205–16.
8. Story M, Kaphingst KM, Robinson-O'Brien R, *et al*. Creating healthy food and eating environments: policy and environmental approaches. *Annu Rev Public Health* 2008;29:253–724.

9. Fox MK, Dodd AH, Wilson A, *et al.* Association between school food environment and practices and body mass index of US public school children. *J Am Diet Assoc* 2009;109(2 Suppl):S108–17.
10. Leatherdale S. A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 to 4 students. *BMC Public Health* 2013;13:982.
11. Waters E, de Silva-Sanigorski A, Burford BJ, *et al.* Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2011;(12):CD001871.
12. Oude Luttikhuis H, Baur L, Jansen H, *et al.* Interventions for treating obesity in children. *Cochrane Database Syst Rev* 2009;(1):CD001872.
13. Katz DL, O'Connell M, Njike VY, *et al.* Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. *Int J Obes (Lond)* 2008;32:1780–9.
14. Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by The National Institute for Health and Clinical Excellence. *Obes Rev* 2009;10:110–41.
15. Sharma M, Ickes J. Psychological determinants of childhood and adolescent obesity. *J Soc Behav Health Sci* 2008;2:33–49.
16. Dobbins M, Husson H, DeCorby K, *et al.* School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev* 2013;(2):CD007651.
17. Moher D, Shamseer L, Clarke M, *et al.*, PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015;4:1.
18. Sackett DL, Richardson WS, Rosenberg W, *et al.* *Evidence-based medicine: how to practice and teach EBM.* New York: Churchill Livingston, 1997.
19. Siegfried N, Clarke M, Volmink J. Randomized controlled trials in Africa of HIV and AIDS: descriptive study and spatial distribution. *BMJ* 2005;331:742–6.
20. Effective Public Health Practice Project. *Quality assessment tool for quantitative studies.* Hamilton (ON): Effective Public Health Practice Project, 1998. http://www.ephpp.ca/index.html. http://www.ephpp.ca/PDF/Quality%20Assessment%20Tool_2010_2.pdf (accessed 13 Feb 2016).
21. Balshem H, Helfand M, Schünemann HJ, *et al.* GRADE guidelines: 3. Rating the quality of evidence. *J Clin Epidemiol* 2011;64:401–6.
22. Cochran WG. The combination of estimates from different experiments. *Biometrics* 1954;10:101–29.
23. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21:1539–58.
24. Egger M, Davey Smith G, Schneider M, *et al.* Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;315:629–34.
25. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986;7:177–88.
26. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.

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Protocol for systematic review of school-based interventions to prevent and control obesity in African learners

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Protocol for a scoping review of existing policies on the prevention and control of obesity across countries in Africa

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ABSTRACT

Introduction: The obesity epidemic is a public health challenge for all, including low-income countries. The behavioural patterns known to contribute to the rise in obesity prevalence occur in an environmental context which is not conducive for healthy choices. A policy approach to obesity prevention constitutes a form of public intervention in that it extends beyond individuals to influence entire populations and is a mechanism for creating healthier environments. Little is known about obesity prevention policies in Africa. This scoping review seeks to examine the nature, extent and range of policies covering obesity prevention in Africa in order to assess how they align with international efforts in creating less obesogenic environments. This will help identify gaps in the approaches that are adopted in Africa.

Methods and analysis: Using the Arksey and O'Malley's scoping methodological framework as a guide, a comprehensive search of MEDLINE (PubMed), MEDLINE (EbscoHost) CINAHL (EbscoHost), Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index) databases will be carried out for peer reviewed journal articles related to obesity prevention policies using the African search filter. A grey literature search for policy documents and reports will also be conducted. There will be no language and date restrictions. Eligible policy documents and reports will be obtained and screened using the inclusion criteria. Data will be extracted and results analysed using descriptive numerical summary analysis and qualitative thematic analysis.

Ethics and dissemination: No primary data will be collected since all data that will be presented in this review are based on published articles and publicly available documents, and therefore ethics committee approval is not a requirement. The findings of this systematic review will be presented at workshops and conferences; and will be submitted for publication in peer-reviewed journal. This will also form a chapter of a PhD thesis.

INTRODUCTION

Obesity/overweight is a major modifiable risk factor for non-communicable diseases (NCDs) including coronary heart disease, type II diabetes and many cancers.[1] According to the World Health Organization (WHO) nearly 80% of NCD deaths occur in low-income and middle-income countries except Africa. Current projections however indicate that by 2020 the largest increases in NCD-related deaths will occur in Africa and by 2030, these deaths are projected to exceed the combined deaths from communicable and nutritional diseases, and maternal and perinatal deaths.[2]

Although there are many causes, the behavioural patterns known to contribute significantly to the rise in obesity prevalence include increased consumption of energy-dense foods, low consumption of fruits and vegetables, increased sedentary lifestyle and low level of physical activity.[3] These behaviours occur in an environmental context which does not support healthy choices also known as 'obesogenic' environment, such as promotion of high density of fast food outlets and restaurants, promoting cheap but energy dense foods and poor urban planning which does not support active transport.[4]

There is the need to create healthy environments as a way to manage the epidemic; policies and regulations are needed to drive the environment and social changes that would have a sustainable impact on controlling obesity. A policy approach to obesity

Strengths and limitations of this study

- This review approach will provide a broad overview of obesity prevention policies and describe key concepts and issues across Africa.
- The review will provide information on the role of these policies in creating less obesogenic environments to further inform future policy directions.
- Some of these policies may not be available as published documents but all efforts will be made to obtain them through key regional and national representatives.

prevention constitutes a form of public intervention in that it extends beyond individuals' effects to influence entire populations and is a mechanism for creating healthier environments.[5]

In response to the global burden of NCDs, the WHO in 2004 adopted the Global Strategy on Diet, Physical Activity and Health (DPAS)[1] with an overall goal to 'promote and protect health by guiding the development of an enabling environment for sustainable actions at individual, community, national and global levels, that when taken together, will lead to reduced disease and death rates related to unhealthy diet and physical inactivity'. The DPAS calls on Member States to develop and implement national policies and programmes depending on their national circumstances to improve diets and promote physical activity, two major risk factors of obesity. The DPAS, together with Global Strategy for the Prevention and Control of Non-communicable Diseases[6] and 2008–2013 Action Plan for the Global Strategy for the Prevention and Control of Non-communicable Diseases[7] are some of the international efforts to control and prevent NCDs.

The role of national governments is seen in providing leadership as a sign of commitment; developing, implementing and monitoring a set of policy instruments that make environments less obesogenic and more health promoting; and securing increased and continuing funding to create healthy environments and encourage physical activity and healthy eating.[8]

There is considerable evidence in support of policy in obesity intervention and this is based largely on studies from high-income countries such as the US, Australia and Europe.[9–11] Some of these policy instruments are laws, regulations, taxes, subsidies and social marketing campaigns that are population-based affecting both children and adults and may target different settings such as schools, health institutions and workplaces. Low-income and middle-income countries may have distinct cultures and infrastructure that limit generalisation of strategies from high-income countries. Moreover, low-income countries may lack the financial resources to implement policies that have shown considerable results in high-income countries. There is also limited information on obesity prevention policies in Africa.

OBJECTIVE

This scoping review seeks to examine the nature, extent and range of policies covering obesity prevention in Africa in order to assess how they align with international efforts in creating less obesogenic environments. This will help identify gaps in the approaches that are adopted in Africa.

METHODS

The methods for this review will follow a scoping review methodological framework.[12] This describes a 6-stage approach to the review process, the sixth stage being optional. Unlike systematic reviews which answer specific research questions by collating all empirical evidence with predefined eligibility criteria, scoping reviews tend to cover broader topics in the research area of interest to map relevant literature, key concepts and identify research gaps.[12 13] Scoping reviews have unclear boundaries at the outset; prespecified eligibility criteria are therefore provisional and may be refined and applied iteratively during the review with emerging knowledge of the existing literature.

Stage 1: Identifying the research questions

Based on the literature and the WHO documents,[1 6] key research questions were derived (box 1). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-Equity 2012 Extension[14] will be used to identify equity-focused questions and operational definitions to be addressed in this review.

Inclusion criteria

1. National policy documents, reports and the literature produced or published that aim at reducing the risk factors of NCDs such as unhealthy diets, physical inactivity, overweight and obesity or that form part of larger chronic diseases prevention strategies, or to prevent and control obesity.
2. No language and date restrictions are set.

Exclusion criteria

Policies that are being implemented in other countries outside Africa

Box 1 Research questions and operational definitions

Research question

1. Which obesity prevention policies are being addressed in the documents?
- Individual-targeted (consumer information and labelling)
- Physical environments
- Economic environments
- Political environments
- Sociocultural environments
- Promotions or educational campaigns

2. Who are the target populations being addressed?
- Individuals (children, adolescents, adults)
- Family
- Subpopulations (age groups)
- Settings (home, schools, health institutions, workplaces)
- Society (industry, general public)

3. How is equity addressed in the obesity prevention literature?
- Equity is explicitly stated in the objective or in the analysis
- Population characteristics such as gender and socioeconomic status

4. What are the barriers and/or facilitators to the implementation of these policies?
Barriers and facilitators as identified by authors

5. Is there evidence of effectiveness of interventions?
Effectiveness as identified by authors

Stage 2: Identifying relevant studies

Two researchers will independently conduct a comprehensive and broad search of the following electronic databases of peer reviewed journal articles and online search registers related to obesity prevention policies using the African search filter:[15] MEDLINE (PubMed), MEDLINE (EbscoHost) CINAHL (EbscoHost), Academic Search Complete (EbscoHost) and ISI Web of Science (Science Citation Index). Search terms will include keywords developed from Medical Subject Headings (MeSH) and 'nutrition', 'food', 'physical activity' in combination with 'policy', guideline', 'action plan', 'strategy,' 'regulation', 'law', relating to 'overweight', 'obesity', 'noncommunicable diseases'. Manual-searching of reference lists of relevant documents, and systematic reviews and meta-analyses will be carried out to identify additional studies that will not be captured by the electronic database search. A grey literature search for unpublished policy documents and reports will be undertaken from Google Scholar, relevant websites such as WHO, UNICEF, Ministries of Health and Departments of Health in different countries, OPENGREY, African Index Medicus (AIM), AFROLIB (WHO Regional Office Database for Africa), workshops and conference proceedings. Key persons at the health and education ministries of the countries will be contacted (at the WHO NCD offices) about existing policy documents and reports and copies obtained where these are available. A search strategy for PubMed database is attached (see online supplementary appendix 1). References will be exported and duplicates removed using citation management software.

Stage 3: Study selection

Two-step approach will be used to select the relevant literature. Two independent researchers will screen the titles, abstracts and executive summaries. Potentially relevant literature will be obtained and inclusion and exclusion criteria applied to check the eligibility. Documents that meet the criteria will be assessed for inclusion in the review. Any disagreement about the eligibility will be resolved by a third reviewer. Regular discussions will be held by team members to assess the progress of the process.[15]

Stage 4: Charting the data

Standardised data charting forms will be developed and used to extract data from included documents. Data will be charted and sorted according to these key issues and themes. Two researchers will independently extract the data and it will be compared. The data extracted will include: geographical location, country, author, year of publication, development of document (multisectoral and/private sector approach), type of document (national health policy, action plan, strategic plan and policy document), target populations (individuals, family and subpopulations), target settings (schools, healthcare institutions and industry), barriers/facilitators to implementation of policies and evidence of intervention effectiveness, if available. The listed data may be modified as reviewers become more familiar with the literature.

Stage 5: Collating, summarising and reporting the results

To guide the assessment of the role of these policies in creating less obesogenic environments, the Analysis Grid for Environments Linked to Obesity (ANGELO) Framework[16 17] will be used to categorise policies into one of four environments: physical (what is available), economic (what are the costs), political (what are the rules) and sociocultural (what are the attitudes and beliefs); and two settings (macrosetting and microsetting). The ANGELO Framework is a common framework for understanding the obesogenicity of the environment. Data will be analysed and presented using descriptive numerical summary analysis and qualitative thematic analysis.

CONCLUSION

This scoping review will provide a broad overview of obesity prevention policies and describe key concepts and issues across Africa to further inform future policy direction. The results will help identify gaps in the approaches that are adopted in Africa, provide better understanding of the progress made and provide needed support for implementation, and the effectiveness of these policy interventions by governments across the continent.

Contributors APK and TA conceived the review approach. APK provided general guidance to the drafting of the protocol. TA drafted the manuscript. APK, TA, ADV and TP reviewed and revised the manuscripts. All authors have read and approved the final version of the manuscript.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. World Health Organization. Global strategy on diet, physical activity and health. Fifty-seventh World Health Assembly, Geneva, 17–22 May 2004. Resolutions and decisions, annexes. Geneva, World Health Organization, 2004.
2. World Health Organization. The global burden of disease: 2004 update. Geneva, World Health Organization, 2008.
3. Allender S, Cavill N, Parker M, *et al*. 'Tell us something new!'—the response of planning and transport professionals to public health guidance on the built environment and physical activity. *J Public Health Policy* 2009;30:102–16.
4. Swinburn B, Egger G. Preventive strategies against weight gain and obesity. *Obes Rev* 2002;3:289–301.
5. Brownson RC, Haire-Joshu D, Luke DA. Shaping the context of health: a review of environmental and policy approaches in the prevention of chronic diseases. *Annu Rev Public Health* 2006;27:341–70.
6. World Health Organization. *2008–2013 Action plan for the global strategy for the prevention and control of noncommunicable*

diseases. Geneva: World Health Organization, 2008. http://www.who.int/nmh/publications/9789241597418/en/ (accessed 7 Jul 2016).
7. World Health Organisation. Political Declaration of the High-level Meeting of the General Assembly on the Prevention and Control of Noncommunicable Diseases. 66th Session of the General Assembly, agenda item 117. A/66/L. 1 2011. http://www.who.int/nmh/events/un_ncd_summit2011/political_declaration_en.pdf
8. Lawrence M, Swinburn B. The role of policy in preventing childhood obesity. In: *Preventing childhood obesity: evidence policy and practice*. Waters E, Swinburn BA, Seidell JC, Uauy R. Blackwell Publishing, 2010:203–11.
9. Chriqui JF. Obesity prevention policies in U.S. States and localities: lessons from the field. *Curr Obes Rep* 2013;2:200–10.
10. Novak NL, Brownell KD. Role of policy and government in the obesity epidemic. *Circulation* 2012;126:2345–52.
11. Boehmer TK, Brownson RC, Haire-Joshu D, *et al*. Patterns of childhood obesity prevention legislation in the United States. *Prev Chronic Dis* 2007;4:A56.
12. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res* 2005;8:19–32.
13. Daudt HM, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Med Res Methodol* 2013;13:48.
14. Welch V, Petticrew M, Tugwell P, *et al*. The PRISMA-Equity Bellagio group. PRISMA-Equity 2012 extension: reporting guidelines for systematic reviews with a focus on health equity. *PLoS Med* 2012;9(10):e1001333. http://dx.doi.org/10.1371/journal.pmed.1001333
15. Siegfried N, Clarke M, Volmink J. Randomized controlled trials in Africa of HIV and AIDS: descriptive study and spatial distribution. *BMJ* 2005;331:742–6.
16. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999;29:563–70.
17. Mooney JD, Jepson R, Frank J, *et al*. Obesity prevention in Scotland: a policy analysis using the ANGELO framework. *Obes Facts* 2015;8:273–81.

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Protocol for a scoping review of existing policies on the prevention and control of obesity across countries in Africa

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REVIEW

Prevalence of overweight and obesity among African primary school learners: a systematic review and meta-analysis

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Summary

Introduction

The increasing trend in the global prevalence of childhood overweight and obesity presents a major public health challenge. This study reports the results of a systematic review and meta-analysis to estimate the prevalence of overweight and obesity among primary school learners residing in Africa according to the different body mass index criteria and population level characteristics.

Methods

A search of multiple databases was conducted to identify relevant research articles published between January 1980 and February 2017. Random effects models were used to pool prevalence data within and across population level characteristics after variance stabilization through arcsine transformation (PROSPERO registration number CRD42016035248).

Results

Data from 45 studies across 15 African countries, and comprising 92,379 and 89,468 participants for overweight and obesity estimates were included. Estimated overweight and obesity prevalence differed significantly across criteria: 10.5% [95% confidence interval, CI: 7.1–14.3] and 6.1% [3.4–9.7] by World Health Organization; 9.5% [6.5–13.0] and 4.0% [2.5–5.9] by International Obesity Task Force; and 11.5% [9.6–13.4] and 6.9% [5.0–9.0] by Centre for Diseases Control, respectively (p = 0.0027 for overweight; p < 0.0001 for obesity). Estimates were mostly higher in urban, and private schools, but generally similar by gender, major geographic regions, publication year and sample size. Substantial heterogeneity in the estimates across and within criteria were not always explained by major study characteristics.

Conclusion

Overweight and obesity are prevalent among African primary school learners, particularly those attending urban, and private schools. The results from this meta-analysis could be helpful in making informed decisions on childhood obesity prevention efforts in African countries.

Keywords: Africa, Meta-analysis, Overweight, learners.

Introduction

Globally, the prevalence of childhood overweight/obesity is increasing (1–3), with public health implications in both developed and developing countries. According to the UNICEF, an estimated 41 million children under five were overweight or obese in 2016 with about 25% of this number living in Africa alone, while among children and adolescents aged 5–19 years, 340 million were overweight or obese (4). The prevalence may have stabilized in some industrialized countries; however, the trend seems to be on the increase particularly in some low-to-middle income countries (5).

Energy imbalance resulting from increased caloric intake and physical inactivity are the main drivers of obesity; however, biological, social and environmental factors also play crucial roles (6). Some documented risk factors for childhood obesity include family socioeconomic status (SES) (7,8), maternal employment (9), parental obesity (10), school food and physical activity environments (11,12) and community and neighbouring factors such as density of fast food restaurants, and living in close proximity to parks and playgrounds (13,14).

Childhood obesity is associated with early onset of cardiovascular risk factors, including elevated blood pressure, and impaired fasting glucose as well as higher odds of remaining overweight or obese in the adulthood (15–18). The growing obesity epidemic with its related health risks has the potential to significantly undermine improvements made in the healthcare delivery systems among populations living in low-to-middle income countries.

There is a growing interest in the epidemic of obesity across Africa, resulting in several in-country studies to determine the prevalence (19). In a systematic review to investigate the trends of overweight and obesity among school-aged children and youth in sub-Saharan Africa, the body mass index (BMI) cut-off points used in each study were not taken into consideration in estimating the prevalence rates (19). Using different BMI cut-off references to estimate overweight and obesity prevalence in children poses a challenge in defining the extent of the problem at the population level. Although substantial heterogeneity was observed in the study methodology, this was not accounted for in the prevalence estimates.

To date, no comprehensive study has been conducted to examine the extent of the overweight and obesity problem among primary school learners overall and by region across Africa. It is important to assess and monitor the prevalence from a young age to provide relevant data that could inform decisions on appropriate interventions. Therefore, the objective of this review was to conduct a systematic review and meta-analysis to estimate the prevalence of overweight and obesity among primary school learners residing in Africa according to different diagnostic criteria, the World Health Organization (WHO) (20), the Centers for Disease Control and Prevention (CDC) (21) and the International Obesity Task Force (IOTF) (22) criteria; and population level characteristics.

Methods

The methods for this systematic review and meta-analysis have been previously described in details (23) and registered with PROSPERO, number CRD42016035248. The review is reported following the PRISMA guidelines (checklist available in Table S1). Included studies had to be school-based surveys involving children aged between 6 and 12 years. Where the age covers a wider range but prevalence was reported by age categories to include the specified age range, the studies were retained. Studies had to be cross-sectional or cross-sectional evaluations in longitudinal surveys. Studies that used objective measures of body weight and height and were published between 1 January 1980 and February 2017 were included. No language restrictions were applied; however, included studies were published in either English or French. For articles reporting more than one study or defining overweight and obesity using different BMI criteria, each was considered as a separate study. Studies were excluded if they were conducted on school learners suffering from critical illness or known chronic health conditions such as diabetes, were conducted in African populations residing outside the continent and were not school-based.

Identification and selection of relevant studies

A comprehensive search of the following electronic databases was conducted to identify eligible studies: MEDLINE (PubMed), MEDLINE (EBSCOHost), CINAHL (EBSCOHost), Academic Search Complete (EBSCOHost) and African Journals Online (AJOL). The complete search strategy comprised combinations of relevant Medical Subject Headings and keywords relating to obesity, overweight, BMI, school children, learners and the names of the 54 African countries and the five African subregions (Table S2). The searches were independently conducted by one reviewer and a research assistant. References were exported, and duplicates were removed and reviewed using EndNote software. The titles, abstracts and full text copies of potentially relevant articles were independently screened by the same reviewer and research assistant for eligibility. Any disagreement about the eligibility was resolved through a consensus and discussion with a third reviewer. The last search date was 20 February 2017.

Data extraction and quality assessment of included studies

The methodological quality of included studies was assessed using a modified version of Downs and Black checklist (24). Ten questions from the checklist were used to provide scores for the quality of reporting, internal validity (bias) and external validity. The following data were extracted: study details (author, year of publication, year of beginning of study and country of study), study characteristics (study design, mean/median age and range, sample size and diagnostic criteria), study setting/location (urban and rural and private and public school), type of sample (national and sub-national and local), gender distribution, African region where the study country was located and prevalence of overweight and obesity (overall and by subgroups).

Data synthesis and analysis

Data analyses used the 'meta' package of the statistical software R (version 3.3.3 [2017-03-06], The R Foundation for Statistical Computing, Vienna, Austria). To minimize the influence of studies with extremely small or extremely large prevalence estimates on the overall estimate, the variance of the study-specific prevalence was first stabilized using the Freeman–Tukey double arcsine transformation (25) before pooling using the random effects meta-analysis model (26). Heterogeneity between studies was assessed using the Cochran's Q and I^2 statistics (27). The I^2 statistic estimates the percentage of total variation across studies due to true between-study differences rather than chance. In general, I^2 values greater than 60–70% indicate the presence of substantial heterogeneity. The sources of heterogeneity were explored by comparing overweight/obesity prevalence between subgroups defined by several pre-specified study-level characteristics like gender for naturally occurring categories, and median values across studies for publication year and sample size. Subgroups comparisons were performed using the Q test based on ANOVA. The presence of publication bias was assessed using funnel plots and the Egger test of bias (28). Potential outliers were investigated in sensitivity analyses by dropping one study at a time. The Duval and Tweedie trim-and-fill method was used to adjust estimates for the effects of publication bias.

Role of the funding source

There was no funding source for this study. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

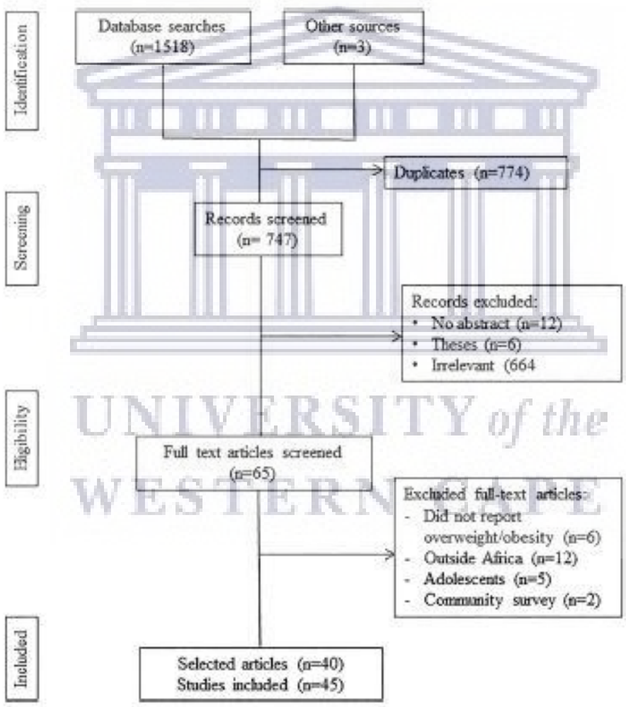

Figure 1 PRISMA flowchart for the study selection process.

Results

Figure 1 shows the PRISMA flow chart of the study selection process. A total of 1,518 records were identified from searches. After removing duplicates, the titles and abstracts of 729 articles were screened for eligibility out of which 65 full text articles were accessed. A total of 40 articles composing of 45 studies met the inclusion criteria and were retained in the meta-analysis.

Characteristics of included studies

Table 1 summarizes the characteristics of studies included in the meta-analysis. The 45 included studies originated from 15 countries. With regard to regional representation, 22 studies were conducted in Southern Africa, six in Western, eight in Eastern, nine in Northern and one in Central Africa. Thirty-seven studies presented data in both boys and girls, three studies reported on exclusively boys and five reported on exclusively girls. Of the studies that reported study settings, 18 were conducted exclusively in urban areas, six in rural areas and 11 in urban/rural areas. Out of the 26 studies that reported on school type, 16 were conducted in private/public schools, nine in public schools and one in exclusively private school. Year of beginning of study that reported in 26 studies ranged from 1994 to 2013. Majority of the included studies were conducted at the subnational level while only two were national in coverage. The mean/median age was 10.1 years, reported in 25 studies. All of the studies except two used the international BMI criteria to define overweight/obesity as WHO (22 studies, $n = 36{,}981$), IOTF (18 studies, $n = 51{,}604$) and the CDC (four studies, $n = 2{,}433$). The publication years varied from 2003 to 2016; 26 studies were published after year 2012.

Quality scores of included studies

Majority of the included studies scored 7 or higher with a median of 7.4 (Table 1). Scores for reporting were moderate to adequate, and these ranged from 51.2% to 97.6%. However, the scores for external validity were low. Less than half of the studies (46.3%) reported that participants were representatives of the population from which they were recruited, and even fewer (14.6%) reported their recruited samples were representative of the population (Table S3).

Overall prevalence of overweight and obesity

The overall overweight prevalence estimates for WHO (21 studies, $n = 36{,}981$), IOTF (18 studies, $n = 51{,}604$) and CDC (four studies, $n = 2{,}433$) and unspecified criteria were 10.5% [95% confidence interval, CI: 7.1–14.3], 9.5% [6.5–13.0], 11.5% [9.6–13.4] and 0.5% [0.0–4.5], respectively, and differed significantly across the various criteria ($p = 0.0027$; Figure 2). Similarly, obesity prevalence for WHO (18 studies, $n = 34{,}895$), IOTF (16 studies, $n = 50{,}779$), CDC (four studies, $n = 2{,}433$) and unspecified criteria were 6.1% [3.4–9.7], 4.0% [2.5; 5.9], 6.9% [5.0–9.0] and 0.5% [0.0–1.7] with significance difference among the criteria ($p < 0.0001$; Figure 3, Tables S4 and S5).

Heterogeneity

There was substantial heterogeneity in estimates across included studies by diagnostic criteria for obesity prevalence (all heterogeneity $p \leq 0.019$) and for overweight prevalence (all $p < 0.0001$) except across studies that used the CDC criteria to diagnose overweight (heterogeneity $p = 0.124$; see Tables S4 and Table S5 for more heterogeneity statistics). In sensitivity analyses using the leave-one-out approach, none of the studies had significant impact of the pooled prevalence estimates and measures of heterogeneity within diagnostic criteria (Figures S1 and S2).

Publication bias

Figure 4 shows the funnel plots for publication bias across the different definition criteria. These plots were asymmetric for WHO (Egger test $p = 0.0029$ for overweight and $p = 0.0019$ for obesity) and IOTF ($p = 0.020$ for overweight and $p = 0.003$ for obesity) but not for CDC criteria (both $p \geq 0.320$; Tables S4 and S5). The small number of studies available precluded similar analyses across studies that applied unspecified criteria to diagnose overweight or obesity.

For the CDC criteria as expected, no study was imputed through the trim-and-fill approach, and pooled estimates remained unchanged for both overweight and obesity. For the WHO criteria, nine studies were imputed for obesity and 10 for overweight, while equivalents for IOTF were eight and nine studies. Funnel plots became symmetrical and Egger test non-significant when imputed studies were accounted for (Figure S3). However, for both criteria and outcomes, imputed studies had to be of large sample size, with a null prevalence of overweight or obesity (Figures S4 and S5). This is unrealistic in the context of the current epidemiology of overweight and obesity in children and adolescents. Therefore, the publication bias found in the main analysis was likely artefactual.

Table 1 Summary characteristics of included studies

Reference	Publication year	Start year	Country	Region location	Data type	Study site	School type	Study design	Diagnostic criteria	Sample size: Overall	Sample size: Boys/girls	Sample size: Urban/rural	Sample size: Private/public	Quality score
Abrahams et al. (29)	2011	–	South Africa	Southern	Sub-national	Urban–rural	–	–	WHO	643	NS	–	NS	7
Amidu et al. (30)	2013	2012	Ghana	Western	Sub-national	Urban	Private–public	Cross-sectional	CDC	400	200 B 200 G	400 U	200 PR 200 PU	8
Armstrong et al. (31)	2006	2001	South Africa	Southern	National	Urban–rural	Private–public	Cross-sectional	IOTF	10195	5611 B 4584 G	–	NS	10
Boukthir et al. (32)	2011	2007	Tunisia	Northern	Sub-national	Urban	Public	Cross-sectional	IOTF	1335	637 B 698 G	1335 U	1335 PU	8
Caleyachetty et al. (33)	2012	2006	Mauritius	Southern	Sub-national	Urban–rural	–	Cross-sectional	IOTF	841	412 B 429 G	298 U 543 R	NS	9
Chebet et al. (34)	2014	–	Uganda	Eastern	Sub-national	–	Private–public	Cross-sectional	WHO	958	435 B 523 G	NS	456 PR 502 PU	5
Daboné et al. (35)	2011	2008	Burkina Faso	Western	Sub-national	Urban–rural	Private–public	Cross-sectional	WHO	649	309 B 340 G	543 U 106 R	192 PR 457 PU	8
Dekkaki et al. (36)	2011	2010	Morocco	Northern	Sub-national	Urban	Public	Cross-sectional	WHO	1570	768 B 802 G	1570 U	1570 PU	8
El-Sabely et al. (37)	2013	–	Egypt	Northern	Sub-national	–	Private–public	Cross-sectional	WHO	288	288 G	–	182 PR 106 PU	7
Fetuga et al. (38)	2011	–	Nigeria	Western	Sub-national	Urban	Public	Cross-sectional	WHO	1016	479 B 537 G	1016 U	574 PU	8
Hassan et al. (39)	2008	2002	Egypt	Northern	Sub-national	NS	Public	Cross-sectional	CDC	1283	681 B 602 G	–	1283 PU	6
Jinabhai et al. (40)	2005	1995	South Africa	Southern	Sub-national	Rural	NS	Cross-sectional	IOTF	643	292 B 351 G	643 R	–	9
Jinabhai et al. (41)	2003	1994	South Africa	Southern	National	Urban–rural	–	Secondary analysis	IOTF/ WHO	24391	14503 B 9888 G	–	–	9
Kirsten et al. (42)	2013	–	South Africa	Southern	Sub-national	Urban	–	Cross-sectional	IOTF	638	NS	638 U	NS	8
Kyallo et al. (43)	2013	2008	Kenya	Eastern	Sub-national	Urban	Private–public	Cross-sectional	WHO	321	153 B 168 G	321 U	138 PR 183 PU	7
Maruf et al. (44)	2013	2009	Nigeria	Western	–	–	Private–public	–	IOTF	1775	873 B 902 G	NS	NS	9
McKersie et al. (45)	2014	–	South Africa	Southern	Sub-national	Urban	–	Cross-sectional	IOTF	713	372 B 341 G	713 U	NS	7
Mogre et al. (46)	2013	2010	Ghana	Western	Sub-national	Urban	–	Cross-sectional	WHO	218	91 B 127 G	218 U	NS	7

Continues

Table 1. *Continued*

Reference	Publication year	Start year	Country	Region location	Data type	Study site	School type	Study design	Diagnostic criteria	Sample size: Overall	Sample size: Boys/girls	Sample size: Urban/rural	Sample size: Private/public	Quality score
Mohammed et al. (47)	2012	–	Ghana	Western	Sub-National	Urban	Private	Cross-sectional	WHO	270	141 B 129 G	270 U	270 PR	6
Moselakgomo et al. (48)	2015	–	South Africa	Southern	Sub-national	–	–	Cross-sectional	NS	1361	678 B 683 G	NS	NS	8
Mosha et al. (49)	2010	2008	Tanzania	Eastern	Sub-national	–	Private–public	Cross-sectional	WHO	428	150 B 278 G	NS	NS	6
Mpembeni et al. (50)	2014	–	Tanzania	Eastern	Sub-national	Urban–rural	Private–public	Cross-sectional	CDC	446	209 B 237 G	NS	NS	9
Muhihi et al. (51)	2013	2011	Tanzania	Eastern	Sub-national	Urban–rural	Private–public	Cross-sectional	IOTF	446	209 B 237 G	249 U 197 R	NS	9
Muthuri et al. (52)	2014	–	Kenya	Eastern	Sub-national	Urban	Private–public	–	WHO	563	262 B 301 G	563 U	268 PR 295 PU	9
Mwaikambo et al. (53)	2015	–	Tanzania	Eastern	Sub-national	–	Private–public	Cross-sectional	IOTF	1722	779 B 943 G	NS	692 PR 1030 PU	7
Navti et al. (54)	2014	–	Cameroon	Central	Sub-national	Urban–rural	Private–public	Cross-sectional	WHO	557	287 B 270 G	384 U 173 R	NS	7
Oldewage-Theron et al. (55)	2010	–	South Africa	Southern	Sub-national	Rural	Public	–	WHO	142	72 B 70 G	142 R	NS	6
Pangani et al. (56)	2016	–	Tanzania	Eastern	Sub-national	Urban	Private–public	Cross-sectional	WHO	1781	753 B 1028 G	1781 U	678 PR 1103 PU	8
Pedro et al. (57)	2014	2009	South Africa	Southern	Sub-national	Rural	–	Cross-sectional	WHO	588	292 B 296 F	588 R	NS	8
Pienaar, 2015 (58)	2015	2013	South Africa	Southern	Sub-national	–	–	Longitudinal	IOTF	574	282 B 292 G	NS	NS	7
Prista et al. (59)	2003	1999	Mozambique	Southern	Sub-national	Urban–rural	Private–public	–	WHO	1070	475 B 595 G	NS	–	7
Puckree et al. (60)	2011	2006	South Africa	Southern	Sub-national	Urban	Public	Cross-sectional	WHO	120	48 B 72 G	120 U	120 PU	7
Regaieg et al. (61)	2014	2010	Tunisia	Northern	Sub-national	Urban	Public	Cross-sectional	IOTF	1529	782 B 747 G	1529 U	1529 PU	7
Salman et al. (62)	2010	–	Sudan	Northern	Sub-national	Urban	–	Cross-sectional	CDC	304	68 B 236 G	304 U	NS	6
Sebbani et al. (63)	2013	2011	Morocco	Northern	National	Urban	Public	Cross-sectional	IOTF/WHO	1418	709 B 709 G	1418 U	1418 PU	6
Taleb et al. (64)	2010	1998	Algeria	Northern	Sub-national	Urban	–	NS	IOTF	3396	1819 B 1577 G	3396 U	–	6
Tathiah et al. (65)	2013	2011	South Africa	Southern	Sub-national	Rural	–	Secondary analysis	IOTF	952	952 G	952 R	NS	7
Truter et al. (66)	2010	–	South Africa	Southern	Sub-national	–	–	One way	IOTF	280	128 B 152 G	NS	NS	7

Table 1. *Continued*

Reference	Publication year	Start year	Country	Region location	Data type	Study site	School type	Study design	Diagnostic criteria	Sample size Overall	Boys/girls	Urban/rural	Private/public	Quality score
Van Den Ende et al. (67)	2014	1999	South Africa	Southern	Sub-national	Rural	–	Cross-sectional	IOTF	825	421 B 404 G	825 R	NS	7
Wiles et al. (68)	2013	–	South Africa	Southern	Sub-national	Urban	–	Cross-sectional	WHO	311	138 B 173 G	311 U	311 PU	6

B, boys; CDC, Centers for Disease Control and Prevention; G, girls; IOTF, International Obesity Task Force; NS, not specified; PR, private; PU, public; R, rural; U, urban; WHO, World Health Organization.

Prevalence of overweight and obesity within and across subgroups

Gender

In all, 29 studies (WHO), 28 studies (IOTF), six studies (CDC), two studies (unspecified criteria); and 18 studies (WHO), 16 studies (IOTF), four studies (CDC) and two studies (unspecified criteria) respectively provided overweight and obesity prevalence data by gender. The overall prevalence of overweight and obesity across these studies were 11.4% [8.4–14.9] and 7.0% [4.5–10.1], respectively, based on WHO criteria; 10.3% [8.4–12.3] and 4.3% [3.4–5.3] based on IOTF criteria and 11.5% [9.5–13.7] and 6.2% [4.7–8.0] based on CDC criteria, with always significant differences across criteria (overweight $p \leq 0.0028$; obesity $p < 0.0001$; Tables S4 and S5).

By gender, point estimates of the pooled prevalence of overweight and obesity were always higher in girls compared to boys, but these did not result in significant gender differences within the major diagnostic criteria (all $p \geq 0.128$ for gender comparisons). Within genders, pooled prevalence estimates always significantly differed across diagnostic criteria (all $p < 0.0001$; Figures S6–S9). There was substantial heterogeneity for WHO-based and IOTF-based studies (all p-heterogeneity $p < 0.0001$) and for CDC-based overweight prevalence in boys only ($p = 0.029$). Publication bias was apparent only for IOTF-based obesity prevalence in boys (Egger $p = 0.034$; Tables S4 and Table S5).

Urban–rural settings

The estimates for overweight and obesity were 12.8% [8.7–17.5] and 9.8% [6.0–14.6] among children in urban compared to 6.9% [3.3–11.6] and 1.5% [0.6–2.9] in children in rural settings by WHO criterion. The respective estimates by the IOTF criteria were 9.4% [5.2–14.7] and 4.9% [3.0–7.2] among urban areas compared to 4.0% [1.3–8.2] and 1.8% [0.6–7.2] in rural areas. By CDC criterion, the prevalence were 12.0% [9.8–14.4] and 7.5% [5.1–10.5] overweight and obesity in only urban school children. The point estimates were consistently higher in children in urban, compared to those in rural schools, and significant with obesity estimates only within the major criteria (all $p < 0.0001$ for urban–rural comparison; Tables S4 and S5). Within urban–rural settings, the pooled estimates did not differ across diagnostic criteria ($p \geq 0.076$; Figures S10–S14). There was substantial heterogeneity for WHO-based and IOTF-based prevalence (all p-heterogeneity $p \leq 0.035$) and for CDC-based obesity prevalence estimate in urban areas ($p = 0.015$). Further, there was publication bias in IOTF-based obesity

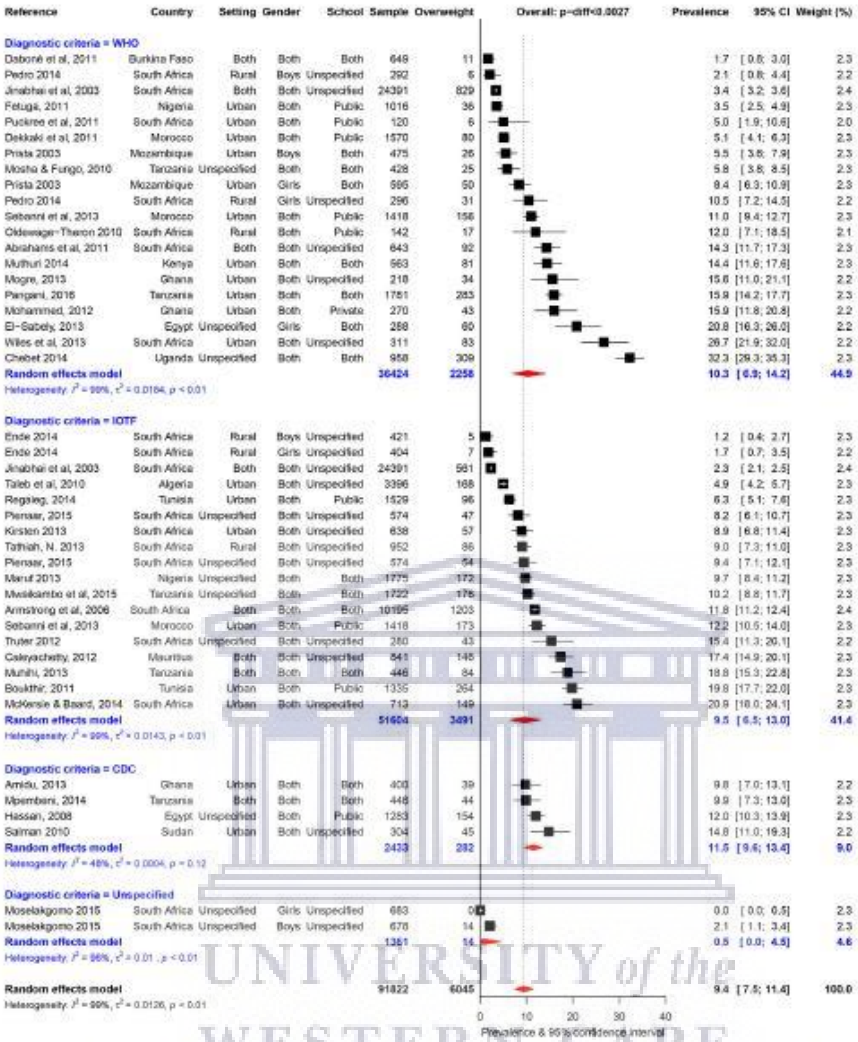

Figure 2 Forest plot of the prevalence of overweight by major diagnostic criteria. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

prevalence in urban areas only (Egger $p < 0.035$; Tables S4 and S5).

Private–public schools

Across all criteria, the pooled overweight and obesity estimates were higher in private compared to public schools. Overweight prevalence were 22.6% [16.0–30.0] and 11.2% [7.4–15.7] by WHO criterion, 18.2% [15.4–21.2] and 7.6% [3.7–12.9] by IOTF criterion and 15.0% [10.4–20.3] and 8.0% [2.2–17.0] by CDC criterion in private and public schools, respectively. The corresponding estimates for obesity in private and public schools were 16.6% [10.4–23.8] and 6.2% [3.1–10.3] for

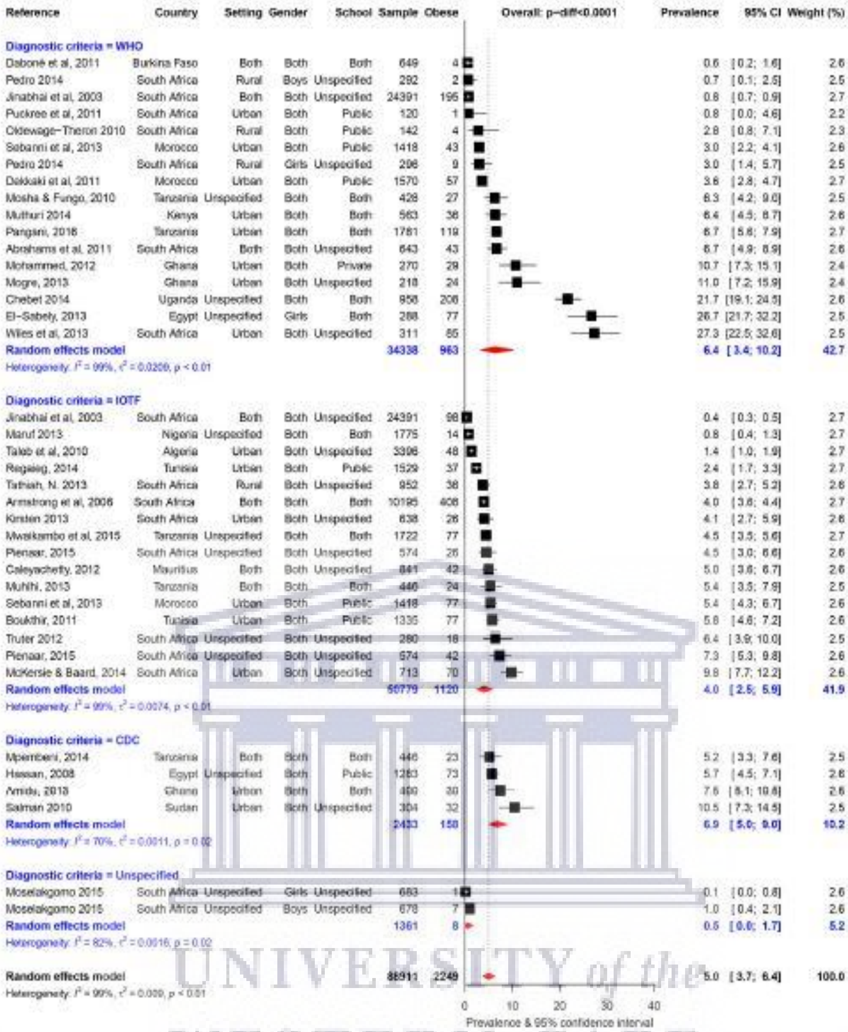

Figure 3 Forest plot of the prevalence of obesity by major diagnostic criteria. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

WHO, 1.2% [0.5–2.1] and 4.9% [2.5–8.1] for IOTF and 12.5% [8.3–17.4] and 4.2% [1.6–7.9] for CDC. With the exception of overweight prevalence by CDC criterion, the pooled estimates differed by school type within the major criteria ($p \leq 0.018$ for private–public comparisons). Within private–public schools, the point estimates did not differ significantly across the criteria (all $p \geq 0.209$) except for obesity prevalence in private schools ($p < 0.0001$; Figures S15–S18). Heterogeneity was apparent across studies irrespective of criteria used (all p-heterogeneity $p \leq 0.031$). There was no evidence of publication bias for type of school (Egger $p \geq 0.241$; Tables S4 and S5).

Regional distribution

The pooled overweight prevalence ranged from 7.7% [2.4–15.7] in Western Africa to 16.1% [6.1–26.8] in

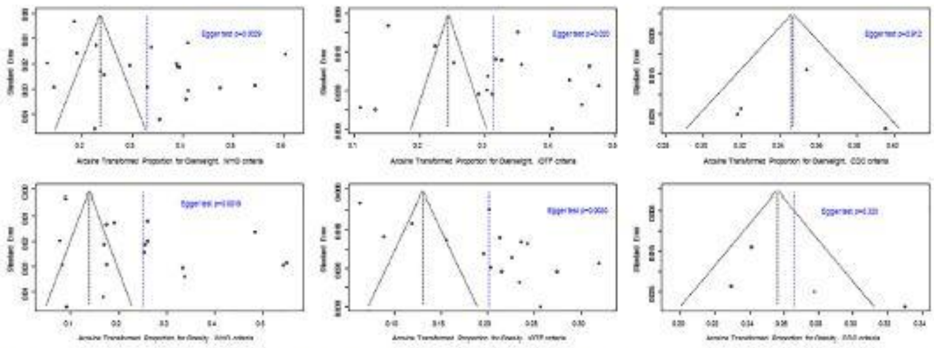

Figure 4 Funnel plots for the assessment of publication bias in studies of prevalent overweight (upper panels) and obesity (lower panels) by the World Health Organization (left column), International Obesity Task Force (middle column) and Centers for Diseases Control (right column) criteria, in African learners. For each figure panel, the dots are the arcsine transformed prevalence estimates of individual studies (horizontal axis) plotted against their standard error (vertical exist). The dotted vertical blue line is for the observed pooled prevalence estimates, while the dotted vertical black line bisector of the angle formed by the two upward converging lines, indicated where the pooled estimates should have been in the absence of publication bias. The *p*-value from the egger test of bias is also shown.

Eastern Africa by WHO criteria (p = 0.155); 8.5% [4.6–13.5] in Southern Africa to 14.1% [6.8–23.5] in Eastern Africa by IOTF (p = 0.684); and 9.7% [7.0–12.8] in Western Africa to 12.1% [7.7–17.3] in Eastern Africa by CDC (p = 0.434). Obesity estimates ranged from 4.1% [0.7–9.9] in Southern Africa to 9.6% [3.8–17.6] in Eastern Africa by WHO ($p < 0.0001$); 0.8% [0.4–1.2] in Western Africa to 4.6% [2.2–7.8] in Southern Africa by IOTF ($p < 0.0001$); and 5.7% [4.5–7.0] in Northern Africa to 7.6% [3.2–13.6] in Eastern Africa by CDC criteria (p = 0.019). The point estimates across the regional subgroups were comparable within the major criteria and differed only for obesity prevalence by IOTF-based criteria ($p < 0.0001$).

Within regional subgroups, the point estimates did not differ across the major criteria (all $p \geq 0.125$) except for studies conducted in Southern Africa ($p \leq 0.014$) and obesity for Western Africa ($p < 0.0001$). Substantial heterogeneity was observed in estimates across diagnostic criteria with regional subgroups (all $p \geq 0.042$), with the exception of IOTF-based obesity prevalence in Eastern Africa (p = 0.428). Publication bias was apparent in Southern African studies reporting overweight by WHO-based criteria (Egger p = 0.032) and obesity by IOTF-based criteria (Egger p = 0.043; Tables S4 and S5).

Publication year

By diagnostic criteria, the pooled estimates of overweight and obesity were always higher in recent studies (published in 2013 or after) compared to studies published earlier (published before 2013) by WHO criteria (p = 0.0007). Among studies that applied the IOTF and CDC criteria, overweight estimates were lower in recent compared to earlier studies, whereas obesity prevalence were higher in recent compared to earlier studies. Within publication year, pooled estimates of both overweight and obesity differed across all criteria except for studies published earlier (p = 0.154). Heterogeneity was observed for WHO and IOTF criteria (all $p < 0.0001$) and for CDC-based obesity prevalence in studies published earlier only ($p < 0.005$). Publication bias was apparent in earlier studies (Egger $p \leq 0.028$) using WHO criteria (Tables S4 and S5).

Sample size

Pooled estimates of overweight and obesity were not appreciably different between small (less than 638 participants) and large studies (638 or more participants), and regardless of criteria (all $p \geq 0.05$). Pooled prevalence estimates of overweight and obesity were similar across criteria within small studies (both $p \geq 0.532$) but differed significantly within large studies (both $p < 0.0016$), primarily driven by very low prevalence in studies based on unspecified diagnostic criteria. With the exception of small studies using CDC criteria for overweight (p = 0.074) and IOTF criteria for obesity (p = 0.221), there was substantial heterogeneity by diagnostic criteria within small and large studies (all $p < 0.019$). Publication bias was apparent only in large studies using IOTF-based criteria (Egger p = 0.017; Tables S4 and S5).

Discussion

This study provides the first detailed contemporary meta-analysis of overweight and obesity prevalence in African primary school learners. The results showed that by criteria, overall estimates ranged from 9.5% to 11.5% for overweight and 4.0% to 6.9% for obesity by IOTF and CDC, respectively, with significant variations across major diagnostic criteria. Prevalence estimates were mostly higher in urban compared with in rural schools, and in private compared with public schools, but mostly similar by gender, major geographic region, publication period and study size. There were substantial heterogeneities in the estimates across studies, which were not always explained by major study characteristics. Sensitivity analyses proved the few apparent publication biases to be artefactual.

These results highlight the increasing burden of overweight and obesity and are largely consistent with previous estimates suggesting an increasing overweight and obesity prevalence among children and adolescents globally (1). The estimates are notably higher than the prevalence estimates reported among children and adolescents in previous reviews (1,19). By the major diagnostic criteria used, the highest overall estimated overweight and obesity prevalence was by the CDC-based criterion and the lowest by IOTF definition. Notably, the CDC definition was used in four studies whereas 18 studies employed the IOTF definition. Together, CDC and IOTF criteria were used in over half of the studies. Given that the CDC and IOTF criteria underestimate the prevalence of overweight/obesity in children and adolescents compared with the WHO criterion (19), it is plausible that the overall prevalence reported in the present meta-analysis have been underestimated. The lack of consensus on the BMI cut-off references to use across studies presents a challenge for results comparability. The observed variations in the overall prevalence estimates by the major criteria thus underscores the relevance of the stratified meta-analysis based on diagnostic criteria as performed in the present study.

Unlike other studies, gender differences were not observed in the prevalence estimates of overweight and obesity in the present meta-analysis. The association between gender and overweight/obesity is inconsistent in the literature. A number of studies reported higher prevalence in girls (19,69), some found higher estimates in boys (70–73) and others reported similar prevalence estimates (74). In a study involving Australian school children, obesity prevalence did not differ between boys and girls in primary school children; however, substantial gender differences were observed among adolescents in high school (74) suggesting age–gender interactions (70,73). While the prevalence tend to be similar in boys and girls in this study, among adults, the prevalence is consistently higher in women than in men (1,75).

In addition to biology, this could be partially due to certain sociocultural practices that influence food choices and dietary intakes, overall energy expenditure and physical activity and perception of overweight/obesity. In some cultures in Africa for instance, overweight/obesity is perceived as an indicator of beauty, good health and wealth particularly among women (76,77). Additionally, women tend to be more sedentary compared to men (78). Besides, adverse early life experiences such as abuse (physical, sexual and emotional) and child neglect have been linked with higher BMI, and development of overweight, or obesity in adulthood, especially among women, but not in childhood and adolescence (79–81). While some showed abuse-specific effects, others reported more general effects across the spectrum of abuse.

Substantial variations in prevalence of overweight and obesity were observed across the rural–urban divide and also across private–public schools in the present study, broadly in line with previous studies (19,82,83,72) that suggest significantly higher estimates in urban children attending private schools, compared to children living in rural areas, and in public schools. The results showed that studies conducted in private schools were mainly in urban areas as opposed to most of those studies in public schools, which were a mix of urban and rural.

African countries are undergoing increasingly rapid urbanization, globalization of the food markets and economic and human development. These are associated with lifestyle changes such as increased sedentary behaviours, physical inactivity and increased consumption of the 'Westernized diets' (84). Economic and human development may be linked to increased SES, which could reflect in higher disposable incomes for high-calorie and ultra-processed convenient foods, with low nutritional value. Working parents especially mothers who work longer hours may have limited time to prepare fresh nutritious meals and may depend on convenient foods for the family. For example, in the Millennium Cohort Study in the UK, a significant relationship of maternal employment and obesity was found only for children from households with higher annual incomes (9).

Access to technology like motorized transportation and varieties of gaming consoles for the children may be increased in the higher SES households. For instance, results from a study in Africa showed that increasing total annual income was inversely associated with meeting physical activity (PA) guidelines of children (78). Additionally, rapid urbanization may result in overcrowding and congestion, increased crime rates, limited space for neighbourhood playgrounds and parks for children, which may invariably lead to decreased physical activity. On the other hand, undernutrition (85) and PA like active transport and active play (19,86) generally tend to be higher in rural children in sub-Saharan Africa.

Preventing excess weight gain in childhood is a major preventive strategy with lasting benefits, and the school provides opportunities and challenges for implementation of behavioural change programmes in children and adolescents. Restricting or limiting of marketing of unhealthy foods and beverages to children and provision of PA facilities are some of the recommended strategies (87), and the schools could provide children with the supportive environments to improve the PA and healthy eating habits by strengthening the school health promotion programmes.

A strength of this study is the stratified meta-analysis based on the diagnostic criteria used. The PRISMA checklist guided the study from selection of studies to synthesis. This meta-analysis pooled and compared results from different studies that employed various diagnostic criteria to define overweight and obesity. Although there were substantial heterogeneity across studies, the sources of heterogeneity were thoroughly investigated on pre-specified population level characteristics. Likewise, an exhaustive search of multiple databases was conducted to identify relevant studies originating from Africa. The study has highlighted the extent of the problem of overweight/obesity and provided valuable data for consideration by policymakers and public health practitioners on the prevention and control strategies among primary school learners in Africa.

There are a number of limitations that might influence the interpretation of the results. Some of the studies were not originally designed to assess prevalence of overweight and obesity. Results were pooled from studies conducted at different geographical locations, among different ethnic groups and with methodological differences, but attempts were made to adjust for these differences through robust methodology. It is possible that some studies that were published in local and unindexed journals were missed. Also, all the geographical locations were not evenly represented. Finally, the predictors of childhood overweight and obesity were not explored in this study because this was an aggregated data meta-analysis.

Conclusions

In conclusion, the high prevalence of overweight and obesity reported in this review is of great concern considering the negative health impact across the life cycle. Results from the present study demonstrate that while overweight and obesity are more prevalent in urban children, rural residence does not protect against the epidemic. The similar prevalence estimates observed between genders also suggest that among African learners, boys and girls are equally affected. Private school attendance, an indicator of SES of families and urban residence are thus major driving forces of overweight and obesity among African school children. If this prevalence persists, it may lead to increased healthcare cost and burden on healthcare facilities. Results from this meta-analysis could be helpful in making informed decisions on childhood obesity prevention efforts in African countries.

Conflicts of interest statement

No conflict of interest was declared.

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Author contributions

T. A. contributed to study conception, study design, literature search, data collection, data analysis and interpretation and drafted the first manuscript. A. P. K. contributed to study conception, study design and data analysis and critically reviewed the first draft manuscript. A. D. V. and T. P. contributed to study design and critically reviewed the manuscript. All the authors read and approved the final version of the manuscript.

References

1. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; **384**: 766–781. https://doi.org/10.1016/s0140-6736(14)60460-8.
2. de Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. *Am J Clin Nutr* 2010; **92**: 1257–1264. https://doi.org/10.3945/ajcn.2010.29786.1.
3. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. *Int Rev Psychiatry* 2012; **24**: 176–188. https://doi.org/10.3109/09540261.2012.688195.

4. UNICEF, World Health Organization, World Bank Group. Levels and trends in child malnutrition. 2016:1-8. https://doi.org/10.1016/S0266-6138(96)90067-4.
5. Wabitsch M, Moss A, Kromeyer-hauschild K. Unexpected plateauing of childhood obesity rates in developed countries. *BMC Med* 2014; **12**: 17. http://www.biomedcentral.com/1741-7015/12/17.
6. McLeroy K, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Health Educ Q* 1988; **15**: 351–377.
7. Ogden CL, Lamb MM, Carroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief* 2010; **127**: 1–8. https://doi.org/10.1001/archsurg.138.4.354.
8. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: Epidemiology, determinants, and prevention. *Endocr Rev* 2012; **33**: 48–70. https://doi.org/10.1210/er.2010-0028.
9. Hawkins S, Cole TJ, Law C. The Millennium Cohort Study Child Health Group. Maternal employment and early childhood overweight: findings from the UK Millennium Cohort Study. *Int J Obes (Lond)* 2008; **32**: 30–38. https://doi.org/10.1038/sj.ijo.0803682. Maternal.
10. Keane E, Layte R, Harrington J, Kearney PM, Perry IJ. Measured parental weight status and familial socio-economic status correlates with childhood overweight and obesity at age 9. *PLoS ONE* 2012; **7**: e43503. https://doi.org/10.1371/journal.pone.0043503.
11. Mâsse LC, de Niet-Fitzgerald J, Watts AW, Naylor P-J, Saewyc EM. Associations between the school food environment, student consumption and body mass index of Canadian adolescents. *Int J Behav Nutr Phys Act* 2014; 11: 29. https://doi.org/10.1186/1479-5868-11-29.
12. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EMF. The school environment and adolescent physical activity and sedentary behaviour: A mixed-studies systematic review. *Obes Rev* 2016; **17**: 142–158. https://doi.org/10.1111/obr.12352.
13. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC. The built environment and obesity. *Epidemiol Rev* 2007; **29**: 129–143.
14. Cummins S, Macintyre S. Food environments and obesity - Neighbourhood or nation? *Int J Epidemiol* 2006; **35**: 100–104. https://doi.org/10.1093/ije/dyi276.
15. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. *Int J Obes (Lond)* 2011; **35**: 891–898. https://doi.org/10.1038/ijo.2010.222.
16. Singh AS, Mulder C, Twisk JWR, Van Mechelen W, Chinapaw MJM. Tracking of childhood overweight into adulthood: A systematic review of the literature. *Obes Rev* 2008; 9: 474–488. https://doi.org/10.1111/j.1467-789X.2008.00475.x.
17. Noubiap JJ, Essouma M, Bigna JJ, Jingi AM, Aminde LN, Nansseu JR. Prevalence of elevated blood pressure in children and adolescents in Africa: a systematic review and meta-analysis. *Lancet Public Health* 2017; **2**: e375–e386. https://doi.org/10.1016/S2468-2667(17)30123-8.
18. Agyemang C, Redekop WK, Owusu-Dabo E, Bruijnzeels M. a. Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. *BMC Public Health* 2005; **5**: 114. https://doi.org/10.1186/1471-2458-5-114.
19. Muthuri SK, Francis CE, Wachira L-JM, et al. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS ONE* 2014; **9**: 1–26. https://doi.org/10.1371/journal.pone.0092846.
20. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; **85**: 812–819. https://doi.org/10.2471/BLT.
21. Kuczmarski R, Ogden CL, Guo S, Grummer-Strawn L, Flegal K, Al E. CDC Growth Charts for the United States: methods and development. *Vital Health Stat* 2000: 1–190. https://www.cdc.gov/growthcharts/2000growthchart-us.pdf.
22. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000; **320**: 1–6. https://doi.org/10.1136/bmj.320.7244.1240.
23. Adom T, Puoane T, De Villiers A, Kengne AP. Prevalence of obesity and overweight in African learners: a protocol for systematic review and meta-analysis. *BMJ Open* 2017; **7**: e013538. https://doi.org/10.1136/bmjopen-2016-013538.
24. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomized and non-randomized studies of health care interventions. *J Epidemiol Community Health* 1998; **52**: 377–384. https://doi.org/10.1136/jech.52.6.377.
25. Barendregt JJ, Doi SA, Lee YY, Norman RE, Vos T. Meta-analysis of prevalence. *J Epidemiol Community Health* 2013; **67**: 974–978. https://doi.org/10.1136/jech-2013-203104.
26. Dersimonian R, Laird N. Meta-Analysis in Clinical Trials*. *Stat Med* 1986; **188**: 177–188. https://doi.org/10.1016/0197-2456(86)90046-2.
27. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ Br Med J* 2003; **327**: 557–560. https://doi.org/10.1136/bmj.327.7414.557.
28. Egger M, Smith GD, Schneider M, Minder C. Bias in meta analysis detected by a simple , graphical test. *BMJ* 1997; **14**: 1–16. https://doi.org/10.1136/bmj.315.7109.629.
29. Abrahams Z, de Villiers A, Steyn NP, et al. What's in the lunchbox? Dietary behaviour of learners from disadvantaged schools in the Western Cape, South Africa. *Public Health Nutr* 2011; **14**: 1752–1758. https://doi.org/10.1017/s1368980011001108.
30. Amidu N, Owiredu WKBA, Saaka M, et al. Determinants of childhood obesity among basic school children aged 6 – 12 years in Tamale Metropolis. *J Med Biomed Sci* 2013; **2**: 26–34.
31. Armstrong ME, Lambert MI, Sharwood KA, Lambert EV. Obesity and overweight in South African primary school children - the Health of the Nation Study. *S Afr Med J* 2006; **96**: 439–444.
32. Boukthir S, Essaddam L, Mazigh Mrad S, et al. Prevalence and risk factors of overweight and obesity in elementary schoolchildren in the metropolitan region of Tunis, Tunisia. *Tunis Med* 2011; **89**: 50–54.
33. Caleyachetty R, Rudnicka AR, Echouffo-Tcheugui JB, Siegel KR, Richards N, Whincup PH. Prevalence of overweight, obesity and thinness in 9-10 year old children in Mauritius. *Glob Heal* 2012; **8**: 28. https://doi.org/10.1186/1744-8603-8-28.
34. Chebet M, Goon DT, Nsibambi C, Otala J. Prevalence of overweight and obesity among primary school children in Kampala central, Uganda. *AJPHERD* 2014; **20**: 1365–1378.
35. Daboné C, Delisle HF, Receveur O. Poor nutritional status of schoolchildren in urban and peri-urban areas of Ouagadougou (Burkina Faso). *Nutr J* 2011; **10**: 34. https://doi.org/10.1186/1475-2891-10-34.

36. Dekkaki IC, Mouane N, Ettair S, Meskini T, Bouklouze A, Barkat A. Prevalence of obesity and overweight in children: A study in government primary schools in rabat, Morocco. *Arch Med Res* 2011; **42**: 703–708. https://doi.org/10.1016/j.arcmed.2011.12.004.
37. El-Sabely AA, Tork HMM, Hussien YE. Comparative Study of Nutritional Status and Dietary Habits of Children from Public and Private Primary Schools in Zagazig City, Egypt. *IOSR J Nurs Heal Sci* 2013; **3**: 47–52.
38. Fetuga MB, Ogunlesi TA, Adekanmbi AF, Alabi AD. Nutritional Status of Semi-Urban Nigerian School Children using the 2007 WHO Reference Population. *West Afr J Med* 2011; **30**: 331–336. http://www.ncbi.nlm.nih.gov/pubmed/22752820.
39. Hassan NE, El-Masry SA, El-Sawaf AE. Waist circumference and central fatness of Egyptian primary-school children. *East Mediterr Health J* 2008; **14**: 916–925.
40. Jinabhai CC, Taylor M, Sullivan KR. Changing patterns of under- and over-nutrition in South African children - future risks of non-communicable diseases. *Ann Trop Paediatr* 2005; **25**: 3–15. https://doi.org/10.1179/146532805X23290.
41. Jinabhai CC, Taylor M, Sullivan KR. Implications of the prevalence of stunting, overweight and obesity amongst South African primary school children: a possible nutritional transition? *Eur J Clin Nutr* 2003; **57**: 358–365. https://doi.org/10.1038/sj.ejcn.1601534.
42. Kirsten AP, Marais D, Schübl C. The influence of socio-demographic factors on the nutritional status of children in the Stellenbosch area , Western Cape. *S Afr J Clin Nutr* 2013; **26**: 124–131.
43. Kyallo F, Makokha A, Mwangi AM. Overweight and obesity among public and private primary school children in Nairobi, Kenya. *Health (Irvine Calif)* 2013; **5**: 85–90. https://doi.org/10.4236/health.2013.58A3012.
44. Maruf FA, Aronu U, Chukwuegbu K, Aronu AE. Influence of gender on prevalence of overweight and obesity in Nigerian schoolchildren and adolescents. *Tanzan J Health Res* 2013; **15**: 247–251.
45. McKersie JM, Baard ML. Body mass index and associated physical activity levels in 7 - 10-year-old children in primary schools in Port Elizabeth. *South African J Sport Med* 2014; **26**: 115–118. https://doi.org/10.7196/SAJSM.551.
46. Mogre V, Gaa PK, Nagumsi R, Abukari S. Overweight , Obesity and Thinness and Associated Factors Among School- Aged Children (5-14 Years) in Tamale. *Eur Sci J* 2013; **9**: 160–175.
47. Mohammed H, Vuvor F. Prevalence of childhood overweight/obesity in basic school in Accra. *Ghana Med J* 2013/05/11 2012; **46**: 124–127.
48. Moselakgomo VK, Monyeki MA, Toriola AL. Relationship between physical activity and risk factors of body weight disorders among south African primary school children. *Biomed Res* 2015; **26**: 730–738.
49. Mosha TC, Fungo S. Prevalence of overweight and obesity among children aged 6-12 years in Dodoma and Kinondoni municipalities, Tanzania. *Tanzan J Health Res* 2010; **12**: 6–16.
50. Mpembeni RN, Muhihi AJ, Maghembe M, et al. Overweight, obesity and perceptions about body weight among primary schoolchildren in Dar es Salaam. *Tanzania Tanzan J Heal Res* 2014; **16**: 304–311.
51. Muhihi AJ, Mpembeni RNM, Njelekela MA, et al. Prevalence and determinants of obesity among primary school children in Dar es Salaam, Tanzania. *Arch Public Heal* 2013; **71**: 26. https://doi.org/10.1186/0778-7367-71-26.
52. Muthuri SK, Wachira LM, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. *BMC Public Health* 2014; **14**: 1–11. https://doi.org/10.1186/1471-2458-14-436.
53. Mwaikambo SA, Leyna GH, Killewo J, Simba A, Puoane T. Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. *BMC Public Health* 2015; **15**: 1269. https://doi.org/10.1186/s12889-015-2598-0.
54. Navti LK, Ferrari U, Tange E, Bechtold-Dalla Pozza S, Parhofer KG. Contribution of socioeconomic status, stature and birth weight to obesity in Sub-Saharan Africa: cross-sectional data from primary school-age children in Cameroon. *BMC Public Health* 2014; **14**: 320. https://doi.org/10.1186/1471-2458-14-320.
55. Oldewage-Theron WH, Egal AA. Nutrition knowledge and nutritional status of primary school children in QwaQwa. *South African J Clin Nutr* 2010; **23**: 149–154.
56. Pangani IN, Kiplamai FK, Kamau JW, Onywera VO. Prevalence of Overweight and Obesity among Primary School Children Aged 8–13 Years in Dar es Salaam City, Tanzania. *Adv Prev Med* 2016; **2016**: 1–5. https://doi.org/10.1155/2016/1345017.
57. Pedro T, Kahn K. Under- and overnutrition and evidence of metabolic disease risk in rural black South African children and adolescents. *S Afr J Clin Nutr* 2014; **27**: 194–200.
58. Pienaar AE. Prevalence of overweight and obesity among primary school children in a developing country: NW-CHILD longitudinal data of 6–9-yr-old children in South Africa. *BMC Obes* 2015; **2**: 2. https://doi.org/10.1186/s40608-014-0030-4.
59. Prista A, Maia JAR, Damasceno A and BG. Anthropometric indicators of nutritional status :implications for fitness, activity, and health in school-age children and adolescents. *Am J Clin Nutr* 2003; **77**: 952–959.
60. Puckree T, Naidoo P, Pillay P, Naidoo T. Underweight and overweight in primary school children in eThekwini district in kwazulu-Natal, South Africa. *African J Prim Heal Care Fam Med* 2011; **3**: 1–6. https://doi.org/10.4102/phcfm.v3i1.203.
61. Regaieg S, Charfi N, Trabelsi L, et al. Prevalence and risk factors of overweight and obesity in a population of school children in urban areas Sfax, Tunisia. *Pan Afr Med J* 2014; **17**: 57. https://doi.org/10.11604/pamj.2014.17.57.3351.
62. Salman Z, Kirk GD, DeBoer MD. High Rate of Obesity-Associated Hypertension among Primary Schoolchildren in Sudan. *Int J Hypertens* 2011; **2011**: 1–5. https://doi.org/10.4061/2011/629492.
63. Sebbani M, Elbouchti I, Adarmouch L, Amine M. Prevalence of obesity and overweight among children in primary schools in Marrakech, Morocco. *Rev Epidemiol Sante Publique* 2013; **61**: 545–549. https://doi.org/10.1016/j.respe.2013.08.002.
64. Taleb S, Oulamara H, Agli AN. Prevalence of overweight and obesity in schoolchildren in Tebessa (Algeria) between 1998 and 2005. *East Mediterr Health J* 2010; **16**: 746–751.
65. Tathiah N, Moodley I, Mubaiwa V, Denny L, Taylor M. South Africa's nutritional transition: overweight, obesity, underweight and stunting in female primary school learners in rural KwaZulu-Natal, South Africa. *S Afr Med J* 2013; **103**: 718–723. https://doi.org/10.7196/samj.6922.
66. Truter L, Pienaar AE, Du Toit D. The relationship of overweight and obesity to the motor performance of children living in South Africa. *S Afr Fam Pract* 2012; **54**: 429–435. https://doi.org/10.1080/20786204.2012.10874268.
67. van den Ende C, Twisk JW, Monyeki KD. The relationship between BMI and dietary intake of primary school children from a rural area

of South Africa: The Ellisras longitudinal study. *Am J Hum Biol* 2014; **26**: 701–706. https://doi.org/10.1002/ajhb.22585.

68. Wiles NL, Green JMVF. Tuck-shop purchasing practices of Grade 4 learners in Pietermaritzburg and childhood overweight and obesity. *S Afr J Clin Nutr* 2013; **26**: 37–42.
69. Negash S, Agyemang C, Matsha TE, Peer N, Erasmus RT, Kengne AP. Differential prevalence and associations of overweight and obesity by gender and population group among school learners in South Africa: a cross-sectional study. *BMC Obes* 2017; **4**: 29. https://doi.org/10.1186/s40608-017-0165-1.
70. Ogden CL, Fryar CD, Hales CM, Carroll MD, Aoki Y, Freedman DS. Differences in Obesity Prevalence by Demographics and Urbanization in US Children and Adolescents, 2013-2016. *JAMA* 2018; **319**: 2410–2418. https://doi.org/10.1001/jama.2018.5158.
71. Song Y, Wang H-J, Dong B, Ma J, Wang Z, Agardh A. 25-year trends in gender disparity for obesity and overweight by using WHO and IOTF definitions among Chinese school-aged children: a multiple cross-sectional study. *BMJ Open* 2016; **6**: e011904. https://doi.org/10.1136/bmjopen-2016-011904.
72. Chirita-Emandi A, Barbu CG, Cinteza EE, Chesaru BI, Gafencu M, Mocanu V. Overweight and Underweight Prevalence Trends in Children from Romania – Pooled Analysis of Cross-Sectional Studies between 2006 and 2015. *Obes Facts* 2016; **9**: 206–220. https://doi.org/10.1159/000444173.
73. Wang VH, Min J, Xue H, et al. What factors may contribute to sex differences in childhood obesity prevalence in China? *Public Health Nutr* 2018; **21**: 1–9.
74. O'Dea JA. Gender, ethnicity, culture and social class influences on childhood obesity among Australian schoolchildren: implications for treatment, prevention and community education. *Health Soc Care Community* 2008; **16**: 282–290. https://doi.org/10.1111/j.1365-2524.2008.00768.x.
75. The GBD. 2015 Obesity Collaborators. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. *N Engl J Med* 2017; **377**: 13–27. https://doi.org/10.1056/NEJMoa1614362.
76. Ziraba AK, Fotso JC, Ochako R. Overweight and obesity in urban Africa: A problem of the rich or the poor? *BMC Public Health* 2009; **9**: 465. https://doi.org/10.1186/1471-2458-9-465.
77. Mokhtar N, Elati J, Chabir R, et al. Diet Culture and Obesity in Northern Africa. *J Nutr* 2001; **131**: S887–S892.
78. Muthuri SK, Wachira LJ, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. *BMC Public Health* 2014; **14**: 436. https://doi.org/10.1186/1471-2458-14-436.
79. Hemmingsson E, Johansson K, Reynisdottir S. Effects of childhood abuse on adult obesity : a systematic review and meta-analysis. *Obes Rev* 2014; **15**: 1–12. https://doi.org/10.1111/obr.12216.
80. Danese A, Tan M. Childhood maltreatment and obesity: systematic review and meta-analysis. *Mol Psychiatry* 2014; **19**: 544–554. https://doi.org/10.1038/mp.2013.54.
81. Hawton K, Norris T, Crawley E, Bch BM, Shield JPH, Chb MB. Is Child Abuse Associated with Adolescent Obesity? A Population Cohort Study. *Child Obes* 2018; **14**: 1–8. https://doi.org/10.1089/chi.2017.0141.
82. Yu Z, Han S, Chu J, Xu Z, Zhu C, Guo X. Trends in Overweight and Obesity among Children and Adolescents in China from 1981 to 2010: A Meta-Analysis. *PLoS ONE* 2012; 7https://doi.org/10.1371/journal.pone.0051949.
83. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. *Clin Obes* 2016; **6**: 19–32. https://doi.org/10.1111/cob.12130.
84. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev* 2012; **70**: 3–21. https://doi.org/10.1111/j.1753-4887.2011.00456.x.
85. Akombi BJ, Agho KE, Hall JJ, Wali N, Renzaho AMN, Merom D. Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review. *Int J Environ Res Public Health* 2017; **14**: 1–18. https://doi.org/10.3390/ijerph14080863.
86. Johnson JA, Johnson AM. Urban-Rural Differences in Childhood and Adolescent Obesity in the United States: A Systematic Review and Meta-Analysis. *Child Obes* 2015; **11**: 233–241. https://doi.org/10.1089/chi.2014.0085.
87. WHO. Report of the commission on ending childhood obesity. 2016.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Search strategy for PubMed
Table S2. PRISMA checklist
Table S3. Summary of the quality scores of the included studies
Table S4. Summary statistics from meta-analyses of prevalence studies of overweight in African school going children using random effects model and arcsine transformations
Table S5. Summary statistics from meta-analyses of prevalence studies of obesity in African school going children using random effects model and arcsine transformations
Fig S1. Forest plot showing the effect of omitting one study at a time on pooled prevalence and heterogeneity statistics from studies that used World Health Organisation (WHO) criteria to diagnose prevalent obesity (first panel) and overweight (second panel) in African school learners
Fig S2. Forest plot showing the effect of omitting one study at a time on pooled prevalence and heterogeneity statistics from studies that used International Obesity Task Force (IOTF, upper panels) and Centre for Diseases Control (CDC, lower panels) criteria to diagnose prevalent obesity (left panels) and overweight (right panels) in African school learners
Fig S3. Funnel plots for the assessment of publication bias in studies of prevalent overweight (upper panels) and obesity (lower panels) by the World Health organisation (left column), International Obesity Task Force (middle column) and Centre for

Diseases Control (right column) criteria, in African school going children, after implementation of the trim & fill methods to correct for publication bias.

Fig. S4. Forest plots showing the effect of studies imputations on pooled prevalence estimates from trim and fill methods, for studies that used the World Health Organisation (WHO) criteria to diagnose obesity (first panel) or overweight (second panel) in African school going children

Fig. S5. Forest plots showing the effect of studies imputations on pooled prevalence estimates from trim and fill methods, for studies that used the International Obesity Task Force (IOTF, upper panels) or Centre for Diseases Control (CDC, lower panels) criteria to diagnose obesity (left panels) or overweight (right panels) in African school going children

Fig. S6. Prevalence of overweight by major diagnostic criteria in boys. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig.S7. Prevalence of overweight by major diagnostic criteria in girls. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig S8. Prevalence of obesity by major diagnostic criteria in boys. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S9. Prevalence of obesity by major diagnostic criteria in girls. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S10. Prevalence of overweight by major diagnostic criteria in urban studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S11. Prevalence of overweight by major diagnostic criteria in rural studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S12. Prevalence of overweight by major diagnostic criteria in urban and rural studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S13. Prevalence of obesity by major diagnostic criteria in urban studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S14. Prevalence of obesity by major diagnostic criteria in rural studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S15. Prevalence of overweight by major diagnostic criteria in public schools studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S16. Prevalence of overweight by major diagnostic criteria in private schools studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S17. Prevalence of obesity by major diagnostic criteria in public schools studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

Fig. S18. Prevalence of obesity by major diagnostic criteria in private schools studies. Black boxes represent the effect estimates (prevalence) and the horizontal bars about are for the 95% confidence intervals (CIs). The diamond is for the pooled effect estimate and 95% CI.

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RESEARCH ARTICLE Open Access

Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana

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Abstract

Background: There is limited data on risk factors associated with childhood overweight and obesity in Ghanaian school children. Therefore, the aim of this study was to assess the prevalence of overweight and obesity and associated risk factors in Ghanaian school children.

Methods: Data for this study were obtained from a cross-sectional survey of 543 children aged 8 and 11 years, attending private and public primary schools in the Adentan Municipality of Greater Accra Region, Ghana. Anthropometric, dietary, physical activity, sedentary behaviours, sleep duration and socio-demographic data were collected. BMI-for-age Z-scores were used to classify children as overweight/obesity. Multivariable logistic regressions were used to assess the determinants of overweight and obesity.

Results: The overall prevalence of overweight/obesity was 16.4%. Children living in middle (OR = 1.88; 95% CI = 1.01–3.50) and high socioeconomic status (SES) households (2.58; 1.41–4.70) had increased odds of being overweight or obese compared to those living in low SES household. Attending private school (2.44; 1.39–4.29) and watching television for more than 2 h each day (1.72; 1.05–2.87) were significantly associated with increased likelihood of overweight and obesity. Children who slept for more than 9 h a night (0.53; 0.31–0.88) and walked or cycled to school (0.51; 0.31–0.82) had lower odds of being overweight or obese.

Conclusions: A number of modifiable risk factors were associated with overweight and obesity in this study. Public health strategies to prevent childhood obesity should target reduction in television watching time, promoting active transport to and from school, and increasing sleep duration.

Keywords: Ghana, Obesity, Overweight, School children

Background

The increasing prevalence of childhood obesity continues to be a major public health concern globally [1–3]. In 2013, the Global Burden of Disease estimated that 23.8% of boys and 22.6% of girls in developed countries were overweight or obese [3]. During the same period, the prevalence increased from 8.1 to 12.9% in boys and from 8.4 to 13.4% in girls in developing countries [3]. In sub-Saharan Africa where countries are still developing, there is growing evidence of increasing overweight and obesity among school-aged children [4, 5].

The health implications of overweight and obesity cannot be ignored [6]. Children with obesity are at increased risk of developing hypertension, high cholesterol, orthopaedic problems, and type 2 diabetes in childhood [6–8], which may persist in adulthood [9]. There is also considerable evidence that overweight and obesity in childhood predict adult obesity [10]. Preventing unhealthy weight gain from an early age is a public health strategy and identifying modifiable risk factors in the local context is important for a successful intervention.

Childhood obesity reflects complex interactions between the individual, behavioural and environmental factors [11]. Traditionally, long-term energy imbalance resulting from

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high energy intake and low energy expenditure has been implicated in the epidemiology of overweight and obesity [12]. Lifestyle and behavioural changes including consumption of diets high in refined sugars and saturated fats but low in fruits and vegetables, physical inactivity, increased sedentary behaviours [13] and short sleep duration have contributed to the increasing prevalence of overweight and obesity in children and adults [14–19]. Moreover, studies in developed and developing countries have linked socioeconomic status to obesity prevalence [4, 20, 21]. In Africa, the type of school a child attends is invariably linked to the SES of the family; children from higher SES households are more likely to attend private or affluent schools and have higher risk of becoming overweight or obese [4, 22] than children from low SES households.

In developing countries including Ghana, nutrition transition and lifestyle changes associated with rapid urbanisation, globalisation and industrialisation are major contributing factors towards unhealthy lifestyles [12, 18, 19]. There is growing evidence of increasing prevalence of overweight and obesity among children under the age of five [23] and school-aged children [24, 25] in Ghana. Findings from the Ghana Demographic and Health Survey revealed that the prevalence of obesity increased from less than 1% in 1988 to 5% in 2008 in children under the age of five [23]. During the primary school period, unhealthy weight gains may arise from energy imbalance resulting from poor dietary habits [26] and physical inactivity [24]. Despite these, older children, unlike children under 5 and adolescents are usually not targets of representative health surveys in developing countries including Ghana [23, 27]. Nationally representative data on the prevalence of overweight and obesity among school-aged children are lacking. While a number of individual studies involving Ghanaian children have reported increasing prevalence [24, 25, 28, 29], fewer studies have investigated the independent associations of determinants or associated risk factors with overweight and obesity. Therefore, the objective of this study was to determine the prevalence of overweight and obesity and to examine the associated risk factors in Ghanaian school children.

Methods

Study design and population

This was a cross-sectional study that involved children aged 8–11 years attending private and public primary schools in the Adentan Municipality of Greater Accra Region, Ghana. Adentan is one of the 213 districts in Ghana. There are 13 public basic schools and 135 private basic schools in the Municipality which are either exclusively primary (grades 1–6), or Primary and Junior High (Grades 1-JHS 3). The Adentan Municipality was chosen because it is one of the fastest growing municipalities and a high proportion (62.5%) of the population resides in urban areas [30].

The study was approved by the Ethical Review Committees of the Ghana Health Service and the Senate Research Committee of the University of the Western Cape. Approval was also obtained from the Municipal Education Directorate of the Ghana Education Service as well as from the Heads of all participating schools. Written informed consent were given by parents/legal guardians of children. Verbal assent was given by each participating child.

Sampling

A minimum sample size of 206 was estimated based on an overweight/obesity prevalence of 15% among school children in urban Ghana [31], using the formula for prevalence studies [32]. This was multiplied by design effect for cluster sampling of 2 to give a sample of 412. Assuming a non-response rate of 10%, the sample size was adjusted to 453 children. Fourteen schools were selected from a list of basic schools in the district obtained from the Municipal Education Directorate of the Ghana Education Service using a random cluster sampling technique. In each school, all apparently healthy children between the ages of 8 and 11 years were eligible. Exclusion criteria were known medical conditions such as diabetes because some medications like insulin treatment in such individuals predisposes them to excess weight gain [33]. None of the children was however excluded from the study.

Simple random sampling technique (balloting) was used to select pupils from each selected school. The children were asked to pick from a bowl, papers that were pre-coded as "yes" or "no". The number of children selected from each school ranged from 40 to 100. In each class, sampling was stratified on gender so that boys were sampled separately from girls. A total of 790 invitations and consent forms were distributed to those who picked "yes" for parental approval. Out of this, 562 returned with informed parental consent (71.1%) and were sampled.

Data collection

Dietary, physical activity, sedentary behaviours and sleep duration

A pre-tested questionnaire was used to obtain data from the children by trained research assistants. Each child was given a printed form and pencil to write their responses. Questions and response options were read out in the classroom setting and the children were encouraged to answer independently under the supervision of the research assistants, who also ensured that children responded to the previous question before proceeding to the subsequent questions. This approach was adopted because of the younger children (8–9 years), as it helped them to concentrate for a longer period during data collection. Dietary data collected included eating breakfast before school, fruits and vegetables intake, fried foods, consumption of sweetened beverages and soft drinks, and eating sweets, chocolates and chips for snacks. Responses were "No", "sometimes, 2-3 times a week"; and "Yes, more than 3 times a week" for breakfast, fried foods, of sweetened beverages and soft drinks. For snacks, fruits and vegetables, responses were "No/rarely", and "Yes, more than 3 times a week".

Questions on physical activity level was collected using a modified version of the International Physical Activity Questionnaire for Children [34]. Questions were grouped in 9 categories. The frequency of performing certain activities one week prior to the study was reported. Each of the 9 items was scored using a scale of 1 to 5 and the mean of the items used to calculate the final summary score. The physical activity level was categorised as: light (score < 2), moderate (score 2–4), and vigorous (score $= 5$) with a higher score indicating a higher level of activity [34]. The cut-off points for meeting physical activity recommendations were defined as ≥ 2.9 for boys and ≥ 2.7 for girls [35].

To assess the mode of transportation to and from school, children responded to "how they usually travelled to and from school in the last seven days" with response options "walking/cycling", "bus, car, vehicle" or "both". The responses were dichotomised as "walking/cycling" and "motorised". Children responded to the frequency of playing video/computer games. The time spent in watching television daily was reported in hours and dichotomised as moderate (< 2 h) and excessive (≥ 2 h). Screen time was used as a measure of sedentary behaviour. Sleep duration was assessed by asking the usual time of going to bed at night and usual time of waking up in the morning on a typical weekday and weekend or holiday. We dichotomised sleep duration as short (< 9 h) and sufficient (> 9 h) based on the recommendations by the National Sleep Foundation [36].

Socio-demographic data

A structured questionnaire was used to collect the following data on demographic and household characteristics: gender, age, parents' occupation, household size, source of water and sanitation, and fuel for cooking. Additional data on possession of household assets including television, radio, car/motorbike, refrigerator, washing machine, telephone, computer, cable TV and microwave oven were collected.

Anthropometry

Body weight was measured to the nearest 0.1 kg with an electron digital scale (Seca 869, GmbH & Co, Germany). Children were weighed in their school uniforms but asked to remove shoes, socks, watches, sweaters, jackets and items in the pockets. Height was measured to the nearest 0.1 cm using the Shorr Board (Shorr Productions, Olney, MD). All measurements were done in duplicates by the same research assistants. From the averages of the duplicate measures, BMI was computed as body weight (in kilogramme) divided by height (in metre square). BMI-for-age z-scores (BAZ) were used to categorise pupils as thin, normal weight, overweight or obese [37]. Data collection was done at the schools' premises.

Statistical analysis

Variables on source of water and sanitation, and household assets were subjected to principal component analysis. The first component was extracted to create wealth scores of the household which were then split into thirds and reported as low SES (lowest third), middle SES (middle third) and high SES (highest third) households [38]. Categorical variables were reported as counts and percentages, and mean and standard deviations for continuous variables. For group comparisons, chi-square test and student t-test were performed.

For the purposes of analysis, we collapsed overweight (pre-obesity) and obesity into one variable "overweight or obesity" and other weight categories as "non-overweight/obesity". The proportions of children who were overweight or obese was computed as BAZ $> +1.0$ SD. Multivariable logistic regressions were used to identify sociodemographic characteristic, dietary, physical activity and sedentary behaviours associated with overweight or obesity while controlling for age and gender. Variables that correlated ($p < 0.05$) or tended to be associated with the outcome variable (p-values < 0.1) at the univariable levels were selected and included in the models. In the multivariable analyses, only variables that were associated with overweight/obesity ($p < 0.05$) were retained. Covariates such as age, gender, SES, physical activity and dietary habits were forced in all multivariable models. All analyses were performed with Stata 13.0 using cases with complete data. Statistical significance was set at $p < 0.05$.

Results

Background characteristics

This analysis involves data from 543 children. The sociodemographic characteristics of children are presented in Table 1. The mean age of children who participated in the study was 9.8 ± 1.0 years with majority being females (62.4%). Compared with public schools, more children attending private schools live in households in the high socioeconomic category (16.2% vs 50.4%; $p < 0.0001$).

The behavioural characteristics of the children are summarised in Table 2. Fruits and vegetables intake was high (91.5 and 87.5%). Generally, the intakes did not differ by gender or school type. Compared with children who attended public schools, a significantly higher proportion of children in private schools consumed breakfast (78.3% vs 65.7%; $p = 0.001$), chips, sweets and chocolates snacks (68.7% vs 57.9%; $p = 0.009$), fried foods (56.2% vs

Table 1 Background characteristics of participating children by gender and type of school[a, b]

	Overall	Gender		p-value	School type		p-value
		Female	Male		Private	Public	
Number (%)	543 (100)	339 (62.4)	204 (37.6)	0.265	272 (50.1)	271 (49.9)	
Age (years)	9.8± 1.0	9.8 ± 1.0	9.9 ± 1.0		9.8 ± 1.0	9.9 ± 1.0	0.725
Age groups							
8–9	199 (36.7)	129 (38.0)	70 (34.3)	0.217	98 (36.0)	101 (37.3)	0.764
10–11	344 (63.4)	210 (62.0	134 (65.7)		174 (64.0)	170 (62.7)	
Household size				0.020			0.396
≤ 3	31 (5.7)	17 (5.0)	14 (6.9)		16 (5.9)	15 (5.5)	
4 - 6	323 (59.5)	210 (62.0)	113 (55.4)		170 (62.5)	153 (56.5)	
7 - 10	168 (30.9)	94 (27.7)	74 (36.3)		78 (28.7)	90 (33.2)	
≥ 10	21 (3.9)	18 (5.3)	3 (1.4)		8 (2.9)	13 (4.8)	
Father's occupation				0.913		*	< 0.0001
Artisan	149 (27.4)	96 (28.3)	53 (26.0)		34 (12.5)	115 (42.2)	
Trading	58 (10.7)	36 (10.6)	22 (10.8)		42 (15.4)	16 (5.9)	
Professional[c]	181 (33.3)	112 (33.0)	69 (33.8)		138 (50.7)	43 (15.9)	
Other	117 (21.6)	69 (20.3)	48 (23.5)		42 (15.4)	75 (27.7)	
I do not know	18 (3.3)	12 (3.5)	6 (2.9)		12 (4.4)	6 (2.2)	
Unemployed/retired	20 (3.7)	14 (4.1)	6 (2.9)		4 (1.5)	16 (5.9)	
Mother's occupation				0.311			0.003
Artisan	75 (13.8)	46 (13.6)	29 (14.2)		38 (14.0)	37 (13.7)	
Trading	290 (53.4)	187 (55.2)	103 (50.5)		142 (52.2)	148 (54.6)	
Professional[c]	99 (18.2)	57 (16.8)	42 (20.6)		65 (23.9)	34 (12.6)	
Other	35 (6.5)	23 (6.8)	12 (5.9)		12 (4.4)	23 (8.5)	
I do not know	5 (0.9)	5 (1.5)	–		2 (0.7)	3 (1.1)	
Unemployed/retired	39 (7.2)	21 (6.2)	18 (8.8)		13 (4.8)	26 (9.6)	
Socioeconomic status of household				0.639			< 0.0001
Low	181 (33.3)	116 (34.2)	65 (31.9)		41 (15.1)	140 (51.7)	
Middle	181 (33.3)	115 (33.9)	66 (32.3)		94 (34.6)	87 (32.1)	
High	181 (33.3)	108 (31.9)	73 (35.8)		137 (50.4)	44 (16.2)	

[a]Values presented as numbers and percentages; [b]Mean (SD); [c]Professionals include doctors, lawyers, engineers, pharmacists and teachers
$p < 0.05$

40.6%; $p < 0.0001$) and, sweetened beverages and soft drinks (84.2% vs 74.2%; $p = 0.004$).

The overall mean physical activity score was 2.56 ± 0.56. The majority of the children (81.8%) engaged in moderate physical activity with only a few (1.4%) participating in high physical activity. Overall, about one-third met physical activity recommendations levels with a higher proportion of girls than boys (37.2 and 29.4%), and more children in public compared with those in private schools (39.9% vs 28.7%; $p = 0.006$). Additionally, the mode of transport to and from school differed by school type, but not by gender. A significantly higher proportion of children attending private schools used cars, vehicles or bus compared with their counterparts in public schools (49.3% vs 29.1%, $p < 0.0001$). Majority (62.1%) spent less than 2 h a day watching television and this did not differ by gender or type of school. Moreover, a higher proportion of boys than girls (45.1% vs 35.7%; $p = 0.03$) played video and computer games. The majority of the children had sufficient sleep at night; only 23.9% slept for less than 9 h a night.

Prevalence of overweight and obesity

With regards to BMI status, 6.1% of the children were thin, 77.5% were normal weight, 9.2% overweight and 7.2% obese (Table 3). More girls (10.6%) than boys (6.9%) were overweight whereas more boys (9.3%) than girls (5.9%) were obese. Nonetheless, the observed difference was not significant. A significantly higher proportion of children attending private schools were overweight and obese (12.9 and 11.0%) compared with those in public

Table 2 Behavioural characteristics of participating children by sex and type of school [a,b]

	Overall	Sex		p-value	School type		p-value
		Female	Male		Private	Public	
Breakfast				0.343			0.001
No	152 (28.0)	95 (28.0)	57 (27.9)		59 (21.7)	93 (34.3)	
2–3 days/week	93 (17.1)	64 (18.9)	29 (14.2)		41 (15.1)	52 (19.2)	
3 or more times/week	298 (54.9)	180 (53.1)	118 (57.8)		172 (63.2)	126 (46.5)	
Fruits				0.069			0.213
No/rarely	46 (8.5)	23 (6.8)	23 (11.3)		19 (7.0)	27 (10.0)	
3 or more times/week	497 (91.5)	316 (93.2)	181 (88.7)		253 (93.0)	244 (90.0)	
Vegetables				0.084			0.808
No/rarely	68 (12.5)	36 (10.6)	32 (15.7)		35 (12.9)	33 (12.2)	
3 or more times/week	475 (87.5)	303 (89.4)	172 (84.3)		237 (87.1)	238 (87.8)	
Chips, sweets, chocolates				0.107			0.009
No/rarely	199 (36.7)	133 (39.2)	66 (32.4)		85 (31.3)	114 (42.1)	
3 or more times/week	344 (63.3)	206 (60.8)	138 (67.6)		187 (68.7)	157 (57.9)	
Fried foods				0.357			< 0.0001
No	156 (28.7)	109 (32.1)	47 (23.0)		89 (32.7)	67 (24.7)	
2–3 times/week	124 (22.8)	71 (20.9)	53 (26.0)		30 (11.0)	94 (34.7)	
More than 3 times/week	263 (48.4)	159 (46.9)	104 (51.0)		153 (56.3)	110 (40.6)	
Sweetened beverages and soft drinks				0.787			< 0.0001
No	104 (19.1)	68 (20.1)	36 (17.7)		46 (16.9)	58 (21.4)	
2–3 times/week	149 (27.4)	92 (27.1)	57 (27.9)		55 (20.2)	94 (34.7)	
More than 3 times/week	290 (53.4)	179 (52.8)	111 (54.4)		171 (62.9)	149 (43.9)	
Mean physical activity score [b]	2.56 ± 0.56	2.55 ± 0.54	2.57 ± 0.61	0.652	2.52 ± 0.57	2.60 ± 0.57	0.116
Physical activity level				0.388			0.995
Low	91 (16.8)	52 (15.3)	39 (19.1)		46 (16.9)	45 (16.6)	
Moderate	444 (81.8)	283 (83.5)	161 (78.9)		222 (81.6)	222 (81.9)	
High	8 (1.4)	4 (1.2)	4 (2.0)		4 (1.5)	4 (1.5)	
Meeting PA guidelines				0.065			0.006
No	357 (65.8)	213 (62.8)	144 (70.6)		194 (71.3)	163 (60.1)	
Yes	186 (34.2)	126 (37.2)	60 (29.4)		78 (28.7)	108 (39.9)	
Transport to and from school				0.362			< 0.0001
Walking/cycling	330 (60.8)	201 (59.3)	129 (63.2)		138 (50.7)	192 (70.9)	
Motorised	213 (39.2)	138 (40.7)	75 (36.8)		134 (49.3)	79 (29.1)	
TV Watch duration				0.177			0.056
2 h or less/day	337 (62.1)	203 (59.9)	134 (65.7)		158 (58.1)	179 (66.1)	
More than 2 h/day	206 (37.9)	136 (40.1)	70 (34.3)		114 (41.9)	92 (33.9)	
Playing video/ computer games				0.030			0.449
No/rarely	330 (60.8)	218 (64.3)	112 (54.9)		161 (59.2)	169 (62.4)	
3 times or more/week	213 (39.2)	121 (35.7)	92 (45.1)		111 (40.8)	102 (37.6)	
Sleep duration				0.810			0.074
Less than 9 h	130 (23.9)	80 (23.60)	50 (24.5)		74 (27.2)	56 (20.7)	
9 h or more	413 (76.1)	259 (76.4)	154 (75.5)		198 (72.8)	215 (79.3)	

[a]Values presented as number and percentages; [b]mean (SD)
$p < 0.05$

Table 3 Anthropometric characteristics of school children by gender and type of school

	Overall	Gender		*p*-value	School type		*p*-value
		Female ($n = 339$)	Male ($n = 204$)		Private ($n = 272$)	Public ($n = 271$)	
Body mass index categories (%)				0.230			< 0.0001
Thinness	33 (6.1)	22 (6.5)	11 (5.4)		18 (6.6)	15 (5.5)	
Normal weight	421 (77.5)	261 (77.0)	160 (78.4)		189 (69.5)	232 (85.6)	
Overweight	50 (9.2)	36 (10.6)	14 (6.9)		35 (12.9)	15 (5.5)	
Obesity	39 (7.2)	20 (5.9)	19 (9.3)		30 (11.0)	9 (3.3)	

Thinness: BAZ < −2SD; Overweight: +1SD < BAZ < +2SD; Obese: + ≥2SD BAZ; (WHO, 2007)
$p < 0.05$

schools (5.5 and 3.3%). Overall prevalence of overweight (and obesity) was 16.4%; 16.5% of girls and 16.2% of boys and by school type 23.9% private and 8.8% public.

Factors associated with overweight and obesity

Table 4 shows the factors associated with overweight or obesity. In the gender and age-adjusted analyses, children living in middle and high SES households were more likely to be overweight or obese compared with those living in low SES households (OR = 1.87, 1.0–3.48 and OR = 2.57, 1.41–4.68 respectively). Children who attending private schools had higher odds of overweight or obesity than those attending public schools (OR = 3.23, 1.95–5.35). It was realised that children who watched television for more than 2 h a day (OR = 2.08, 1.31–3.28) were twice likely to be overweight or obesity.

Active transport to and from school (OR = 0.39, 0.25–0.62) was associated with decreased likelihood of overweight or obesity as compared with motorised transport. Additionally, longer sleep duration (for at least 9 h a night) was similarly associated with decreased odds of overweight or obesity (OR = 0.41, 0.25–0.66).

Intake of sweetened beverages and soft drinks, chips, sweets and chocolate for snack, breakfast, fruits and vegetables, and overall physical activity were not significantly associated with overweight or obesity.

After adjusting for SES, age, gender, physical activity and dietary habits, attending private school (AOR = 2.44, 1.39–4.29) and watching television for at least 2 h a day (AOR = 1.72, 1.05–2.82) were significantly associated with increased likelihood of overweight and obesity whereas sleeping for at least 9 h a night (AOR = 0.53, 0.31–0.88), and using active transport to and from school were associated with decreased odds of overweight and obesity.

Discussion

The results of this study highlights the burden of overweight and obesity, the behavioural and sociodemographic correlates in school children aged 8–11 years living in an urban area in Ghana. Among these urban children, the overall prevalence of overweight or obesity was 16.4%, supporting results from previous studies in South Africa, Tanzania and Kenya [5, 39–41], and also in developed countries [20, 42]. In a study involving Kenyan urban school children aged 9–11 years, an overweight/obesity prevalence of 20.8% was reported [41]. In another study in South Africa, overweight or obesity prevalence of 22.9% was reported among school children aged 7–18 years [5]. While the prevalence in the present study may be lower than what had been reported in other countries, the results has demonstrated the burden of overweight and obesity in Ghanaian school children considering that the participants in the present study were younger (8–11 years). The observed trend is mostly consistent with the nutrition transition and urbanisation in the region [21].

Positive associations were found between overweight or obesity, SES and attending private school, a finding supportive of results from previous studies [22, 24, 41, 43]. Results from a recent systematic review of 20 studies involving school-aged children from sub-Saharan Africa suggested that children from the highest SES households and attending affluent or private schools were significantly more likely to be overweight or obese [22].

High SES households in developing countries may have access to high energy foods and drinks and processed foods compared with low SES households [44, 45]. Moreover, there may be increased use of technology [45] such as cars, electronic devices and indoor entertainments facilities like gaming consoles and televisions in the high SES households compared to low SES households. In this study, significantly higher proportion of children attending private schools were from higher SES households, consumed high energy foods, snacks and drinks, and used motorised transport to and from school compared to children attending public schools, consistent with the aforementioned findings. Additionally, more children in private schools were engaged in sedentary activities compared to those in public schools, though not significant. These dietary and sedentary habits could contribute to weight gain among the children [39]. The results from this study however contrast observations from developed countries where inverse associations exist between SES and overweight or obesity prevalence [42, 46, 47]. This has been attributed to low

Table 4 Factors associated with overweight or obesity

	Odds ratio	95% CI	*p*-value	Adjusted Odds Ratio[a]	95% CI	*p*-value
Age group						
8–9	1	0.46–1.16				
10–11	0.73		0.183			
Sex						
Female	1	0.61–1.56				
Male	0.97		0.917			
School type						
Public	1	1.95–5.35		1		
Private	3.23		< 0.0001	2.44	1.39–4.29	0.002
Household socioeconomic status						
Low	1			1		
Medium	1.87	1.01–3.48	0.048	1.30	0.67–2.55	0.437
High	2.57	1.41–4.68	0.002	1.27	0.66–2.66	0.494
Eat breakfast						
No	1	0.51–2.00	0.984			
2–3 days/week	1.01	0.54–1.53	0.717			
More than 3 days	0.91					
Eat fruits						
No	1					
Yes	0.789	0.37–1.70	0.544			
Eat vegetables						
No	1					
Yes	0.723	0.38–1.37	0.319			
Eat chips, sweets, chocolate snacks						
No	1					
Yes	1.17	0.72–1.88	0.529			
Fried foods						
No	1	0.46–1.72				
2–3 times/week	0.89	0.65–1.89	0.728			
More than 3 times/week	1.11		0.699			
Sweetened beverages and soft drinks						
No	1					
2–3 times/week	1.62	0.79–3.30	0.184			
More than 3 times	1.39	0.72–2.68	0.329			
Physical activity level						
Low	1	0.46–1.49				
Moderate	0.83	0.07–5.40	0.529			
High	0.62		0.667			
Mode of transport to/from school						
Motorised	1			1		
Walking/cycling	0.39	0.25–0.62	< 0.0001	0.51	0.31–0.82	0.006
TV watch duration						
2 h or less/day	1	1.31–3.28		1		
More than 2 h/day	2.08		0.002	1.72	1.05–2.82	0.031

Table 4 Factors associated with overweight or obesity *(Continued)*

	Odds ratio	95% CI	p-value	Adjusted Odds Ratio[a]	95% CI	p-value
Sleep duration						
8 h or less	1	0.25–0.66		1		
9 h or more	0.41		< 0.0001	0.53	0.31–0.88	0.015

[a]Models adjusted for age, sex, SES, physical activity and dietary habits
$p < 0.05$

consumption of healthy foods [48], less physical activity and high sedentary behaviours in low SES groups [49].

The present study did not observe an association of overweight or obesity with overall physical activity participation. However a significant inverse association was found with active transport to and from schools, consistent with previous studies [24, 39, 50, 51]. For example in the International Study of Childhood Obesity, Lifestyle and Environment (ISCOLE) multinational study involving 12 countries, active transport was associated with lower risk of obesity [50]. Children who engage in active transport to school had higher odds of meeting moderate-to-vigorous physical activity recommendations [41, 52, 53]. However other studies also reported conflicting results of an association [13].

There is epidemiological evidence linking sleep duration to overweight or obesity in children and adolescents [14–16, 54]. In the present study, a significant inverse association was found between sleep duration and overweight or obesity, an observation consistent with previous studies [16, 55, 56]. For example results from one recent systematic review and meta-analysis indicate short sleep duration increases the risk of childhood obesity [14]. Likewise, results from cross-sectional and prospective studies highlighted consistent inverse associations between sleep duration and the risk of obesity [54]. The underlying mechanisms through which sleep influences weight status are not well-understood. Results from 29 studies conducted in 16 countries involving children and adolescents suggest changes in food intake pathways [54] and excessive media use [57] may play a role. Shorter sleep duration may result in several hormonal changes and metabolic abnormalities [54]. While available evidence suggests that sleep influences weight status through increased appetite, hunger and food intake [58, 59], the evidence in support of reduced energy expenditure through decreased physical activity and increased sedentary behaviour is conflicting [60].

The association of television viewing time and overweight or obesity observed in this study is consistent with previous studies [16, 61–64]. Results from a large sample of children and adolescents from mostly low-to-middle income countries demonstrated a positive association between television time and BMI [61]. Similarly, results from a recent meta-analysis of 14 cross-sectional studies and 24 reports involving 106,169 children suggested that increased TV watching is associated with higher risk of childhood obesity [63]. Also, findings from the review by Tremblay et al. [64] indicated that watching television for more than two hours a day was associated with unfavourable health outcomes including body composition, of children and youth. Although it does not capture the whole spectrum of sedentary behaviour, television viewing which is most commonly used as a proxy for sedentary behaviour in children and adolescents [64], appears to be more closely associated with weight status in children.

Several potential mechanisms have been proposed to explain the link between television viewing and obesity. These include limited time available to engage in outdoor games leading to overall reduced physical activity [65, 66], increased energy intake via snacking while watching television as well as exposure to advertisements involving high energy foods and snacks [66, 67]. Among US children, hours of television watch was positively associated with total energy intake and inversely associated with physical activity [66]. Evidence from Australia, the USA and eight European countries suggests an association between overweight in children and the number of advertisements per hour on children television, particularly those advertisements that promote the consumption of energy-dense, nutrient-poor foods [67]. It is however worth noting that playing video and computer games was not associated with being overweight or obese in the present study contrary to results from other studies.

Unlike other studies [19, 47, 68–70], no evidence of an association was found among overweight/obesity with dietary intake and overall physical activity. Physical education and physical activity are mandatory requirement of the basic school curriculum in Ghana and as such all healthy school-going children are expected to fully participate. Nonetheless, data available suggest that 50% of Ghanaian children and adolescents in schools engage in sports [71]. In the present study, the proportion of children who met recommended physical activity guidelines was 34.2% consistent with results from Physical Activity Report Card [71], suggesting low physical activity participation. Despite not meeting the guidelines, it is possible majority of the children engaged in games and sporting activities during and after school hours. This could partly explain the lack of association between physical activity and overweight or obesity.

Strengths and limitations

The present study was conducted in an urban district hence the findings can be generalised to apparently healthy children in urban schools in Ghana. Another strength of the study was the objective measurement of weight and height as opposed to self-reported anthropometric data. Further, physical activity was assessed using PAQ-C, a validated tool for physical activity assessment among children in the school settings. Additionally, the sleep duration cut-off points used were based upon guidelines of a well-recognised organisation.

There were limitations to the interpretation of the findings of the current study. Firstly, the study design was cross-sectional and inferences of causality could not be made. Secondly, self-reported data was obtained from children and this has its inherent challenges including: social desirability, recall bias and misreporting [72]. The lack of association with dietary intake could be attributed to inaccuracies in measuring dietary data by recall, and under-reporting of snack, fatty foods, and foods rich in carbohydrates, commonly observed in obese individuals [72]. Since data was not collected on quantities of foods and drinks consumed, it is possible that children in the overweight/obesity category consumed these foods less often but in higher quantities. In addition, grouping the wealth score of the households into thirds may have resulted in ranking the poor and the very poor incorrectly. Nevertheless this methodology is reliable in ranking household SES status in these settings in the absence of income and expenditure data [38]. Another potential limitation worth noting was that the multilevel structure of the data was not accounted for in the analyses. Although several potential covariates including physical activity and dietary habits were controlled for in the analyses, these were not objectively assessed. Data on an important confounder, parental BMI was not collected. Despite these limitations, the data collected was reliable and reflected what had been reported in the literature on the issues of childhood overweight and obesity.

Conclusion

Changes in economic status and sociodemographic profiles associated with urbanisation favour lifestyle behaviours shifts towards less physical activity, increased sedentary habits and unhealthy dietary patterns. Several correlates such as attending private school, short sleep duration, high level of television watching, and motorised transport were associated with overweight and obesity among school children in urban Ghana. Public health interventions to address childhood overweight and obesity could target both homes and schools. Watching television may represent one important area of intervention targeting obesity prevention in children. At the home settings, parents could consider restricting time spent in watching television among school children. We recommend the promotion and support of regular active transport by the schools and families.

Abbreviations

AOR: Adjusted odds ratio; BAZ: Body mass index for age Z scores; BMI: Body mass index; CI: Confidence intervals; ISCOLE: International Study of Childhood Obesity, Lifestyle and Environment; OR: Odds ratio; PA: Physical activity; PAQ-C: Physical activity questionnaire for children; SD: Standard deviation; SES: Socio-economic status; WHO: World Health Organisation

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Availability of data and materials

The dataset(s) supporting our findings are available from the corresponding author upon reasonable request.

Authors' contributions

TA, APK, ADV and TP designed the study. TA collected and assembled the data. TA and APK analysed the data. TA, APK, TP and ADV interpreted the data. TA drafted the first manuscript. APK, TP and ADV participated in revision of the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Ethical Review Committee of the Ghana Health Service and the Senate Research Committee of the University of the Western Cape. Approval was also obtained from the Municipal Education Directorate of the Ghana Education Service as well as from the heads of all participating schools. Written informed consent was obtained from parents/legal guardians of all participating children. Verbal assent was obtained from every participating child.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interest.

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References

1. de Onis M, Blössner M, Borghi E. Global prevalence and trends of overweight and obesity among preschool children. Am J Clin Nutr. 2010; 92(5):1257–64.
2. Lobstein T, Baur L a, Uauy R. Obesity in children and young people: A crisis in public health. Obes Rev. 2004;5 Suppl 1:4–85.
3. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384(9945):766–81.
4. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an overweight/obesity transition among school-aged children and youth in sub-Saharan Africa: a systematic review. PLoS One. 2014;9(3):1–26.

5. Negash S, Agyemang C, Matsha TE, Peer N, Erasmus RT, Kengne AP. Differential prevalence and associations of overweight and obesity by gender and population group among school learners in South Africa: a cross-sectional study. BMC Obes. 2017;4(1):29.
6. Reilly JJ. Health consequences of obesity. Arch Dis Child. 2003;88(9):748–52.
7. Agyemang C, Redekop WK, Owusu-Dabo E, Bruijnzeels M. a. Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. BMC Public Health. 2005;5:114.
8. Salman Z, Kirk GD, DeBoer MD. High rate of obesity-associated hypertension among primary schoolchildren in Sudan. Int J Hypertens. 2011;2011:1–5.
9. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes. 2011;35(7):891–8.
10. Singh AS, Mulder C, Twisk JWR, Van Mechelen W, Chinapaw MJM. Tracking of childhood overweight into adulthood: a systematic review of the literature. Obes Rev. 2008;9(5):474–88.
11. Swinburn B, Egger G, Ph D, Raza F. Dissecting Obesogenic Environments : The Development and Application of a Framework for Identifying and Prioritizing Environmental Interventions for Obesity 1. Prev Med. 1999; 29(5 70):563–70.
12. Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. Int J Obes. 2004;28:S2–9.
13. Larouche R, Saunders TJ, John Faulkner GE, Colley R, Tremblay M. Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. J Phys Act Health. 2014;11(1):206–27.
14. Li L, Zhang S, Huang Y, Chen K. Sleep duration and obesity in children: a systematic review and meta-analysis of prospective cohort studies. J Paediatr Child Health. 2017;53(4):378–85.
15. Chen X, Beydoun MA, Wang Y. Is Sleep Duration Associated With Childhood Obesity ? A Systematic Review and Meta-analysis. Obesity (Silver Spring). 2008;16(2):265–7.
16. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Relationship between lifestyle behaviors and obesity in children ages 9–11: Results from a 12-country study. Obes (Silver Spring). 2015;23(8):1696–702.
17. Huang J-Y, Qi S-J. Childhood obesity and food intake. World J Pediatr. 2015; 11(2):101–7.
18. Candib LM. Obesity and diabetes in vulnerable populations: reflection on proximal and distal causes. Ann Fam Med. 2007;5(6):547–56.
19. Newby PK. Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence. J Law Med Ethics. 2007; 35(1):35–60.
20. Ogden CL, Lamb MM, Caroll MD, Flegal KM. Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. NCHS Data Brief. 2010;127(51):1–8.
21. Ziraba AK, Fotso JC, Ochako R. Overweight and obesity in urban Africa: a problem of the rich or the poor? BMC Public Health. 2009;9(1):465.
22. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. Clin Obes. 2016;6(1):19–32.
23. Ghana Statistical Service. Ghana Demographic and Health Survey Preliminary Report 2008. 2009;
24. Aryeetey R, Lartey A, Marquis GS, Nti H, Colecraft E, Brown P. Prevalence and predictors of overweight and obesity among school-aged children in urban Ghana. BMC Obes. 2017;4(1):38.
25. Mogre V, Gaa PK, Nagumsi R, Abukari S. Overweight , Obesity and Thinness and Associated Factors Among School- Aged Children (5–14 Years) in Tamale. Eur Sci J. 2013;9(20):160–75.
26. Ochola S, PK Iny M. Dietary intake of schoolchildren and adolescents in developing countries. Ann Nutr Metab. 2014;64:24–40.
27. Peltzer K, Pengpid S. Overweight and obesity and associated factors among school-aged adolescents in Ghana and Uganda. Int J Env Res Public Heal. 2011;8(10):3859–70.
28. Pengpid S, Peltzer K. Overweight and Obesity and Associated Factors among School-Aged Adolescents in Six Pacific Island Countries in Oceania. Int J Env Res Public Heal. 2015;12(11):14505–18.
29. Mohammed H, Vuvor F. Prevalence of childhood overweight/obesity in basic school in Accra. Ghana Med J. 2012;46(3):124–7.
30. Ghana Statistical Service. Adentan Municipality: Population and housing census. Vol. 2, District Analytical Report. 2014.
31. Ghana School Survey. Nutrition and obesity report of the Ghana school survey results dissemination workshop, September 2012. Accra: Department of Nutrition and Food Science, University of Ghana and School of Human Nutrition and Dietetics, McGill University, Montreal; 2012; 2012.
32. Daniel WW. Biostatics; a foundation for analysis in the health sciences. 7th ed. New York: John Wiley and sons; 1999.
33. Onge ES, Miller SA, Motycka C, DeBerry A. A review of the treatment of type 2 diabetes in children. J Pediatr Pharmacol Ther. 2015;20(1):4–16.
34. Kowalski KC, Crocker PRE, Donen RM. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. Coll Kinesiol Univ Saskatchewan. 2004:1–37.
35. Voss C, Ogunleye AA, Sandercock GRH. Physical activity questionnaire for children and adolescents: English norms and cut-off points. Pediatr Int. 2013;55(4):498–507.
36. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National sleep foundation's sleep time duration recommendations: methodology and results summary. Sleep Heal. 2015;1(1):40–3.
37. De Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Heal Organ. 2007;85(10):812–9.
38. Filmer D, Pritchett L. Estimating wealth effects without expenditure data--or tears: an application to educational enrollments in states of India. Demography. 2001;38(1):115–32.
39. Mwaikambo SA, Leyna GH, Killewo J, Simba A, Puoane T. Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. BMC Public Health. 2015;15:1269.
40. McKersie J, Baard ML. Obesity in 7–10-year-old children in urban primary schools in Port Elizabeth. South African J Sport Med. 2014;26(2):55.
41. Muthuri SK, Wachira LJ, Onywera VO, Tremblay MS. Correlates of objectively measured overweight/obesity and physical activity in Kenyan school children: results from ISCOLE-Kenya. BMC Public Health. 2014;14(9):436.
42. Sanigorski AM, Bell C, Kremer PJ, Swinburn B. High childhood obesity population in an Australian population. Obesity. 2007;15(8):1908–12.
43. Ajayi EO, Elechi HA, Alhaji MA. Prevalence of overweight / obesity among primary school pupils in Urban Centre. Nigeria. 2015:59–65.
44. Hanson MD, Chen E. Socioeconomic status and health behaviors in adolescence: a review of the literature. J Behav Med. 2007;30(3):263–85.
45. Dinsa GD, Goryakin Y, Fumagalli E, Suhrcke M. Obesity and socioeconomic status in developing countries : a systematic review. Obes Rev. 2012:1067–79.
46. Rogers R, Eagle TF, Sheetz A, Woodward A, Leibowitz R, Song M, et al. The relationship between childhood obesity, low socioeconomic status, and race/ethnicity: lessons from Massachusetts. Child Obes. 2015;11(6):691–5.
47. Gupta N, Goel K, Shah P, Misra A. Childhood obesity in developing countries: epidemiology, determinants, and prevention. Endocr Rev. 2012;33(1):48–70.
48. Drewnowski A. Obesity, diets, and social inequalities. Nutr Rev. 2009; 67(SUPPL. 1):S36–S39.
49. Drenowatz C, Eisenmann JC, Pfeiffer KA, Welk G, Heelan K, Gentile D, et al. Influence of socio-economic status on habitual physical activity and sedentary behavior in 8- to 11-year old children. BMC Public Health. 2010;10.
50. Sarmiento OL, Lemoine P, Gonzalez SA, Broyles ST, Denstel KD, Larouche R, et al. Relationships between active school transport and adiposity indicators in school-age children from low-, middle- and high-income countries. Int J Obes Suppl. 2015;5(Suppl 2):S107–14.
51. Larouche R, Lloyd M, Knight E, Tremblay MS. Relationship Between Active School Transport and Body Mass Index in Grades- 2011;3:22–30.
52. Denstel KD, Broyles ST, Larouche R, Sarmiento OL, Barreira TV, Chaput J-P, et al. Active school transport and weekday physical activity in 9–11-year-old children from 12 countries. Int J Obes Suppl. 2015;5:S100–6.
53. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV, et al. Physical activity of children: a global matrix of grades comparing 15 countries. J Phys Act Health. 2014;11(s1):S113–25.
54. Hart CN, Cairns A, Jelalian E. Sleep and obesity in children and adolescents. Pediatr Clin N Am. 2012;58(3):715–33.
55. Rosi A, Calestani MV, Parrino L, Milioli G, Palla L, Volta E, et al. Weight status is related with gender and sleep duration but not with dietary habits and physical activity in primary school Italian children. Nutrients. 2017;9(6):1–10.
56. Morrissey B, Malakellis M, Whelan J, Millar L, Swinburn B, Allender S, et al. Sleep duration and risk of obesity among a sample of Victorian school children. BMC Public Health. 2016;16(1):1–8.

57. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and adolescents: a review. Sleep Med. 2010;11(8):735–42.
58. Westerlund L, Ray C, Roos E. Associations between sleeping habits and food consumption patterns among 10-11-year-old children in Finland. Br J Nutr. 2009;102(10):1531–7.
59. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. Sleep. 2010;33(9):1201–9.
60. Chaput J-P, Tremblay A. Insufficient sleep as a contributor to weight gain: an update. Curr Obes Rep. 2012;1(4):245–56.
61. Braithwaite I, Stewart AW, Hancox RJ, Beasley R, Murphy R, Mitchell EA. The Worldwide Association between Television Viewing and Obesity in Children and Adolescents: Cross Sectional Study. PLoS One. 2013;8(9).
62. Peck T, Scharf RJ, Conaway MR, DeBoer MD. Viewing as little as 1 hour of TV daily is associated with higher change in BMI between kindergarten and first grade. Obesity. 2015;23(8):1680–6.
63. Zhang G, Wu L, Zhou L, Lu W, Mao C. Television watching and risk of childhood obesity: a meta-analysis. Eur J Pub Health. 2016;26(1):13–8.
64. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act. 2011;8(1):98.
65. Dutra GF, Kaufmann CC, Pretto ADB, Albernaz EP. Television viewing habits and their influence on physical activity and childhood overweight. J Pediatr. 2015;91(4):346–51.
66. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children. ArchPediatrAdolescMed. 2001;155:360–5.
67. Lobstein T, Dibb S. Evidence of a possible link between obesogenic food advertising and child PubMed commons. Obes Rev. 2005;6(3):203–8.
68. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. Obes Rev. 2013;14(8):606–19.
69. Zakrzewski JK, Gillison FB, Cumming S, Church TS, Katzmarzyk PT, Broyles ST, et al. Associations between breakfast frequency and adiposity indicators in children from 12 countries. Int J Obes Suppl. 2015;5(Suppl 2):S80–8.
70. Mushtaq MU, Gull S, Mushtaq K, Shahid U, Shad MA, Akram J. Dietary behaviors, physical activity and sedentary lifestyle associated with overweight and obesity, and their socio-demographic correlates, among Pakistani primary school children. Int J Behav Nutr Phys Act. 2011;8(1):130.
71. Ocansey R, Aryeetey R, Sofo S, Delali MB, Pambo P, Nyawornota VK. Results from Ghana's 2014 report card on physical activity for children and youth. J Phys Act Health. 2014;11(Supp 1):21–5.
72. Heitmann BL, Lissner L. Dietary underreporting by obese individuals: is it specific or non-specific? BMJ. 1995;311:986–9.

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Association between school-level attributes and weight status of Ghanaian primary school children

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Abstract

Background: Little is known about the impact of the school environmental context on the emerging trend of childhood obesity in Africa. We examined the association of the schools' contextual factors with body mass index (BMI), abdominal obesity and overweight (including obesity) in urban Ghana.

Method: Using cross-sectional data from 543 school children aged 8–11 years attending 14 primary schools, we applied multilevel logistic regressions and linear regression models to investigate the association of child- and school level attributes with overweight, abdominal obesity, and BMI.

Results: We observed significant variance of the random effects of schools in BMI (2.65, $p < 0.05$), abdominal obesity (0.85, $p < 0.05$), and overweight (1.41, $p < 0.05$) with school contextual levels accounting for 19.7, 20.6, and 30.0% of the total variability observed in BMI, abdominal obesity and overweight respectively. Attending high socioeconomic (SES) level school, private school and school with increased after-school recreational facilities were associated with higher BMI. Children were more likely to be overweight if they attended a high SES level school, had access to healthful foods at school, and after-school recreational facilities. With regards to abdominal obesity, attending a school with increased physical activity facilities decreased the odds of abdominal obesity; however the odds increased if they attended a school with access to after-school recreational facilities.

Conclusion: A number of school-level factors were associated with BMI, overweight and abdominal obesity of children in the present study. Our results provide support for improved school environment to reduce overweight.

Keywords: Body mass index, Overweight, Multilevel modelling, School children, Ghana

Background

Obesity among children presents a significant public health concern globally [1, 2] making its prevention a priority. It is well established that the aetiology of obesity is multifactorial [3]. Given the limited success of individual behavioural-based interventions to address the increasing prevalence of overweight and obesity [4], it is imperative to consider other factors outside of the individual. The ecological model, which postulates that changes in individual outcomes are influenced not only by individual-level factors such as age, gender, genetics and race/ethnicity but are also largely influenced by the socio-cultural, economic, and environmental context in which the individual lives, has been widely used in health promotion [5–8]. It is useful in providing better understanding of the multiple factors that may either facilitate or serve as barriers to making healthy choices. For the school-going child, the school is considered one important setting for the development of health-related behaviours and outcomes.

Schools are identified as one of the potential settings to deliver nutrition and physical activity interventions aimed at reducing childhood obesity [4, 9] as school children a spend considerable amount of their waking hours in the school settings. Prior research has investigated the associations of school demographics, school physical activity and food policies and resources, school

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neighbourhood, support for active transport, after-school recreational facilities and programmes in relation with the obesity epidemic [10–15]. Other studies have also examined school environments and health-related behaviours such as nutrition and physical activity [16–19]. The evidence from these studies underscores the importance of the school food and physical activity environments in shaping dietary and physical activity behaviours of school children and adolescents, and subsequently weight status. While the evidence is limited with regards to the contributions of school-level factors to the health-related behaviours and the emerging trend of childhood obesity in Africa, even fewer studies have examined the correlates of obesity in the context of the school environment using a multilevel approach. Moreover, the evidence provided by the aforementioned studies may not be generalisable to low-to-middle income countries like Ghana. Thus it is imperative to investigate the school contextual factors affecting child weight status, to inform the design and implementation of appropriate interventions. The present study aimed to examine the association of the schools' contextual factors with body mass index (BMI), abdominal obesity and overweight (including obesity) in urban Ghana.

Methods

Study design and study population

This was a school-based cross-sectional study with data collected in 543 school children aged 8–11 years in the Adentan Municipality of Greater Accra Region, an urban area in Ghana. We used a two-stage random sampling method to select schools and recruit the study participants. Briefly, 14 schools (eight private and six public) were selected from 148 basic schools (which were either exclusively primary, or primary and Junior High) in the Municipality. Five hundred and sixty-two (562) healthy children aged 8–11 years who provided parental and child approval were enrolled from the selected schools. Anthropometric data was collected by objective methods. Child- and school- level variables were obtained by self-report.

Outcome variables

The outcome variable was child weight status, defined as BMI, overweight (including obesity), and abdominal obesity.

Weight, height and waist circumference were measured by trained research assistants. Weight was measured twice to the nearest 0.1 kg with a digital scale (Seca 869, GmbH & Co, Germany). Children were weighed in their school uniforms, without shoes while removing extra clothing like jackets, sweaters, and also any heavy objects from the pockets. Height was measured twice to the nearest 0.1 cm with a Shorr Board (Shorr Productions, Olney, MD). Waist circumference was measured with a Seca measuring tape (tension tape) to the nearest 0.1 cm with the participants' arms relaxed at the sides and following normal expiration. Body mass index (BMI) was computed from the average measurements of weight and height as weight (in kilogramme) divided by height (in metres)^2. BMI-for-age Z-score (zBMI) was computed with the WHO AnthroPlus v.1.0.4 and used to categorise pupils into overweight (zBMI > = 1.0 SD) or not overweight (zBMI < 1.0 SD) [20]. Waist-to-height ratio (WHtR) was calculated from the average of the height and waist circumference. Abdominal obesity was defined as WHtR ≥0.45 in girls and ≥ 0.46 in boys [21].

Individual (child) level explanatory variables

Age was computed as the difference of date of birth and date of measurement. Children self- reported their sex by responding to the question "Are you a boy or a girl?" Data on household socioeconomic status (SES) indicators were obtained from self-reports. Household SES was evaluated using variables on source of water and sanitation, and household assets which were subjected to principal component analysis. The first component was extracted to create wealth scores of the household which were then split into three and reported as poor (lowest 40%), middle SES (40%) and rich (highest 20%) households [22]. Child age was modelled as a continuous variable. Two variables for wealth score were included, one continuous and the other categorical.

School level explanatory variables

The school heads/administrators completed interview-administered questionnaires on perceived built environment of neighbourhood/community surrounding the schools, school food environment and physical activity environment, policies and practices of physical activity and healthy eating. Two variables were used as indicators of school SES; the type of school (private/public) and aggregated wealth scores, computed from household wealth scores of individual children attending the same school. The school type was dummy coded as public = 0 and private = 1. The school-level SES was treated as a continuous variable in the analysis.

To assess the perceived neighbourhood quality, questions were asked on seven selected variables including mixed land use/access, places for walking and bicycling, free or low cost playgrounds or recreational facilities, aesthetic, traffic and crime rate. Four-point Likert scales responses ranging from "strongly disagree [1] to strongly agree [4] were used. Responses were collapsed and dichotomized into strongly disagree/somewhat disagree and strongly agree/somewhat agree. Negatively worded items were reverse coded and a summary score

"Perceived neighbourhood quality" was generated from 6 items (Cronbach alpha = 0.81), as one item was constant (that is no variability) such that a higher score indicates favourable environment. Perceived neighbourhood quality was modelled as a continuous variable.

To assess school policies and practices, respondents provided answers to the questions *"Does your school have written policies or practices concerning physical activity?", "Does your school have written policies or practices concerning healthy eating?"* Options were *"No/not applicable", "Yes, existing written policies", "Yes, written policies still under development"* and *"yes, practices.*

The respondents answered the questions: *"Is structured physical activity currently in the weekly timetable for the pupils", "How many sessions per week, and "How long is each physical activity session"*. Minutes spent per week for physical activity was computed from the number of sessions and time spent in physical activity and included as a continuous variable.

Six items were used to assess schools' support for active transport to and from school. The respondents answered questions on variables on safe walking/bicycling areas, and allowing or encouraging children to use bicycles and protective headgear like helmet. The response options included: no/I do not know (0) and yes [1]. One item *"Identify safe routes to use for walking and cycling to and from school"*, was constant and was therefore excluded from the analysis. A new variable "Support for active transport" was generated from the summary score of the remaining five [5] items (Cronbach alpha = 0.55), where a higher score indicated favourable ratings.

Access to 13 facilities on and off school grounds during school hours were used: fitness room, secure change room lockers, art room and music room, playground equipment like footballs, skipping ropes, basketballs, playgrounds, outdoor sport fields like basketball courts and any paved area for skipping; running tracks, playground equipment like basketballs, footballs, skipping ropes, netballs, gym, dance studio, auditorium for aerobics. A score of 1 was assigned where available, and 0 not available/do not know. Access to facilities on and off school grounds during school hours were compared with not available/do not know. Five [5] items were excluded (fitness room, secure change room lockers, art room and music room because none of the schools had these facilities) and one other item (playground equipment like footballs, skipping ropes, basketballs, etc.) was reported to be available in all 14 schools so was also excluded from analysis. A new quantitative variable "PA facilities index" was generated from the summary score based on seven items (Cronbach alpha = 0.60).

Respondents answered the questions *"Do pupils have access to the cafeterias, school shops, as well as restaurants close to school (within 1 km radius) where they can buy foods or drinks during school hours?"* The available options were yes and no. In addition, a checklist of foods and drinks on sale at the facilities was completed. If an item was available, a score of yes [1], or no (0) was given. Foods were categorised as healthful (raw fruits, raw vegetable salads, cooked meals, 100% fresh fruit juices) and less healthful (chocolates; sweets/toffees; sodas/soft drinks; packaged fruit juices; cakes, cookies, biscuits; chips; sausages rolls, doughnuts and & pies; regular chips & crackers; popcorn; and ice creams) and a composite scores generated for each school with higher scores indicating availability of these foods. The Cronbach alpha coefficient was 0.70 for healthful foods (four items) and 0.76 for less healthful foods (10 items). These were treated as continuous variables in the analysis.

Availability and accessibility of recreational facilities provided by the school, outside school hours was assessed using four items: 1) equipment (e.g., basketballs, skipping ropes, footballs); 2) indoor facilities, 3) outdoor facilities (e.g., playing fields, paved activity areas; and 4) gymnasium. A score of 1 was given where available, otherwise 0. A summary score "After-school recreational facilities" was generated (Cronbach alpha = 0.70) and modelled as a continuous variable.

The Senate Research Committee of the University of the Western Cape and Ethical Review Committee of the Ghana Health Service approved the study. Additional approval was obtained from the Municipal Education Directorate of the Ghana Education Service and from the heads of participating schools while parents or legal guardians of children provided written informed consent. Also, every participating child gave verbal assent after explaining the study.

Statistical analysis

All analyses were conducted with Stata 13.0. Mean and standard deviation, median and 25-75th percentiles, student t-test and Mann-Whitney test were used for continuous variables while frequencies and percentages, and chi-square (χ^2) test were used for categorical variables. Mixed effects models were used to account for the hierarchical nature of the data (pupils nested within schools). To estimate the association of binary outcomes, overweight and abdominal obesity, with child- and school level variables, mixed effects logistic regressions models (*melogit* command) with schools as random effects were fitted. The null model (model with no explanatory variables) was first fitted to report the random effects of the schools and also the intraclass correlation coefficient (ICC). Univariable analyses were then performed with each of the explanatory variables, individually. Explanatory variables which tended to contribute to the variability of outcome variables at $p < 0.20$ were selected and included in the multivariable models.

The estimated fixed-effects coefficients are reported as odds ratios (ORs), 95% confidence intervals (CI) and standard errors (SE).

For the continuous BMI variable, mixed effects linear regressions models with schools as random effects were performed to estimate the association of BMI with child level and school level explanatory variables. Similar to the mixed effects logistic regressions, the null model was fitted after which three other models, model 2 (individual level variables), model 3 (school level variables) and model 4 (individual and school levels variables) were fitted to estimate the effects of the variables. For model 4, only variables that contributed significantly to the variability in BMI were included. Estimates are maximum likelihood-based using the *mixed* command. Results are reported as estimates with 95% CI and SE. For all analyses, significance was set at $p < 0.05$. Child age and sex were controlled for in all multivariate models.

Results

Table 1 summarises the descriptive statistics at the individual (child) and school levels. The study reports data from 543 school children (37.6% boys). Half of the children attended private (50.1%) schools with median age 10 (25th -75th percentiles 9, 11) years. The overall mean BMI and WHtR were 17.03 (SD 3.56) kg/m^2 and 0.43 (SD 0.05). The corresponding prevalence of overweight (including obesity) and abdominal obesity were 16.4 and 18.8%. Children attending private schools had significantly higher BMI and WHtR compared to their peers in public schools (17.72 (SD 4.29) kg/m^2 vs 16.34 (SD 2.47) kg/m^2; $p < 0.0001$) and (0.43 (SD 0.06) vs 0.42 (SD 0.03); $p = 0.026$). Additionally, more than two-thirds of the children who were overweight, and 63.7% of those with abdominal obesity were attending private schools.

Nearly all the participating schools (seven private and six public) have some policies and practices on physical activity, which were existing, under development and or undergoing implementation. Policies and practices on nutrition and healthy eating were available in 90.4% (six private and six public) of the schools. Moreover, 81.7% of the children attended schools (seven private and five public) that had structured physical activity in the weekly timetable. Whereas over half (52.8%) of the schools had cafeteria, 34.4% had school shops. All (95.0%) but one private school reported that the communities surrounding the schools have fast food outlets. Overall summary scores for healthful and less healthful foods were 2.44 (SD 1.06) and 8.24 (SD 2.04) respectively. Children attending private schools had more options of both healthful (3.16 vs 1.72 $p < 0.0001$) and less healthful (9.10 vs 7.37; $p < 0.0001$) food available compared to their counterparts in public schools.

More facilities were available and accessible to children in private schools compared to those attending public schools. The overall mean physical activity facility index, after-school recreational facilities, schools' support for active transport and perceived neighbourhood quality were: 3.54 (SD 1.30), 0.65 (SD 0.97), 2.59 (SD 1.19) and 3.71 (SD 1.83). Children spent an average of 69.0 min (SD 16.4) weekly on physical activity. Moreover, the PA facility index was higher in private, compared to public schools (4.21 vs 2.87; $p < 0.0001$). On average, children in private schools spent more time per week in physical activities relative to those in public schools (76.5min vs 60.0min; $p < 0.0001$). Also, the summary score of after-school recreational facilities was higher in private compared to public schools (0.93 vs .037; $p < 0.0001$). Schools' support for active transport was 2.75 vs 2.43 in private and public schools respectively ($p = 0.0018$). Additionally, the perceived school neighbourhood quality were 3.99 ± 1.11 and 3.43 ± 2.3 ($p = 0.0004$) in private and public schools.

Factors associated with overweight (including obesity)

Table 2 shows factors associated with overweight. In the null model, the variance of random effects of schools was 1.408 ($p < 0.05$) and the ICC was 0.300, suggesting that 30% (12.8 to 55.4%) of the total variance observed in overweight in the study was at the school level. In univariable analyses, school level SES, school type, availability of cafeteria and shops at the schools, healthful foods and after-school recreational facilities predicted the likelihood of overweight. Children were more likely to be overweight if they attended private school, 4.19 (1.35, 13.00) and a higher level SES school, 2.05 (1.43, 2.94). Availability of school cafeteria and shops significantly increased the likelihood of overweight by 3.82 (1.25, 11.69) and 5.07 (1.74, 14.72) respectively. Similarly, availability of healthful foods increased the odds by 2.31 (1.26, 4.23), as did also after-school recreational facilities 1.85 (1.19, 2.88). In the model mutually adjusted for all significant predictors, and variables that tended to be related to overweight at $p < 0.2$ (less healthful foods and PA facility index) in univariable models, the likelihood of overweight increased by 2.00 (1.15, 3.46) with every unit increase in school-level SES. Moreover, for every extra unit increase in the availability of healthful foods and after-school creational facilities, the odds of overweight increased by 1.58 (1.06, 2.36) and 1.38 (1.01, 1.87) respectively. The school type, school cafeteria and shops were not significant in the adjusted model. Individual level variables were not significantly associated with the odds of being overweight. None of the school variables decreased the likelihood of overweight.

Table 1 Descriptive statistics at the individual and school levels

	Overall	Private	Public	*p*-value
Continuous variables*				
Individual level ($N = 543$)				
Age (years) ᵃ	10 (9, 11)	10 (9,11)	10 (9,11)	0.756
BMI (kg/m^2)	17.03 (3.56)	17.72 (4.29)	16.34 (2.47)	< 0.0001
WHtR	0.43 (0.05)	0.43 (0.06)	0.42 (0.03)	0.026
Household wealth index	0.27 (−1.47, 1.69)	1.10 (−0.11, 2.16)	− 0.87 (−2.43, 0.51)	< 0.0001
School level ($n = 14$)				
School level SES	0.11 (−0.34, 0.79)	0.78 (0.34, 1.27)	−0.34 (−1.73, − 0.20)	< 0.0001
Healthful foods	2.44 (1.06)	3.16 ± 0.85	1.72 ± 0.70	< 0.0001
Less healthful foods	8.24 (2.04)	9.10 ± 1.07	7.37 ± 2.39	< 0.0001
PA facility index	3.54 (1.30)	4.21 ± 1.07	2.87 ± 1.16	< 0.0001
Minutes per week for PA	69.00 (16.43)	76.5 ± 19.31	60.00 ± 0.00	< 0.0001
After-school recreational facilities	0.65 (0.97)	0.93 ± 1.23	0.37 ± 0.48	<0.0001
Support for active transport	2.59 (1.19)	2.75 ± 1.12	2.43 ± 1.24	0.002
Perceived neighbourhood quality	3.71 (1.83)	3.99 ± 1.11	3.43 ± 2.3	0.0004
Categorical variables*				
Individual level				
Sex				0.833
Boys	37.6 (204)	49.5 (101)	50.5 (103)	
Girls	62.4 (339)	50.5 (171)	49.5 (168)	
Household SES				<0.0001
Poor	40.1 (218)	26.1 (57)	73.9 (161)	
Middle	40.0 (217)	60.4 (131)	39.6 (86)	
Rich	19.9 (108)	77.8 (84)	22.2 (24)	
Overweight (including obesity)	16.4 (89)	73.0 (65)	27.0 (24)	<0.0001
Abdominal obesity	18.8 (102)	63.7 (65)	36.3 (37)	0.002
School level				
Physical activity policies and practices	94.3 (512)	47.1 (241)	52.9 (271)	< 0.0001
Nutrition and healthy eating policies and practices	90.4 (491)	44.8 (220)	55.2 (271)	<0.0001
Physical activity on timetable	81.7 (444)	88.6 (241)	74.9 (203)	<0.0001
School cafeteria	52.8 (287)	73.9 (212)	26.1 (75)	<0.0001
School shop	34.4 (187)	100. 0 (187)	–	<0.0001
Fast food outlets close to school	95.0 (516)	52.7 (272)	47.3 (244)	<0.0001

BMI Body mass index, *WHtR* waist-to-height ratio, *SES* socioeconomic status; * for continuous variables, mean (standard deviation), median (25th–75th percentiles) are reported and percent (frequency) for categorical variables

Factors associated with abdominal obesity

As shown in Table 3, in the null model, the variance of random effects of schools was 0.85 ($p < 0.05$) and the ICC was 0.206. This indicates that the school level contributes 20.6% (8.3 to 42.4%) of the total variance observed in abdominal obesity in the study sample. Higher school- level SES [1.64 (95% CI: 1.16, 2.32)]; availability of cafeterias [2.66 (1.02, 6.96)] and shops [3.47 (1.41, 8.56)] at the schools; and after-school recreational facilities [1.82 (1.32, 2.49)] were significantly associated with abdominal obesity in the univariable analyses. In the mutually adjusted model, additional variables that tended to be related to abdominal obesity (school type, healthful foods and PA facility index) in the univariable analyses were included. For every extra unit increase in PA facility index, the likelihood of abdominal obesity significantly decreased by 0.78 (0.63, 0.97), whereas the availability and accessibility of after-school recreational facilities increased the odds by 1.64 (1.23, 2.19). Individual level variables were not significantly associated with the odds of abdominal obesity.

Table 2 Individual and school factors associated with overweight

	Univariable models [a]			Multivariable models [b]		
	OR (95% CI)	SE	p-value	OR 95% CI	SE	p-value
Intercept (null model)	0.150 (0.074, 0.303)	0.054				
Age	0.931 (0.710, 1.220)	0.128	0.604	1.031 (0.791, 1.343)	0.139	0.823
Sex (Boys)	0.901 (0.540, 1.502)	0.235	0.689	0.921 (0.551, 1.540)	0.241	0.755
Median household wealth index	1.068 (0.915, 1.246)	0.084	0.404	–	–	–
Household SES						
Poor	1					
Middle	1.398 (0.751, 2.560)	0.442	0.290	–	–	–
Rich	1.220 (0.562, 2.648)	0.482	0.615	–	–	–
School level SES	2.052 (1.433, 2.939)	0.376	**< 0.0001**	1.998 (1.153, 3.462)	0.560	**0.014**
School type (Private)	4.190 (1.350, 13.004)	2.421	**0.013**	0.399 (0.110, 1.442)	0.262	0.161
School cafeteria	3.815 (1.245, 11.690)	2.179	**0.019**	1.329 (0.458, 3.857)	0.722	0.601
School shop	5.067 (1.744, 14.721)	2.757	**0.003**	1.343 (0.557, 3.237)	0.603	0.511
Fast food outlets close to school	1.379 (0.091, 20.851)	1.911	0.871	–	–	–
Healthful foods	2.313 (1.265, 4.229)	0.712	**0.006**	1.577 (1.055, 2.358)	0.323	**0.026**
Less healthful foods	1.274 (0.946, 1.716)	0.193	0.110	0.944 (0.735, 1.214)	0.121	0.656
PA facility index	0.848 (0.672, 1.071)	0.101	0.167	0.835 (0.661, 1.054)	0.099	0.129
Minutes per week for PA	0.980 (0.935, 1.028)	0.024	0.420	–	–	–
School support for active transport	0.936 (0.547, 1.603)	0.267	0.810	–	–	–
Perceived neighbourhood quality	1.263 (0.845, 1.887)	0.259	0.255	–	–	–
After-school recreational facilities	1.849 (1.187, 2.883)	0.419	**0.007**	1.375 (1.013, 1.866)	0.214	**0.041**
Physical activity policies and practices	0.217 (0.020, 2.325)	0.263	0.207	–	–	–
Nutrition and healthy eating policies and practices	1.076 (0.131, 8.808)	1.154	0.946	–	–	–
Physical activity on timetable	0.571 (0.087, 3.741)	0.547	0.559	–	–	–
Random effects						
School level	1.408 (0.485, 4.090)	0.766				
ICC	0.300 (0.128, 0.554)	0.114				

[a] Univariable models using mixed effects logistic regression; [b] Explanatory variables with p-values less than 0.20 were forced into the same multivariable model (full model). Covariates adjusted for school level SES, school type, school cafeteria, school shop, healthful foods, less healthful foods, PA facility index, after school recreational facilities, sex and child's age. *OR* odds ratio, *SE* standard error, *CI* confidence intervals. *PA* physical activity, *SES* socioeconomic status

Factors associated with BMI

Table 4 summarises the multilevel analysis of individual and school level variables associated with child BMI. In model 1 (null model), the variance of the random effects of schools was significant (2.65, $p < 0.05$). The ICC was 0.197, indicating that 19.7% of the total variance observed in child BMI existed at the school level. In model 2 (individual level), none of the variables (age, sex, household wealth index) were significantly associated with BMI. At the school level, model 3, school level SES ($\beta = 0.96$, $p < 0.0001$), private school ($\beta = 1.74$, $p = 0.028$), availability of school cafeteria ($\beta = 1.83$, $p = 0.017$) and shops ($\beta = 2.34$, $p = 0.001$), healthful foods ($\beta = 0.77$, $p = 0.046$), less healthful foods ($\beta = 0.38$, $p = 0.048$) and after-school recreational facilities ($\beta = 1.134$, $p < 0.0001$) predicted child BMI. In model 4, (individual and school levels), child age ($\beta = 0.40$, $p = 0.008$), school level SES ($\beta = 1.02$, $p < 0.0001$), private school ($\beta = -1.80$, $p = 0.006$), and after-school recreational facilities ($\beta = 0.89$, $p < 0.0001$) predicted BMI. At the individual level, none of the child level variables considered in the present study made substantial contributions to the overall variability in BMI. Nonetheless, in model 4, we observed a significant contribution of child age.

Discussion

Our results indicate that generally, private schools tended to have facilities that promote healthy choices (both food and physical activity environments), and also unhealthy options (food environment) compared to public schools, which were resource-constrained. The proportions of children with abdominal obesity and overweight (including obesity) were higher in private schools. We found that individual and school level

Table 3 Individual and school factors associated with abdominal obesity

	Univariable model [a]			Multivariable model [b]		
	OR (95% CI)	SE	*p*-value	OR (95% CI)	SE	*p*-value
Intercept (null model)	0.209 (0.120, 0.362)	0.059				
Age	1.108 (0.857, 1.432)	0.145	0.433	1.145 (0.891, 1.471)	0.146	0.289
Sex (Boy)	0.879 (0.545, 1.418)	0.214	0.597	0.888 (0.549, 1.437)	0.218	0.629
Median household wealth index	1.018 (0.885, 1.170)	0.072	0.805	–	–	–
Household SES						
Poor	1			–	–	–
Middle	1.262 (0.721, 2.211)	0.361	0.416	–	–	–
Rich	1.236 (0.607, 2.517)	0.448	0.559	–	–	–
School level SES	1.636 (1.155, 2.317)	0.290	**0.006**	1.501 (0.951, 2.369)	0.349	0.081
School type (Private)	2.420 (0.880, 6.655)	1.249	0.087	0.489 (0.150, 1.593)	0.295	0.235
School cafeteria	2.661 (1.017, 6.962)	1.306	**0.046**	1.401 (0.678, 2.896)	0. 519	0.362
School shop	3.473 (1.410, 8.555)	1.597	**0.007**	1.234 (0.531, 2.871)	0.532	0.625
Fast food outlets close to school	0.597 (0.075, 4.756)	0.632	0.626	–	–	–
Healthful foods	1.556 (0.968, 2.503)	0.377	0.068	1.253 (0.881, 1.783)	0.225	0.210
Less healthful foods	1.166 (0.910, 1.495)	0.148	0.224			
PA facility index	0.822 (0.663, 1.019)	0.090	0.073	0.782 (0.627, 0.974)	0.088	**0.028**
Minutes per week for PA	0.993 (0.960, 1.027)	0.017	0.694	–	–	–
School support for active transport	0.940 (0.614, 1.438)	0.204	0.775	–	–	–
Perceived neighbourhood quality	1.128 (0.821, 1.550)	0.183	0.456	–	–	–
After-school PA facilities	1.815 (1.323, 2.492)	0.293	**< 0.0001**	1.642 (1.233, 2.187)	0.240	**0.001**
Physical activity policies and practices	0.308 (0.046, 2.081)	0.300	0.227	–	–	–
Nutrition and healthy eating policies and practices	0.715 (0.149, 3.427)	0.512	0.675	–	–	–
Physical activity on timetable	0.702 (0.157, 3.132)	0.535	0.642	–	–	–
Random effects						
School level	0.871 (0.299, 2.421)	0.044				
ICC	0.206 (0.083, 0.424)	0.087				

[a] Univariable models using mixed effects logistic regression; [b] Explanatory variables with p-values less than 0.20 were forced into the same multivariable model (full model). Variables adjusted for: school level SES, school type, school cafeteria, school shop, healthful foods, PA facility index, after-school recreational facilities, sex and child's age. *OR* odds ratio, *SE* standard error, *CI* confidence intervals. *PA* physical activity, *SES* socioeconomic status

factors are independently and jointly related to BMI, abdominal obesity and overweight in these children. The school context explained between 19.7 and 30.0% of the school level variability in weight status. We found significant associations of child weight status with school type, school-level SES, availability of school cafeterias (providing school meals) and school shops (sale of competitive foods and beverages), healthful foods, less healthful foods, PA facilities index, availability and accessibility of after-school recreational facilities. With respect to individual level variables, only age was significantly related to BMI. School policies and practices on physical activity were unrelated to child weight status.

School type explained the highest percentage of variability in individual child BMI. We observed that children attending private and higher SES schools have higher BMI, and increased odds of abdominal obesity and overweight compared to their peers attending public and lower SES schools. When controlling for individual and school-level variables, the association with school-level SES was seen with BMI and overweight, but not abdominal obesity. The school type continued to be linked with only BMI, but the direction of the association changed such that children attending private schools had lower BMI compared to their counterparts attending public schools. Our findings paralleled those from prior research among African populations that suggested that attending affluent, private or high SES school increases the odds of overweight and obesity [23, 24]. On the other hand, studies conducted in the US [14, 25] found that children attending higher SES schools had lower BMI. Higher SES schools tend to have more resources that would promote healthy

Table 4 Individual and school factors associated with BMI

	Model 1 Null model		Model 2 Individual		Model 3 School		Model 4 Individual & school	
	Estimate (95% CI)	SE	Estimate (95% CI)	SE	Estimate (95% CI)	SE	Estimate (95% CI)	SE
Fixed effects								
Individual level								
Intercept	17.136 (16.233, 18.038)	0.460						
Age			0.304 (−0.002, 0.609)	0.156			**0.396** (0.102, 0.691)*	0.150
Sex (Boys)			0.011 (−0.563, 0.583)	0.293			0.001 (− 0.571, 0.573)	0.292
Household wealth index			0.010 (−0.152, 0.172)	0.083				
Household SES								
Poor (ref)								
Middle			0.113 (−0.547, 0.774)	0.337				
Rich			0.132 (−0.726, 0.990)	0.438				
School level								
School level SES					**0.959** (0.481, 1.437)**	0.244	**1.015** (0.499, 1.530)**	0.263
School type (private)					**1.744** (0.185, 3.303)*	0.795	**−1.795** (−3.078, −0.513)*	0.654
School cafeteria					**1.832** (0.324, 3.340)*	0.769	0.742 (−0.330, 1.814)	0.547
School shop					**2.344** (0.926, 3.762)*	0.724	0.276 (−0.781, 1.333)	0.539
Fast foods restaurants close to school					1.101 (−2.401, 4.602)	1.787	–	–
Healthful foods					**0.769** (0.012, 1.526)*	0.386	0.306 (−0.136, 0.748)	0.225
Less healthful foods					**0.382** (0.003, 0.762)*	0.194	−0.094 (− 0.306, 0.119)	0.108
PA facility index					−0.143 (− 0.391, 0.105)	0.126	–	–
Minutes per week for PA					−0.014 (− 0.064, 0.035)	0.025	–	–
School support for active transport					−0.136 (− 0.840, 0.568)	0.359	–	–
Perceived neighbourhood quality					0.176 (−0.327, 0.678)	0.256	–	–
After school recreational facilities					**1.134** (0.562, 1.706)**	0.291	**0.894** (0.525, 1.263)**	0.23
Physical activity policy					−2.957 (−6.088, 0.174)	1.597	–	–
Nutrition policy & healthy eating policy					−0.657 (−3.247, 1.933)	1.321	–	–
Physical activity on timetable					−1.098 (3.585, 1.389)	1.269	–	–
Random effects								
Individual level	**10.802** (9.574, 12.187)**	0.665						
School level	**2.650** (1.121, 6.265)**	1.163						
ICC	0.197 (0.098, 0.370)	0.070						

Explanatory variables that were significant compared with the empty model were selected for the final model (model 4). Variables included: school level SES, school type, school cafeteria, school shop, healthy food, less healthful foods, after school recreational facilities, sex and child's age. [b] Linear mixed models used, where variables were modelled as fixed effects and school as random effects. *SE* standard error, *CI* confidence intervals. * = $p < 0.05$, ** = $p < 0.0001$

behaviours and hence lower the odds of overweight and obesity in developed countries.

School food environment has a significant impact on children's eating behaviours [16] and subsequently body weight [10, 12], as more than one-third of the daily caloric intake occurs while at school [26]. Our results suggest that over one-third of the children have access to school cafeterias and shops with a wide selection of both healthful and less healthful foods options, although there were fewer healthful options. This suggests the nutrition and healthy eating policies and practices were poorly implemented or enforced. We observed that the availability of less healthful foods was positively associated with BMI but not overweight and abdominal obesity; and the association was no longer significant after controlling for school-level SES, school type, cafeterias, shops, healthful foods, after-school recreational facilities, age and sex.

This analysis adds to an earlier study that found that less healthful foods at school was positively associated with higher BMI and obesity/overweight [10, 12]. Prior research indicated that the absence of school shops and snack bars and also limiting the availability of less healthful foods in school shops were associated with reduced intake of sugar-sweetened beverages and energy dense snacks [16, 26]. We observed that the availability of healthful foods tend to increase the risk of overweight, abdominal obesity and high BMI, which is counterintuitive. We had expected the availability of healthful foods to be associated with healthy dietary intake, and with lower risk of obesity. This finding indicates that healthful foods did not protect the children from poor dietary habits. Given the increased exposure to less healthful options, food preference, the main determinant of food intake in children [27], could have contributed to poor dietary behaviours, thus the overall intake of these foods would displace the healthy options in the diets. Notably, the home food environment, an equally important context for developing food preferences and dietary habits in children [28–30], was not captured in the present analyses.

Among the physical activity environments considered in the present study, only PA facility index was significantly associated with abdominal obesity, but not overweight or BMI. Availability and accessibility to play equipment and resources provide children with the opportunities to be physically active during school hours. Children attending schools that had more PA facilities both on and off grounds tend to have lower odds of abdominal obesity than their counterparts who were attending schools that were poorly-resourced, consistent with existing research [11]. In the aforementioned study conducted among adolescents, students who had access to these facilities were less likely to be overweight. Some existing research has linked the provision of recreational facilities both at the school level and school community to increased physical activity [17] while results from other studies were mixed [13]. Evidence from a meta-analysis by Morton and colleagues [13] indicated that the association was with activity-specific facilities but not the overall physical activity resources. Nonetheless, the evidence linking school physical activity facilities to child weight status has been inconsistent. Researchers found little or no significant association between physical activity resources and programmes and weight status in adolescents attending middle to high schools [31].

After-school programmes may promote increased participation in extracurricular physical activity and related-health outcomes among children and adolescents [19]. Our results suggest that children attending schools with increased access to after-school recreational facilities had higher risk for increased BMI, overweight and abdominal obesity. The counterintuitive finding could be due to some individual and school level confounding variables that were not considered in the analysis. We did not report on after-school programmes being offered to the children. One possible explanation is that the availability of these facilities were not associated with organised sports with trained physical education staff to supervise the children. Moreover, the need for academic excellence may lead to more time being allocated to extra classes than extra sporting activities. Thus children may not have adequate time to engage in after-school programmes despite the facilities being available.

Strengths of the present study include the application of multilevel modelling to account for the hierarchical nature of the data; and use of objective measures of height and weight. There are limitations of the present work which should be noted. The cross-sectional design of the study precludes the inferences of causal relationships. At best, we could say that associations exist between the examined variables and the outcome variables. Another potential source of limitation was that maternal educational, a significant predictor of child weight was not controlled for in the analysis. We did not report on dietary and physical activity behaviours of the children at school which could provide explanations to the observed variability since the present work focused on school environment and weight outcomes.

Conclusion

A number of school-level factors were associated with BMI, overweight and abdominal obesity of the children in the present study. Unhealthy weight status was significantly higher in children in private compared to public schools. The fact that children spend significant amount of time in schools could present a window of opportunity to impact healthy lifestyle behaviours which are likely to be maintained through adulthood thereby reducing the prevalence of overweight. Our results add to the limited and inconsistent findings in this area and provide support for improved school environment to reduce the overweight epidemic.

Abbreviations

BMI: Body mass index; CI: Confidence intervals; IAEA: The International Atomic Energy Agency; ICC: Intraclass coefficient; OR: Odds ratio; PA: Physical activity; SE: Standard error; SES: Socioeconomic status; WHO: World Health Organization; WHtR: Waist-to-height ratio; zBMI: BMI-for-age; β: Beta coefficient

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

TA, APK, ADV and TP designed the study. TA participated in acquisition and assembly of the data. APK provided technical advice on data analysis. TA did the literature search, conducted data analysis and interpretation and wrote the original draft. APK, TP and ADV participated in review of the manuscript. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

The Senate Research Committee of the University of the Western Cape (ID NO: 15/5/5), South Africa and the Ethical Review Committee of the Ghana Health Service (ID NO: GHS-ERC: 01/07/13), Ghana, approved the study. Additional approval was obtained from the Municipal Education Directorate of the Ghana Education Service, and from the heads of participating schools while parents or legal guardians of children provided written informed consent. Also, every participating child gave verbal assent after explaining the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

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References

1. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes. 2011;35(7):891–8.
2. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014/06/02. 2014;384(9945):766–781.
3. Swinburn B, Egger G, Ph D, Raza F. Dissecting obesogenic environments : the development and application of a framework for identifying and prioritizing environmental interventions for obesity 1. Prev Med (Baltim). 1999;29:563–70.
4. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. Cmaj. 2009;180(7):719–26.
5. Davison KK, Birch L. Childhood overweight: a contextual model and recommendations for future research. Obes Rev. 2001;2(3):159–71.
6. Kumanyika S, Jeffery RW, Morabia A, Ritenbaugh C, Antipatis VJ. Public health approaches to the prevention of obesity working Group of the International Obesity Task F. obesity prevention: the case for action. Int J Obes Relat Metab Disord J Int Assoc Study Obes. 2002;26(3):425–36.
7. McLeroy K, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. Health Educ Q. 1988;15(4):351–77.
8. Townsend N, Foster C. Developing and applying a socio-ecological model to the promotion of healthy eating in the school. Public Health Nutr. 2013;16(6):1101–8.
9. Khambalia AZ, Dickinson S, Hardy LL, Gill T, Baur LA. A synthesis of existing systematic reviews and meta-analyses of school-based behavioural interventions for controlling and preventing obesity. Obes Rev. 2012;13(3):214–33.
10. Fox MK, Dodd AH, Wilson A, Gleason PM. Association between school food environment and practices and body mass index of US public school children. J Am Diet Assoc. 2009;109(2):S108–17.
11. Leatherdale ST. A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 to 4 students. BMC Public Health. 2013;13:982.
12. Mâsse LC, de Niet-Fitzgerald J, Watts AW, Naylor P-J, Saewyc EM. Associations between the school food environment, student consumption and body mass index of Canadian adolescents. Int J Behav Nutr Phys Act. 2014;11(1):29.
13. Morton KL, Atkin AJ, Corder K, Suhrcke M, van Sluijs EMF. The school environment and adolescent physical activity and sedentary behaviour: a mixed-studies systematic review. Obes Rev. 2016;17(2):142–58.
14. Richmond TK, Subramanian SV. School level contextual factors are associated with the weight status of adolescent males and females. Obesity. 2008;16(6):1324–30.
15. Harrison F, Jones AP, van Sluijs EMF, Cassidy A, Bentham G, Griffin SJ. Environmental correlates of adiposity in 9-10 year old children: considering home and school neighbourhoods and routes to school. Soc Sci Med. 2011;72(9):1411–9.
16. Hanks AS, Just DR, Smith LE, Wansink B. Healthy convenience: nudging students toward healthier choices in the lunchroom. J Public Heal (United Kingdom). 2012;34(3):370-6.
17. Sallis JF, Floyd MF, Rodríguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. Circulation. 2012;125(5):729-37.
18. Leatherdale ST, Manske S, Faulkner G, Arbour K, Bredin C. A multi-level examination of school programs, policies and resources associated with physical activity among elementary school youth in the PLAY-ON study. Int J Behav Nutr Phys Act. 2010;7:1–13.
19. Beets MW, Beighle A, Erwin HE, Huberty JL. After-School Program Impact on Physical Activity. AMEPRE. 2009;36(6):527–37.
20. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Heal Organ. 2007;85(10):812–9.
21. Nambiar S, Hughes I, Davies PSW. Developing waist-to-height ratio cut-offs to define overweight and obesity in children and adolescents. 2010;13(10):1566–74.
22. Filmer D, Pritchett L. Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. Demography. 2001;38(1):115–32.
23. Fruhstorfer BH, Mousoulis C, Uthman OA, Robertson W. Socio-economic status and overweight or obesity among school-age children in sub-Saharan Africa - a systematic review. Clin Obes. 2016/01/20. 2016;6(1):19-32.
24. Muthuri SK, Francis CE, Wachira L-JM, LeBlanc AG, Sampson M, Onywera VO, et al. Evidence of an overweight/obesity transition among school-aged children and youth in sub-Saharan Africa: a systematic review. PLoS One. 2014;9(3):1–26.
25. Miyazaki Y, Stack M. Examining individual and school characteristics associated with child obesity using a multilevel growth model. Soc Sci Med. 2015;128:57–66.
26. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School food environments and practices affect dietary behaviors of US public school children. J Am Diet Assoc. 2009;109(2):S91–107.
27. Gibson EL, Wardle J, Watts CJ. Fruit and vegetable consumption, nutritional knowledge and beliefs in mothers and children. Appetite. 1998;31(2):205–28.
28. Golan M, Crow S. Parents are key players in the prevention and treatment of weight-related problems. Nutr Rev. 2004;62(1):39–50.
29. Vepsäläinen H, Mikkilä V, Erkkola M, Broyles ST, Chaput J-P, Hu G, et al. Association between home and school food environments and dietary patterns among 9-11-year-old children in 12 countries. Int J Obes Suppl. 2015;5(Suppl 2):S66–73.
30. Brown R, Ogden J. Children's eating attitudes and behaviour: a study of the modelling and control theories of parental influence. Health Educ Res. 2004;19(3):261–71.
31. Richmond TK, Elliott MN, Franzini L, Kawachi I, Caughy MO, Gilliland MJ, et al. School programs and characteristics and their influence on student BMI: findings from healthy passages. PLoS One. 2014;9(1):1–7.

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Article

Diagnostic Accuracy of Body Mass Index in Defining Childhood Obesity: Analysis of Cross-Sectional Data from Ghanaian Children

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Abstract: Background: Screening methods for childhood obesity are based largely on the published body mass index (BMI) criteria. Nonetheless, their accuracy in African children is largely unknown. The diagnostic accuracies of the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the International Obesity Taskforce (IOTF) BMI-based criteria in defining obesity using deuterium dilution as a criterion method in a sample of Ghanaian children are presented. Methods: Data on anthropometric indices and percent body fat were collected from 183 children aged 8–11 years. The sensitivity, specificity, and predictive values were calculated. The overall performance of the BMI criteria was evaluated using the receiver operating characteristics area under the curve (AUC). Results: Overall sensitivity of WHO, CDC, and IOTF were 59.4% (40.6–76.3), 53.1% (34.7–70.9), and 46.9% (29.1–65.3) respectively. The overall specificity was high, ranging from 98.7% by WHO to 100.0% by IOTF. The AUC were 0.936 (0.865–1.000), 0.924 (0.852–0.995), and 0.945 (0.879–1.000) by the WHO, CDC, and IOTF criteria respectively for the overall sample. Prevalence of obesity by the WHO, CDC, IOTF, and deuterium oxide-derived percent body fat were 11.5%, 10.4%, 8.2%, and 17.5% respectively, with significant positive correlations between the BMI z-scores and percent body fat. Conclusions: The BMI-based criteria were largely specific but with moderate sensitivity in detecting excess body fat in Ghanaian children. To improve diagnostic accuracy, direct measurement of body fat and other health risk factors should be considered in addition to BMI.

Keywords: body mass index; obesity; deuterium oxide; percent body fat; sensitivity; specificity; accuracy; school children

1. Introduction

Obesity is a major risk factor for non-communicable diseases [1]. Among children, obesity may present significant health and psychological problems including type 2 diabetes, increased risk of developing hypertension, high cholesterol, orthopedic problems, and low self-esteem [1,2]. The adverse health consequences associated with obesity are related to excess body fat, calling for accurate methods for diagnosis, particularly among children. At present, the screening methods for obesity are based largely on the body mass index (BMI), calculated as body weight (in kg) divided by the square of the height (in meters). Despite its inherent limitations to distinguish between fat mass (FM) and fat-free mass (FFM), both of which contribute to the BMI [3], BMI has been traditionally used in epidemiological studies as a proxy for adiposity because of its relative simplicity and affordability. Nonetheless, BMI is a measure of excess weight rather that excess body fat and changes with age, gender, and maturation in children [3].

Different BMI criteria have been developed for the classification of weight status. These are: The World Health Organization (WHO) reference [4], derived from the z-score of the mean BMI-for-age after computing standard deviations; the Centers for Disease Control and Prevention (CDC) [5], based on the BMI-for-age percentile methodology; and the International Obesity Taskforce (IOTF) [6] definition from the lambda, mu, and sigma (LMS) methodology for the calculation of the z-score.

A number of reference methods are available to measure body fatness including under water weighing, dual-energy X-ray absorptiometry (DXA), total body potassium, air displacement plethysmography, bioelectrical impedance, and isotope dilution method [7]. Some of these methods are limited to laboratory settings, costly, and may not be suitable for children [7,8]. The isotope dilution method is one of the safe, non-invasive methods for body composition assessment that enables measurements of body fat under free-living conditions [8].

Most studies among children and adolescents in Africa apply BMI-based criteria to estimate overweight and obesity [9]. Nonetheless, at the continental level, the diagnostic accuracy of the published BMI references to detect excess body fat among children is largely unknown; only few studies have compared the BMI criteria against a criterion measure of body fat [10,11]. The present study aims to evaluate the diagnostic accuracies of the three international BMI the CDC, IOTF, and WHO based criteria in defining obesity using deuterium dilution as a criterion method in a sample of Ghanaian primary school children.

2. Materials and Methods

This is a cross-sectional analysis of 8–11-year-old school children in six primary schools in an urban area in Ghana. Data on anthropometric indices and percent body fat were collected.

2.1. Study Population

A convenient sample of 183 children from three private and three public schools in the Adentan Municipality of the Greater Region of Ghana were randomly selected. The participants were a sub-sample from a larger study on childhood obesity involving 543 children from 14 schools comprising 111 girls and 72 boys. Details of the recruitment and selection of participants have been previously described [12].

2.2. Data Collection

2.2.1. Anthropometry

Body weight was measured to the nearest 0.1 kg with a digital scale (Seca 869, GmbH & Co., Hamburg, Germany). Children were weighed in their school uniforms but asked to remove shoes, socks, watches, sweaters, jackets, and items in the pockets. Height was measured to the nearest 0.1 cm using the Shorr Board (Shorr Productions, Olney, MD). All measurements were done in duplicates. The means of the duplicate measurements were used to compute BMI as body weight (in kilogramme) divided by height (in meters)^2. BMI-for-age was calculated and obesity defined as BMI-for-age z-score $\geq +2.0$ SD by WHO [4]; BMI-for-age percentile $\geq$ 95th percentile by CDC [5]; and BMI-for-age z-score ≥ 30 kg/m^2 by IOTF adjusted to reflect the cut-off point at age 18 years [6].

2.2.2. Total Body Water for Percent Body Fat Estimation

Body fat of participants was assessed using the deuterium dilution method with Fourier transform infrared spectrometer (FTIR) following the International Atomic Energy Agency (IAEA) guidelines [13].

Children were asked not to eat for at least two hours prior to data collection. Pre-dose saliva samples were collected after which each child received a dose of given weight of deuterium oxide labelled water (99.8% purity, Cambridge Isotope Laboratories Inc. Andover, MA) based on their body weight [13] to drink. The doses were prepared in batches prior to the study. No food or drinks were allowed during equilibration period. Two additional samples were collected 3 and 3.5 h after drinking the dose. The samples were transported on ice to the laboratory and stored at −20 °C prior to analysis.

Deuterium enrichment of the saliva samples were measured using FTIR (Shimadzu IRPrestige-21, Vienna, Austria) at the Ghana Atomic Energy Commission following IAEA guidelines [13]. Samples were analyzed in duplicates and the mean enrichment for each time point was calculated. Total body water (TBW) was calculated from the mean deuterium enrichment at time zero with the use of a correction factor (deuterium space) for non-aqueous dilution of deuterium oxide using the age-and gender- specific values for the hydration of FFM for children [14]. Where only one time point data was available, that was used to calculate the TBW.

Deuterium space = dose ingested (mg)/deuterium enrichment of saliva (mg/kg)

TBW (kg) = deuterium space/1.041

FFM was computed from the TBW as:

FFM (kg) = TBW (kg)/age-and gender-specific hydration factor

The FM was calculated as the difference between body weight and the FFM and expressed as a percentage of the body weight.

Fat mass = Weight (kg) − FFM (kg); expressed as percentage

There is no universally accepted definition for excess body fat using isotope dilution methods in children. For the purposes of this analysis, excess body fat was defined as body fat >25% for boys and >30% for girls, respectively [15].

2.2.3. Ethical Considerations

Ethics approvals were obtained from the Senate Research Committee of the University of Western Cape (ID NO: 15/5/5) and Ethical Review Committee of the Ghana Health Service (ID NO: GHS-ERC: 01/07/13). Approval was also obtained from the Municipal Education Directorate of the Ghana Education Service and from the heads of participating schools. Since the study involved children under 16 years, written informed consent were obtained from the parents or legal guardians of the children. Verbal assent was given by each participating child after explaining the study.

2.2.4. Statistical Analysis

All analyses were performed with Stata 13.0 (StataCorp). Results are expressed as means (±SDs) or medians (and 25th–75th percentiles) for continuous variables, while categorical variables are reported as frequencies and percentages. Chi-square test, Student t-test, and the Mann–Whitney U test were used for comparison as appropriate. A Spearman's correlation was used to assess the relationship between percent body fat and WHO, CDC, and IOTF BMI-for-age z-scores. The performance of the published BMI criteria to discriminate children with excess body fat from those with normal body fat (childhood obesity) was evaluated. The sensitivity (the proportion of children with excess body fat who have high BMI-for-age z-scores), specificity (the proportion of children who do not have excess body fat and who do not have high BMI-for-age z-scores), positive predictive value (proportion of children with high BMI-for-age z-scores who have excess body fat), negative predictive value (proportion of children with low BMI-for-age z-scores who do have excess body fat), and receiver operating characteristics (ROC) curves and area under the curves for the BMI references, were computed. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Descriptive Characteristics and Obesity Prevalence of Children

The descriptive characteristics and prevalence of obesity by the different diagnostic criteria are summarized in Table 1. The median (25th–75th percentiles) age of the study participants was 10 (9–10) years. No significant difference was observed between boys and girls in weight, height, and BMI. However, the girls had significantly higher percent body fat compared to the boys (21.3% vs. 14.7%; $p < 0.0001$).

Obesity prevalence appears to vary by gender and the criteria used; nonetheless, the differences were not significant. The overall prevalence based on the WHO, CDC, IOTF, and percent body fat determined by the deuterium method were 11.5%, 10.4%, 8.2%, and 17.5% respectively. Across criteria, the overall highest obesity prevalence was by percent body fat measured with the deuterium dilution method; 18.0% girls and 16.7% boys were classified as obese ($p = 0.814$). Prevalence based on the WHO criteria was 13.9% among boys and 9.9% among girls ($p = 0.409$). Using the CDC and IOTF cut-offs, the prevalence among boys was 11.1% and 8.3%, and 9.0% and 8.1% among girls respectively. Except for the deuterium method, all diagnostic criteria classified higher proportion of boys as obese compared to girls, although the differences were not significant. There were significant positive correlations between the BMI z-scores and percent body fat (Figures 1–3). Across criteria, the correlation coefficient rho (ρ) was 0.638, $p < 0.0001$, 0.635, $p < 0.001$, and 0.625, $p < 0.0001$ for WHO, CDC, and IOTF, respectively. By gender, the corresponding values for WHO, CDC, and IOTF were higher in girls (0.694, 0.713, 0.719, all $p < 0.0001$) compared to boys (0.550, 0.532, and 0.562, all $p < 0.0001$).

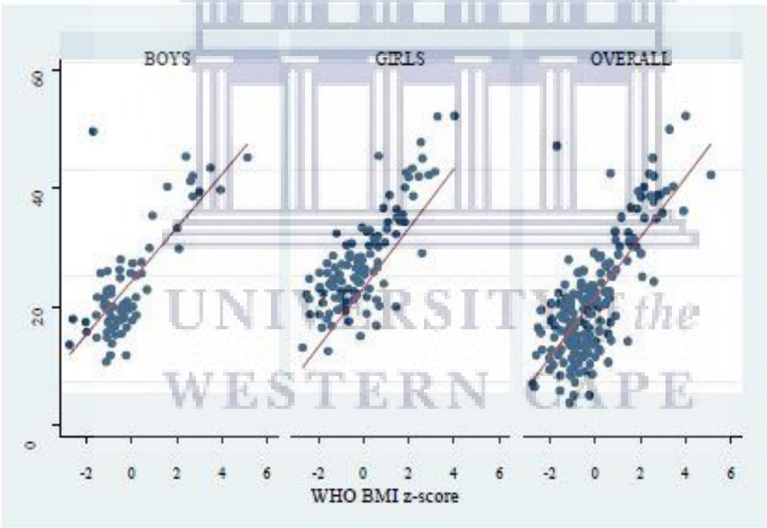

Figure 1. Correlation between percent body fat measured by the deuterium dilution method and World Health Organization (WHO) body mass index (BMI) z-score. The dots represent percent body fat and the red line represent the fitted values.

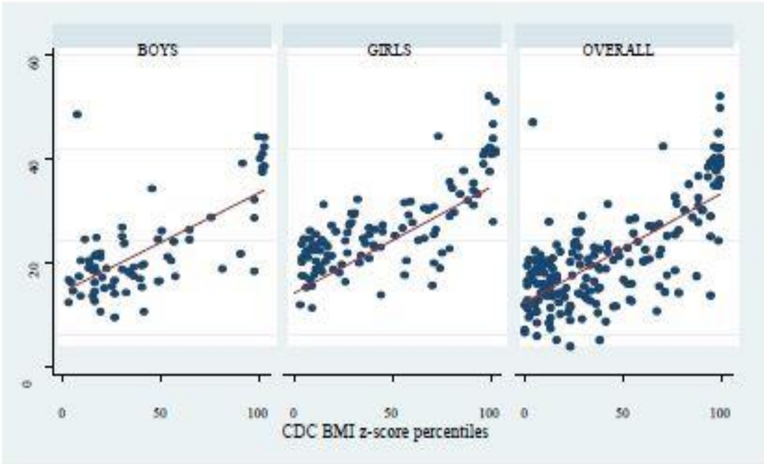

Figure 2. Correlation between percent body fat measured by the deuterium dilution method and Centers for Disease Control and Prevention (CDC) BMI z-score percentiles. The dots represent percent body fat and the red line represent the fitted values.

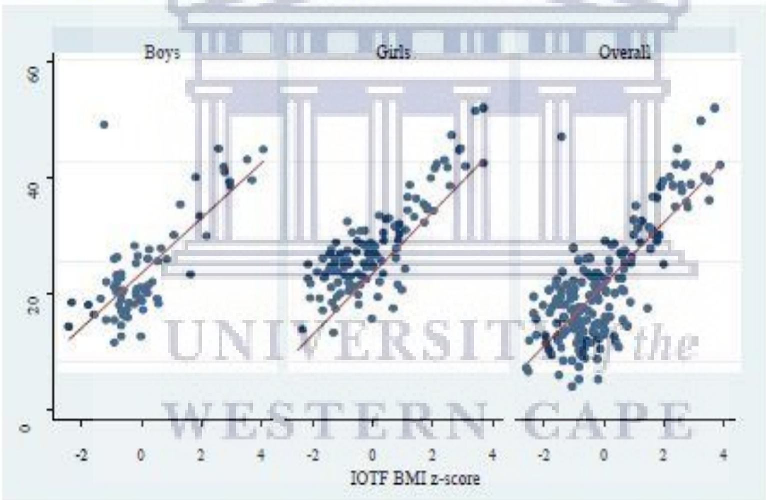

Figure 3. Correlation between percent body fat measured by the deuterium dilution method and International Obesity Taskforce (IOTF) BMI z-score. The dots represent percent body fat and the red line represent the fitted values.

Table 1. Descriptive characteristics and obesity prevalence of children based on different diagnostic criteria.

Variables	Overall (*N* = 183)	Boys (*N* = 72)	Girls (*N* = 111)	*p*-Value
Median age (y)	10 (9, 10)	10.0 (9, 10)	10.0 (9, 10)	
Median Weight (kg)	30.7 (27.2, 37.5)	29.9 (27.5, 34.9)	31.3 (27.1, 39.1)	0.339
Mean height (cm)	139.5 ± 8.2	138 ± 7.2	140.1 ± 8.81	0.232
Median BMI (kg/m^2)	15.7 (14.8, 18.0)	15.5 (14.8, 17.1)	16.0 (14.5, 18.7)	0.617
Median BMI z-score	−0.40 (−1.09, 0.63)	−0.51 (−1.08, 0.19)	−0.22 (−1.16, 0.68)	0.387
Median body fat (%)	19.3 (14.1, 26.1)	14.7 (11.6, 21.1)	21.3 (16.7, 27.4)	<0.0001
WHO % (*n*)	11.5 (21)	13.9 (10.0)	9.9 (11)	0.409
CDC, % (*n*)	10.4 (18)	11.1 (8)	9.0 (10)	0.641
IOTF, % (*n*)	8.2 (15)	8.3 (6)	8.1 (9)	0.957
D2O, % (*n*)	17.5 (32)	16.7 (12)	18.0 (20)	0.814

Data are presented as median (25th, 75th percentiles); mean ± SD; percentage (frequency); CDC: Centers for Disease Control and Prevention; D2O: Deuterium oxide; IOTF: International Obesity Taskforce; WHO: World Health Organization; BMI: Body mass index.

3.2. *Diagnostic Accuracy and Performance of BMI Criteria for Defining Obesity*

The diagnostic performance of BMI-based criteria for classifying deuterium method-based obesity is presented in Table 2. The overall sensitivity was 59.4% (40.6–76.3), 53.1% (34.7–70.9), and 46.9% (29.1–65.3) by WHO, CDC, and IOTF criteria, respectively. The sensitivity was high among boys with the WHO criterion 75.0% (42.8–94.5) and low among girls using the CDC and IOTF criteria, 45.0% (23.1–68.5). By contrast, the specificity was high across the criteria in the overall sample ranging from 98.7% (95.3–99.8) by WHO to 100.0 (97.6–100.0) by IOTF. Further, the positive predictive values (PPV) in the overall sample ranged from 90.5% (69.6–98.8) by WHO to 100.0% (80.5–100.0) by IOTF. The negative predictive values (NPV) were higher with WHO-based criterion; 91.9% (86.7–95.7) and 89.9% (84.3–94.0) by IOTF. The sensitivity, specificity, PPV, and NPV were similar across all criteria by gender.

Table 2. Diagnostic accuracy of BMI-based criteria for defining obesity in children using the percent body fat derived from deuterium method as reference method.

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
		Overall		
WHO	59.4 (40.6–76.3)	98.7 (95.3–99.8)	90.5 (69.6–98.8)	91.9 (86.7–95.7)
CDC	53.1 (34.7–70.9)	99.3 (96.4–99.9)	94.4 (72.7–99.9)	90.9 (72.7–99.9)
IOTF	46.9 (29.1–65.3)	100.0 (97.6–100.0)	100.0 (80.5–100.0)	89.9 (84.3–94.0)
		Boys		
WHO	75.0 (42.8–94.5)	98.3 (91.1–99.9)	90.0 (55.5–99.8)	95.1 (86.5–99.0)
CDC	66.7 (34.9–90.1)	100.0 (94.0–100.0)	100.0 (63.1–100.0)	93.8 (84.8–98.3)
IOTF	50.0 (21.1–78.9)	100.0 (94.0–100.0)	100.0 (54.1–100.0)	90.9 (81.3–96.6)
		Girls		
WHO	50.0 (27.2–72.8)	98.9 (94.0–99.9)	90.9 (58.7–99.8)	90.0 (82.4–95.1)
CDC	45.0 (23.1–68.5)	98.9 (94.0–99.9)	90.0 (55.5–99.8)	89.1 (81.3–94.4)
IOTF	45.0 (23.1–68.5)	100.0 (96.0–100.0)	100.0 (66.4–100.0)	89.2 (81.5–94.4)

CDC: Centers for Disease Control and Prevention; IOTF: International Obesity Taskforce; WHO: World Health Organization.

The overall accuracy and performance analysis of the BMI-for-age z-score and BMI-for-age percentiles in identifying obese children is indicated by the receiver operating characteristics (ROC) area under the curve (AUC). The AUC areas were 0.936 (0.865–1.000), 0.924 (0.852–0.995), and 0.945 (0.879–1.000) by the WHO, CDC, and IOTF criteria, respectively, for the overall sample (Figure 4).

The AUC did not differ in the overall sample and by gender (Supplementary Figures S1–S3) for all criteria.

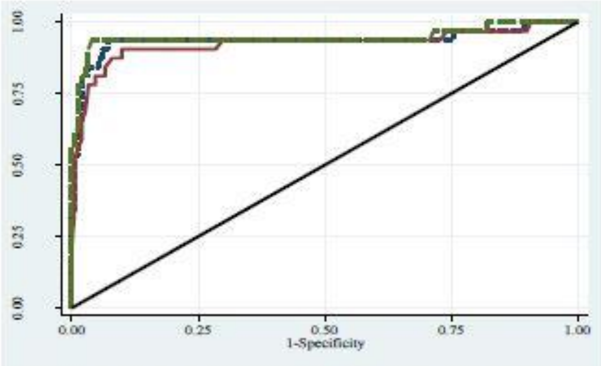

Figure 4. Receiver operating characteristics curve for WHO, CDC, and IOTF criteria. Long broken forest green line: ROC area for IOTF, AUC = 0.945. Dash navy line: ROC area for WHO, AUC = 0.936. Solid maroon line: ROC area for CDC, AUC = 0.924. Diagonal line: ROC area for reference, AUC = 0.500.

3.3. Empirical Cut-Point Estimation for Defining Obesity

Using the Youden index J point approach of the empirical cut-point estimation (Table 3), the WHO, CDC, and IOTF cut-points that optimize sensitivity, specificity, PPV, and NPV for obesity were 0.68, 69.5%, and 0.50 respectively for the overall sample. The corresponding optimal cut-offs by gender were 0.86, 87.5%, and 0.50 for boys; and 0.68, 69.5%, and 0.50 for girls.

Table 3. Optimal cut-point estimation of WHO and CDC criteria for diagnosis of obesity.

	Cut-off	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	AUC (95% CI)
			WHO BMI-for-age z-score			
Overall	0.68	93.8 (79.2–99.2)	92.7 (87.3–96.3)	73.2 (57.1–85.8)	98.6 (95.0–99.8)	0.932 (0.885–0.980)
Boys	0.86	91.6 (61.5–99.8)	96.7 (88.5–99.6)	84.6 (54.5–98.1)	98.3 (90.9–99.6)	0.942 (0.857–1.000)
Girls	0.68	95.0 (75.1–99.9)	90.1 (82.1–95.4)	67.9 (47.6–84.1)	98.8 (93.5–99.7)	0.926 (0.868–0.983)
			CDC BMI-for-age percentiles			
Overall	69.5	90.6 (75.0–98.0)	90.1 (84.1–94.3)	65.9 (50.1–79.5)	97.8 (93.8–99.5)	0.903 (0.847–0.960)
Boys	87.5	83.3 (51.6–97.9)	91.7 (81.6–97.2)	66.7 (38.4–88.2)	96.5 (87.9–99.6)	0.875 (0.759–0.991)
Girls	69.5	95.0 (75.1–99.9)	89.0 (80.7–94.6)	65.5 (45.7–82.1)	98.8 (93.4–99.9)	0.920 (0.813–0.979)
			IOTF BMI-for-age z-score			
Overall	0.50	50.0 (31.9–68.1)	100.0 (97.6–100.0)	100.0 (79.4–100.0)	90.4 (84.9–94.4)	0.750 (0.660–0.840)
Boys	0.50	58.3 (27.7–84.8)	100.0 (94.0–100.0)	100.0 (59.0–100.0)	92.3 (82.5–97.5)	0.792 (0.646–0.937)
Girls	0.50	45.0 (21.1–68.5)	100.0 (96.0–100.0)	100.0 (66.4–100.0)	89.2 (81.5–94.5)	0.725 (0.613–0.837)

CI: Confidence interval; WHO BMI-for-age z-score: World Health Organization Body mass index for age z-score; CDC BMI-for-age: Centers for Disease Control and Prevention; IOTF: International Obesity Taskforce; BMI-for-age: Body mass index-for-age.

4. Discussion

This study provides the findings of the accuracy of the published BMI z-score for WHO, CDC, and IOTF to detect excess body fat in pre-adolescent school children in sub-Saharan Africa. The results show that BMI as an indicator of obesity had high specificity with mostly high predictive values across diagnostic criteria. Nonetheless, none of the published criteria achieved optimal rates of sensitivity. Across criteria, at least 40% of the children who were obese were misclassified. Area under the ROC curve indicated that BMI is an acceptable tool for diagnosing excess body fat. Moreover, the diagnostic accuracy of the WHO, CDC, and IOTF references were similar across the overall samples and also when stratified by gender. We observed positive correlations between the deuterium-derived percent body fat and the published BMI z-scores. Furthermore, the optimal BMI cut-off points for defining obesity, as determined for the present sample were lower; 0.86 for boys, 0.68 for both girls, and overall by WHO reference; 87.5% for boys, 69.5% for both girls, and overall samples by CDC reference; and 0.50 for boys, girls, and overall sample by IOTF reference.

Several factors are known to influence the diagnostic performance of BMI-based criteria to detect excess body fat. These include the methods of body composition assessment, the cut-offs to define excess percent body fat in the evaluation of the BMI-criteria, and characteristics of the reference population such as ethnicity, maturity, and gender [16–20]. The low-to-moderate sensitivity and high specificity reported in the present study are generally consistent with the literature [11,17,21–24]. Furthermore, BMI underestimated adiposity in South Asian children while among children of African origin, body fat was overestimated [18,19]. The present results are contrasting to the findings from a systematic review and meta-analysis of the diagnostic performance of BMI, where a pooled sensitivity of 73.0% and specificity of 93.0% were reported [25].

Although the methodologies for assessing body fat may differ, many studies have consistently reported low sensitivity of IOTF criterion compared with other criteria for diagnosing childhood obesity [17,23,26,27]. For example, using multisite skinfold thicknesses as the measure of body fat, Zimmermann et al. [23] found that IOTF criterion had low sensitivity relative to the CDC in a national sample of 6–12 year old Swiss children. Deurenberg-Yap et al. [17] also observed lower overall prevalence of obesity by IOTF criterion compared to CDC criterion in Asian adolescents. In another study, BMI percentiles had low sensitivity but high specificity in Italian school children aged 8–12 years [22]. On the other hand, BMI showed higher sensitivities and moderate specificities in Brazilian children aged 7–12 years. The authors further observed that the WHO-based criterion was the least sensitive compared to the IOTF [28], contrary to the present study where the IOTF was least sensitive. Among African children, the evidence is limited. A 2018 pooled analysis of data from a relatively large sample of African school children aged 8–11 years from eight countries reported low sensitivity (29.7%) and high specificity (99.7%) for the WHO BMI definition [11], using deuterium oxide method as reference criterion for body fat [11]. In comparison to the aforementioned African study, the present study reported higher sensitivity (59.4%) but with similar specificity (98.7%).

The strong positive correlations observed between BMI and percent body fat was similar to the results from previous studies [26,29–31]. In a cohort of Swiss school children aged 8–11 years, BMI and body fat were highly correlated particularly in the upper half of the BMI regardless of gender, suggesting that BMI is a good proxy for body fat in children with higher BMI. The authors concluded that BMI could be a good surrogate for body fat in pre-pubertal children [29]. Results from studies that applied body fat derived from deuterium oxide are inconsistent. While the present results echo those among Moroccan adolescents [31], they are contrary to results among Brazilian [32], Australian, and Sri Lankan children [33], where low to moderate associations between body fat and BMI indices were found. Contrary to findings from previous studies [16,17,21], we did not find differences between boys and girls with respect to indices of diagnostic accuracy, although boys tended to have higher values relative to girls.

In comparison to the published BMI cut-offs to diagnose obesity, the optimal cut-offs for the present sample were lower across all criteria. This is not surprising given that the BMI reference cut-offs were generated from diverse populations. The present results suggest that it is appropriate to develop country- and population-specific BMI cut-offs to improve diagnosis of childhood obesity instead of the universal references. For example while the present cut-offs for WHO (0.86 for boys and 0.68 for girls) is similar to that reported in an African sample [11], in an Asian population the corresponding cut-offs were 1.86 for boys and 1.38 for girls [17].

These findings have public health implications in the management of childhood obesity. In adults, low to normal BMI with increased body fat is associated with an elevated risk for cardiovascular disease [19,34,35]. The results from the present study indicate that many children with normal BMI-for-age z-scores or percentiles had excess body fat hence BMI could be very useful for detecting excess body fat. Nonetheless, where BMI-for-age is the only criterion in screening children, low sensitivity and moderate sensitivity could lead to misclassification. This is because BMI cannot discriminate body fat and FFM (and the high BMI could be due to high FFM and not necessarily excess fat). This misclassification would lead to missed opportunities for interventions.

Strengths of the present study are: This is one of the first studies to evaluate the diagnostic performance of the three commonly used international BMI-based reference criteria to detect obesity in sub-Saharan Africa, with data obtained from primary school children in Ghana. The use of deuterium to assess body fat in the children is another strength of this study. The deuterium dilution technique employed in the study is safe, accurate, and non-invasive for assessing body composition and obtaining data on body fat and FFM. There are limitations of the present study that need to be considered in interpretation of the findings. The prohibitive costs of deuterium dilution techniques precluded recruitment of a random-representative large sample with broader age range and generation of body fat percentiles. Additionally, the present results could only be generalized to children aged 8–11 years. There is currently no definite cut-off for body fat with deuterium technique. However, the criteria used [15] is associated with elevated risk of cardiovascular disease and has been consistently used. Moreover, the optimal cut-offs derived in the present study have not been cross-validated in an independent sample.

5. Conclusions

Although not significant, the prevalence of obesity varied with the diagnostic criteria applied. BMI z-scores were related to percent body fat in children aged 8–11 years indicating that BMI could be used as a proxy of body fat in this population for screening purposes. The current BMI references for diagnosing obesity in children are largely specific but less sensitive in Ghanaian children. These apparent limitations should be considered by healthcare professionals in diagnosing children. To improve diagnostic accuracy and minimize misclassification, more than one reference could be employed in addition to the direct assessment of body fat and or other health risk factors where practicable.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/1/36/s1, Figure S1: Receiver operating characteristics curves for WHO, stratified by gender. Figure S2: Receiver operating characteristics curves for CDC, stratified by gender. Figure S3: Receiver operating characteristics curves for IOTF, stratified by gender.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Reilly, J.J. Health consequences of obesity. *Arch. Dis. Child.* **2003**, *88*, 748–752. [CrossRef] [PubMed]
2. Reilly, J.J.; Kelly, J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. *Int. J. Obes.* **2011**, *35*, 891–898. [CrossRef] [PubMed]
3. Wells, J.C.K. A Hattori chart analysis of body mass index in infants and children. *Int. J. Obes. Relat. Metab. Disord.* **2000**, *24*, 325–329. [CrossRef] [PubMed]

4. De Onis, M.; Onyango, A.W.; Borghi, E.; Siyam, A.; Nishida, C.; Siekmann, J. Development of a WHO growth reference for school-aged children and adolescents. *Bull. World Health Organ.* **2007**, *85*, 812. [CrossRef] [PubMed]
5. Kuczmarski, R.; Ogden, C.L.; Guo, S.; Grummer-Strawn, L.; Flegal, K.; Al, E. 2000 CDC Growth Charts for the United States: Methods and development. In *Vital Health Statistics*; Series 11, Number 246; Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics: Hyattsville, MD, USA, May 2002; pp. 1–190.
6. Cole, T.J.; Bellizzi, M.C.; Flegal, K.M.; Dietz, W.H. Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ* **2000**, *320*, 1240. [CrossRef] [PubMed]
7. Goran, M.I. Measurement Issues Related to Studies of Childhood Obesity: Assessment of Body Composition, Body Fat Distribution, Physical Activity, and Food Intake. *Pediatrics* **1998**, *101*, 505–518. [PubMed]
8. Duren, D.L.; Sherwood, R.J.; Czerwinski, S.A.; Lee, M.; Choh, A.C.; Siervogel, R.M.; Chumlea, W.C. Body composition methods: Comparisons and interpretation. *J. Diabetes Sci. Technol.* **2008**, *2*, 1139–1146. [CrossRef] [PubMed]
9. Muthuri, S.K.; Francis, C.E.; Wachira, L.J.M.; LeBlanc, A.G.; Sampson, M.; Onywera, V.O.; Tremblay, M.S. Evidence of an Overweight/Obesity Transition among School-Aged Children and Youth in Sub-Saharan Africa: A Systematic Review. *PLoS ONE* **2014**, *9*, e92846. [CrossRef]
10. Craig, E.; Reilly, J.; Bland, R. Body fatness or anthropometry for assessment of unhealthy weight status? Comparison between methods in South African children and adolescents. *Public Health Nutr.* **2013**, *16*, 2005–2013. [CrossRef]
11. Diouf, A.; Adom, T.; Aouidet, A.; El Hamdouchi, A.; Joonas, N.I.; Loechl, C.U.; Leyna, G.H.; Mbithe, D.; Moleah, T.; Monyeki, A.; et al. Body mass index vs deuterium dilution method for establishing childhood obesity prevalence, Ghana, Kenya, Mauritius, Morocco, Namibia, Senegal, Tunisia and United Republic of Tanzania. *Bull. World Health Organ.* **2018**, *96*, 772–781. [CrossRef]
12. Adom, T.; De Villiers, A.; Puoane, T.; Kengne, A.P. Prevalence and correlates of overweight and obesity among school children in an urban district in Ghana. *BMC Obes.* **2019**, *6*, 14. [CrossRef]
13. IAEA. Introduction to body composition assessment using the deuterium dilution technique with analysis of saliva samples by Fourier transform infrared spectrometry. *IAEA Hum. Health Ser.* **2010**, *12*, 96.
14. IAEA. Assessment of body composition and total energy expenditure in humans using stable isotope technique. *IAEA Hum. Health Ser.* **2009**, *3*, 133.
15. Williams, D.P.; Going, S.B.; Lohman, T.G.; Harsha, D.W.; Srinivasan, S.R.; Webber, L.S.; Berenson, G.S. Body Fatness and Risk for Elevated Blood-Pressure, Total Cholesterol, and Serum-Lipoprotein Ratios in Children and Adolescents. *Am. J. Public Health* **1992**, *82*, 358–363. [CrossRef]
16. Neovius, M.G.; Linné, Y.M.; Barkeling, B.S.; Rossner, S.O. Sensitivity and specificity of classification systems for fatness in adolescents. *Am. J. Clin. Nutr.* **2004**, *80*, 597–603. [CrossRef]
17. Deurenberg-Yap, M.; Niti, M.; Foo, L.L.; Ng, S.A.; Loke, K.Y. Diagnostic accuracy of anthropometric indices for obesity screening among asian adolescents. *Ann. Acad. Med. Singap.* **2009**, *38*, 3–8.
18. Hudda, M.T.; Nightingale, C.M.; Donin, A.S.; Fewtrell, M.S.; Haroun, D.; Lum, S.; Williams, J.E.; Owen, C.G.; Rudnicka, A.R.; Wells, J.C.; et al. Body mass index adjustments to increase the validity of body fatness assessment in UK Black African and South Asian children. *Int. J. Obes.* **2017**, *41*, 1048–1055. [CrossRef]
19. Nightingale, C.M.; Rudnicka, A.R.; Owen, C.G.; Cook, D.G.; Whincup, P.H. Patterns of body size and adiposity among UK children of South Asian, black African-Caribbean and white European origin: Child Heart And health Study in England (CHASE Study). *Int. J. Epidemiol.* **2011**, *40*, 33–44. [CrossRef]
20. Liu, A.; Byrne, N.M.; Kagawa, M.; Ma, G.; Poh, B.K.; Ismail, M.N.; Kijboonchoo, K.; Nasreddine, L.; Trinidad, T.P.; Hills, A.P. Ethnic differences in the relationship between body mass index and percentage body fat among Asian children from different backgrounds. *Br. J. Nutr.* **2011**, *106*, 1390–1397. [CrossRef]
21. Reilly, J.J.; Dorosty, A.R.; Emmett, P.M.; Avon Longitudinal Study of Pregnancy and Childhood Study Team. Identication of the obese child: Adequacy of the body mass index for clinical practice and epidemiology. *Int. J. Obes. Relat. Metab. Disord.* **2000**, *24*, 1623–1627. [CrossRef]
22. Bedogni, G.; Iughetti, L.; Ferrari, M.; Malavolti, M.; Poli, M.; Bernasconi, S.; Battistini, N. Sensitivity and specificity of body mass index and skinfold thicknesses in detecting excess adiposity in children aged 8–12 years. *Ann. Hum. Biol.* **2003**, *30*, 132–139. [CrossRef]

23. Zimmermann, M.B.; Gubeli, C.; Puntener, C.; Molinari, L.; Hess, S.Y.; Hurrell, R.F. Detection of overweight and obesity in a national sample of 6–12-y-old Swiss children: Accuracy and validity of reference values for body mass index from the US Centers for Disease Control and Prevention anf the International Obesity Task Force. *Am. J. Clin. Nutr.* **2004**, *79*, 838–843. [CrossRef]
24. Gläßer, N.; Zellner, K.; Kromeyer-Hauschild, K. Validity of body mass index and waist circumference to detect excess fat mass in children aged 7–14 years. *Eur. J. Clin. Nutr.* **2011**, *65*, 151–159. [CrossRef]
25. Okorodudu, D.O.; Jumean, M.F.; Montori, V.M.; Romero-Corral, A.; Somers, V.K.; Erwin, P.J.; Lopez-Jimenez, F. Diagnostic performance of body mass index to identify obesity as defined by body adiposity in children and adolescents: A systematic review and meta-analysis. *Pediatr. Obes.* **2015**, *10*, 234–244.
26. Nichols, S.D.; Cadogan, F. BMI-based obesity cutoffs and excess adiposity in a Caribbean adolescent population of African origin. *Eur. J. Clin. Nutr.* **2009**, *63*, 253–258. [CrossRef]
27. Reilly, J.J. Diagnostic accuracy of the BMI for age in paediatrics. *Int. J. Obes.* **2006**, *30*, 595–597. [CrossRef]
28. da Silva, K.S.; da Silva Lopes, A.; da Silva, F.M. Sensitivity and specificity of different classification criteria for overweight in schoolchildren from João Pessoa, Paraíba, Brazil. *Rev. Nutr.* **2010**, *23*, 27–35.
29. Dencker, M.; Thorsson, O.; Lindén, C.; Wollmer, P.; Andersen, L.B.; Karlsson, M.K. BMI and objectively measured body fat and body fat distribution in prepubertal children. *Clin. Physiol. Funct. Imaging* **2007**, *27*, 12–16. [CrossRef]
30. Gómez-Campos, R.; David Langer, R.; de Fátima Guimarães, R.; Contiero San Martini, M.; Cossio-Bolaños, M.; de Arruda, M.; Guerra-Júnior, G.; Moreira Gonçalves, E. Accuracy of body mass index cutoffs for classifying obesity in Chilean children and adolescents. *Int. J. Environ. Res. Public Health* **2016**, *13*, 472. [CrossRef]
31. Mehdad, S.; Hamrani, A.; El Kari, K.; El Hamdouchi, A.; Barakat, A.; El Mzibri, M.; Mokhtar, N.; Aguenaou, H. Body mass index, waist circumference, body fat, fasting blood glucose in a sample of Moroccan adolescents aged 11–17 years. *J. Nutr. Metab.* **2012**, 510458. [CrossRef]
32. Bila, W.C.; De Freitas, A.E.; Galdino, A.S.; Ferriolli, E.; Pfrimer, K.; Lamounier, J.A. Deuterium oxide dilution and body composition in overweight and obese schoolchildren aged 6–9 years. *J. Pediatr.* **2016**, *92*, 46–52. [CrossRef] [PubMed]
33. Wickramasinghe, V.P.; Cleghorn, G.J.; Edmiston, K.A.; Murphy, A.J.; Abbott, R.A.; Davies, P.S.W. Validity of BMI as a measure of obesity in Australian white Caucasian and Australian Sri Lankan children. *Ann. Hum. Biol.* **2005**, *32*, 60–71. [CrossRef] [PubMed]
34. Romero-Corral, A.; Somers, V.K.; Sierra-Johnson, J.; Korenfeld, Y.; Boarin, S.; Korinek, J.; Jensen, M.D.; Parati, G.; Lopez-Jimenez, F. Normal weight obesity: A risk factor for cardiometabolic dysregulation and cardiovascular mortality. *Eur. Heart J.* **2010**, *31*, 737–746. [CrossRef] [PubMed]
35. World Health Organization. Public health Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Public Health* **2004**, *363*, 157–163.

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Review

School-Based Interventions Targeting Nutrition and Physical Activity, and Body Weight Status of African Children: A Systematic Review

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Abstract: Background: Overweight/obesity is an emerging health concern among African children. The aim of this study was to summarise available evidence from school-based interventions that focused on improving nutrition and physical activity knowledge, attitude, and behaviours, and weight status of children aged 6–15 years in the African context. Methods: Multiple databases were searched for studies evaluating school-based interventions of African origin that involved diet alone, physical activity alone, or multicomponent interventions, for at least 12 weeks in duration, reporting changes in either diet, physical activity, or body composition, and published between 1 January 2000 and 31 December 2018. No language restrictions were applied. Relevant data from eligible studies were extracted. Narrative synthesis was used to analyse and describe the data. Results: This systematic review included nine interventions comprising 10 studies. Studies were conducted among 9957 children and adolescents in two African countries, namely South Africa and Tunisia, and were generally of low methodological quality. The sample size at baseline ranged from 28 to 4003 participants. Two interventions reported enrolling children from both urban and rural areas. The majority of the study participants were elementary or primary school children and adolescents in grades 4 to 6. Participants were between the ages of 12.4 and 13.5 years. All but one intervention targeted children of both sexes. Four studies were described as randomised control trials, while five were pre- and post-test quasi-experiments. Except for one study that involved the community as a secondary setting, all were primarily school-based studies. The duration of the interventions ranged from four months to three years. The interventions focused largely on weight-related behaviours, while a few targeted weight status. The results of the effectiveness of these interventions were inconsistent: three of five studies that evaluated weight status (body mass index (BMI), BMI z-score, overweight/obesity prevalence), three of six studies that reported physical activity outcomes (number of sports activities, and physical activity duration ≥ 30 min for at least six days/week), and four of six reporting on nutrition-related outcomes (number meeting fruit and vegetable intake ≥ 5 times/day) found beneficial effects of the interventions. Conclusion: Given the dearth of studies and the inconsistent results, definite conclusions about the overall effectiveness and evidence could not be made. Nonetheless, this study has identified research gaps in the childhood obesity literature in Africa and strengthened the need for further studies, the findings of which would contribute valuable data and inform policy.

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Keywords: school-based interventions; physical activity; diet; energy balance-related behaviours; overweight/obesity; effectiveness

1. Introduction

Overweight and obesity are major public health threats worldwide [1]. The prevalence of childhood overweight increased by almost 50% between 2000 and 2015 [2]. In 2016, nearly 41 million children under 5 years were overweight or obese worldwide—of which, 49% and 24% lived in Asia and Africa [2]. Further, we recently estimated 9.4% overweight and 5.0% obesity prevalence among African school children [3].

The consequences of childhood obesity, which may be apparent even early in life, include increased risk for cardiovascular diseases [4] from dyslipidaemia, high blood pressure, and dysglycaemia. Documented evidence form Africa suggests positive associations of markers of metabolic syndrome with increased body mass index, body fat, overweight or obesity [5–10]. For instance, in a systematic review and meta-analysis of studies involving children and adolescents in Africa, Noubiap and colleagues [5] reported that elevated blood pressure was associated with body mass index. The blood pressure was six times higher in children who were obese relative to children with normal weight. Among Tunisian [8–10] and South African children [11,12], the prevalence of metabolic syndrome was higher in children and adolescents who were overweight/obese. Psychological issues such as stigmatisation and low self-esteem have similarly been reported [4]. Additionally, childhood obesity is a risk factor for adult obesity, and cardiometabolic morbidity [13], highlighting the importance of early prevention.

Given the multifactorial nature of overweight and obesity, there is the need for a multi-disciplinary approach that focuses on the diverse environments in which children live for successful interventions. The school setting has been identified as ideal for health promotion interventions, since children spend a significant amount of time in schools and are exposed to supportive environments such as school health policies, nutrition education and support, physical education, and physical activity (PA) during school hours. Despite these, the evidence from systematic reviews and meta-analyses on the effectiveness of school-based programmes have been mixed [14–19]. Moreover, the evidence is mostly from high- to middle-income countries. One systematic review [16] of studies from low- to middle-income countries concluded that overall, school-based programmes are promising in improving behavioural determinants of unhealthy body weight. Only one African study was included in that review, making the generalisation of their findings to African countries a challenge. The objective of the present systematic review was therefore to characterise and summarise available evidence from school-based interventions that focused on improving nutrition and physical activity knowledge, attitude, and behaviours, and weight status of learners aged 6–15 years in the African context.

2. Materials and Methods

2.1. Inclusion Criteria, Data Sources and Selection of Relevant Studies

The protocol for this systematic review has been previously described [20] and follows the Preferred reporting items for systematic review and meta-analysis (PRISMA) guidelines [21] (online supplementary material Table S1) with PROSPERO registration no. CRD42016041614. To be eligible for inclusion, studies had to be: conducted in school children aged 6–15 years, or presenting data specific for the subgroup of participants within the specified age range, of African origin and residing in African countries; primary research that evaluated dietary interventions only, PA interventions only, or combined dietary and PA interventions for at least 12 weeks in duration; reported changes in diet and PA knowledge, attitude and self-efficacy, increased participation in PA, increased intake of fruits and vegetables, decreased consumption of high-fat diets and sugar-sweetened beverages, changes in body weight, body mass index (BMI) or BMI z-score and reporting baseline and post-intervention measurements; focused primarily on the school setting; prevention and treatment that used a controlled or no control study design, with or without randomisation; published and unpublished studies between 1 January 2000 and 31 December 2018. Post-2000 studies were selected because, hitherto, the focus of research had been on undernutrition in African children; no language limitations were applied. For studies that evaluated multiple outcomes of the same intervention, these are treated as separate studies or the most comprehensive and recent report is included. Studies were excluded if they were clinic-based studies or had no school-based components; conducted among school children with eating disorders, critical illnesses or chronic conditions; in African populations but residing outside the continent.

A comprehensive search of MEDLINE (PubMed), MEDLINE (EBSCOHost), CINAHL (EBSCOHost), Academic Search Complete (EBSCOHost) and African Journals Online (AJOL) was conducted to identify potentially eligible studies. Key search terms relating to population (learners, 'school children', 'school-aged children', 'school going children'); interventions (diet-related, PA-related, school environment-related); geographical settings (African search filter [22]); and outcomes (changes in nutrition and PA knowledge, attitude, intention and self-efficacy, and behaviours, changes in body weight, percent body fat, BMI or BMI z-score) were used. The search terms were modified for each database. The search strategy for the PubMed database can be found in the online supplementary material Table S2. The reference lists of identified studies were manually checked for other relevant studies and key specialists in the field were contacted for any unpublished study. References were exported and duplicates removed using Endnote citation manager. The titles and abstracts of potentially relevant articles were independently screened by two reviewers for eligibility. Full-text copies of articles that met the eligibility criteria were obtained and assessed by two independent reviewers for inclusion in the review. Any disagreement about the eligibility was resolved through discussion.

2.2. Data Extraction

This was performed by one reviewer using a piloted data sheet that was purposely designed for the study and discussed by two reviewers. The following were extracted: study details (author, year of publication, and country of study); study design; study population (sample size, age, and gender); intervention characteristics (type, content, duration of study, follow-up time points, drop-outs, mode of delivery, and intervention provider); settings; outcome (primary outcomes: changes in body weight, percent body fat, BMI or BMI z-score; changes in intake of fruit and vegetables, and sugar-sweetened beverages, increased participation in PA and physical fitness; other relevant outcomes: changes in nutrition/dietary and PA knowledge, attitude, intention and self-efficacy); intervention effects (as reported by the authors) and theoretical basis of intervention. The corresponding author of one study was contacted for additional information but there was no response. The study was included in the review despite the unavailability of complete data because of its relevance.

2.3. Quality Assessment

The "Effective Public Health Practice Project quality assessment tool for quantitative studies" [23] was used to evaluate the methodological quality of the included studies. The studies were rated based on six components, namely, selection bias, study design, confounders, blinding, data collection methods, withdrawals, and drop-outs. For each study, the six components were rated as weak, moderate, or strong. The ratings for each study were summed to obtain overall scores. A study was rated strong when there were no weak ratings for any of the listed components. Studies with one weak rating were classified as moderate, while those with two or more weak ratings were rated as weak.

2.4. Data Synthesis

Meta-analysis was initially planned for this study. However, it could not be performed due to, the heterogeneity of study designs, interventions, reporting, measures and outcomes. Hence narrative synthesis was used to analyse and describe the data. Each included study was summarised by variables such as study design, setting and population, intervention characteristics including duration, drop-out and follow-up, intervention outcomes and measures, and theoretical basis of interventions. Where results were reported for multiple follow-up points during the intervention, only the final results are presented in this review. Intervention effects are presented as mean differences, Cohen's d, adjusted beta-estimates, only for those primary studies that reported these. Where applicable, simple statistics were computed for changes in outcome variables from baseline to post-intervention and follow-ups and presented as mean differences. The results are grouped and presented according to the outcome measures.

2.5. Ethics Consideration

Since this study did not involve the collection of primary data, ethics was not a requirement.

3. Results

3.1. Description of the Included Studies

The flowchart for the selection of studies is presented in Figure 1. The database and other searches identified 720 studies. After removal of duplicates, 311 titles and abstracts were screened for eligibility. Eighteen full text articles were reviewed and 10 studies that met the inclusion criteria were retained in this review. Two of these studies evaluated the same intervention [24,25].

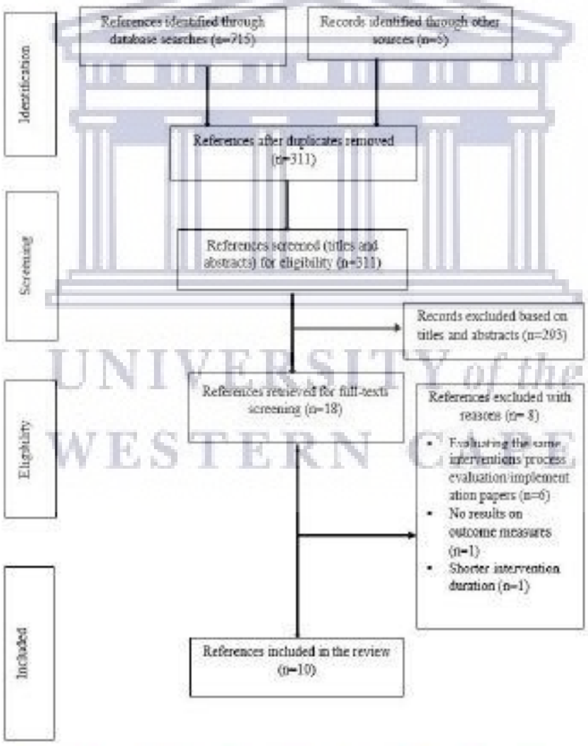

Figure 1. Flow chart for the literature search for intervention studies.

3.1.1. Study Setting, Design, and Population

Table 1 shows the characteristics of the included studies. This systematic review included 10 studies conducted among 9957 children and adolescents in two African countries, namely South Africa [24–29] and Tunisia [30–33]. The included studies were published between 2009 and 2017. Four of the studies were described as randomised control trials (RCTs) [24,25,28,33], five were pre- and post-test quasi-experiments [26,27,30–32], and one did not report the design [29]. Two of the studies were pilot studies to evaluate the feasibility of the interventions [26,27]. All the studies were primarily school-based studies, with one study [32] involving the community as a secondary setting. Three studies reported enrolling children from both urban and rural schools [24,25,28]. Two studies [24,25] reported that participants were from low socioeconomic settings (defined as quintile 1 and 2 vs. quintile 3 schools). The majority of the participants were primary school children and adolescents in grades 4 to 6 [24–28], and grades 7, 8, and 9 [31,32]. One study [30] explicitly reported recruiting adolescents from public secondary schools, while another [28] involved adolescents from urban and rural settings. The number of children that participated at baseline ranged from 28 [33] to 4003 [32]. Except for one study that involved only boys [29], all the interventions targeted children of both sexes. Of the studies that reported the mean age of participants, this ranged from 12.4 years [28] to 13.5 years [31].

3.1.2. Intervention Characteristics

The duration of the interventions ranged from four months [27,33] to three years [24,25,32], with four lasting less than one year [26,27,29,33]. Post-intervention follow-ups, which were reported in three studies, ranged between 4 months [27,31] and 1 year [32]. The drop-out rates reported in five studies [26,28,30,31,33] ranged from 0.0% [33] (100.0% completed the intervention) to 30.8% [31]. Three of the ten studies were only PA-based interventions [27,29,33] and seven were multicomponent interventions involving both diet and PA only [24,25,31,32] or diet, PA and other health-promoting behaviours such as tobacco use, and also the school environments [26,28,30].

Although the research teams comprised school personnel such as teachers, school doctors and nurses, medical personnel, and student leader groups, the majority of the intervention activities were mainly facilitated by school teachers with additional training [24–27,29–31]. Programmes were presented as interactive sessions, games and sports, group discussions and exercise [27–31,33]. One study conducted a delayed intervention for controls [32], while, in another, the controls were exposed to a type of intervention, namely, prevention of human immunodeficiency virus (HIV)/sexually transmitted disease [28]. Furthermore, four studies integrated their additional sessions into the existing school curricula [25–27,30], while two others [28,33] were implemented as extracurricular activities. Additionally, two of the intervention studies targeted overweight and obese children [31,33], one involved parents or caregivers [28] and two involved the school environments by promoting the increased availability of healthy foods at school/tuck shops [26] and provision of PA equipment [31].

Table 1. Summary characteristics of the included studies on school-based interventions targeting nutrition, physical activity, and weight status of children in African countries.

Reference	Design, Setting and Population	Intervention Characteristics		Intervention Outcomes			Measures	Theoretical Basis	Overall Quality
		Intervention Components	Duration, Follow-Up and Drop-Outs	Weight Status	Nutrition	PA			
Naidoo et al., 2009 [26]	Design: Cohort (one group pre- and post-test) Setting: Four primary schools in KwaZulu-Natal, South Africa Participants: 256 children in grade 6 from low- to middle-income settings. Boys/girls: 81/104	Intervention: Diet, PA and school environment Concepts of PA and healthy eating habits were integrated with the existing curriculum. Programme was implemented by school personnel. Teachers were to advise and prompt children to make healthy choices. Schools were to establish health promoting environments by increasing the availability of healthy foods and decrease unhealthy foods at school/tuck shops.	Duration: 6 months Drop-outs: 71 (27.7%)	√		√	BMI, increased participation in sports and PA and the availability of healthy food choices.	No	Weak
Draper et al., 2010 [27]	Design: Pre- and post-test study Setting: Five elementary/primary schools in Alexandra Township, Gauteng Province, South Africa Participants: 508 children in grade 4–6 Age: NR Boys/girls: NR	Intervention: PA Teachers provided physical education as part of an integrated curriculum (Healthnutz project) to children, while situational analysis and focus group discussions were conducted for teachers and research team monitors.	Duration: 6 months Follow-up: 4 months	√		√	Physical fitness, knowledge, self-efficacy and attitudes and weight.	No	Weak

354

Table 1. *Cont.*

Reference	Design, Setting and Population	Intervention Characteristics		Intervention Outcomes			Measures	Theoretical Basis	Overall Quality
		Intervention Components	Duration, Follow-Up and Drop-Outs	Weight Status	Nutrition	PA			
Harrabi et al., 2010 [30]	Design: Pre- and post-test quasi experiment Setting: Seventy-six classes from four public secondary schools in Tunisia Participants: 2200 children Age (range): 12–16 years Boys/girls: 1026/1174	Intervention: Diet, PA and tobacco use This was delivered by project team, teachers and school doctors. Cognitive behavioural components of health knowledge and health promoting concepts such as tobacco use, PA, and healthy diet were integrated with the biological sciences and physical education curriculum.	Duration: 1 year Drop-outs: 138 (5.9%)		√	√	Knowledge, intentions, behaviours of PA and nutrition.	No	Weak
Jemmott et al., 2011 [28]	Design: RCT Setting: 18 schools (14 urban and four rural) in Eastern Cape Province, South Africa Participants: 1057 children in grade 6 Age (mean): 12.4 years; 9–17 years Boys/girls: 558/499	Intervention Diet, PA and cognitive-behavioural health Consisted of 12 one-hour modules, with two modules delivered during each of the six sessions on six consecutive school days; extracurricular sessions held at the end of the school day and included interactive exercises, games, brainstorming, role-playing and group discussions. Homework approach to involve parents or caregivers.	Duration: 13 months Drop-outs: 35 (3.3%)		√	√	Nutrition and PA knowledge, attitudes, self-efficacy and behaviours.	Social cognitive theory and the theory of planned behaviour	Strong

Table 1. *Cont*.

Reference	Design, Setting and Population	Intervention Characteristics		Intervention Outcomes			Measures	Theoretical Basis	Overall Quality
		Intervention Components	Duration, Follow-Up and Drop-Outs	Weight Status	Nutrition	PA			
Monyeki et al., 2012 [29]	Design: NR Setting: Two primary schools in Gauteng Province, South Africa Participants: 322 children Age (range): 9–13 years Boys: 322	Intervention: PA Two 30 min exercise sessions per week during school hours. Lessons consisted of warm-up with stretching exercises, speed, strength, balance and cool down exercises. Intervention was provided by a trained physical education teacher.	Duration: 10 mo	√			BMI and body fat.	No	Weak
Regaieg et al., 2013 [33]	Design: RCT Setting: Elementary schools in Sfax, Tunisia. Participants: 28 obese children Age (range): 12–14 years Boys/girls: 16/12	Intervention: PA Four extracurricular sessions (two sessions on weekdays and two on weekends) of 60 min per week aerobic exercises in addition to regular physical education that was provided by the schools. Exercises were performed under the supervision of a cardiologist.	Duration: 4 months Drop-outs: 0%	√			BMI, weight, waist circumference and FFM.	No	Weak

Table 1. *Cont.*

Reference	Design, Setting and Population	Intervention Characteristics		Intervention Outcomes			Measures	Theoretical Basis	Overall Quality
		Intervention Components	Duration, Follow-Up and Drop-Outs	Weight Status	Nutrition	PA			
Maatoug et al., 2015 [31]	Design: Quasi-experiment Settings: Six schools in Sousse, Tunisia Participants: 585 obese and overweight children in grades 7 and 8 Age: 13.1 ± 0.9 y and 13.5 ± 0.9 years in intervention and control groups Boys/girls: 236/349	Intervention: Diet and PA School personnel including PA teachers and parents were trained on the relevance of healthy behaviours in obesity management. Schools were provided with PA equipment. Children were motivated to engage in regular PA and follow healthy diets in collective interactive sessions twice a week, with each session lasting one hour, as well as individual sessions for obese children. Intervention was facilitated by a dietician, psychologist, medical doctor and teachers ("Contrepoids" program).	Duration: 1 year Follow-up: 4 months Drop-outs: 180 (30.8%)	√			BMI and zBMI.	No	Weak
De Villiers et al., 2016 [25] [a]	Design: Cluster RCT Setting: 16 primary schools (eight urban and eight rural) in low SES settings in Western Cape, South Africa Participants: 998 children in grade 4 Boys/girls: 471/526	Intervention: Diet and PA HealthKick activities included the improvement of the school nutrition environment by developing healthy school nutrition policies, promoting the availability of healthier food options, initiation of vegetable gardens at schools and providing nutrition education support. Teachers were given training and resources, and were to organise an additional 15 min of PA per day and at least one healthy eating activity per month. Intervention was integrated with the existing nutrition curriculum.	Duration: 3 years	√	√		Nutrition behaviour, self-efficacy, overweight and obesity.	Socioecological theory	Weak

Table 1. *Cont.*

Reference	Design, Setting and Population	Intervention Characteristics		Intervention Outcomes			Measures	Theoretical Basis	Overall Quality
		Intervention Components	Duration, Follow-Up and Drop-Outs	Weight Status	Nutrition	PA			
Uys et al., 2016 [24] [a]	Design: Cluster RCT Setting: 16 primary schools (eight urban and eight rural) in low SES settings Participants: 998 children in grade 4 Boys/girls: 471/526	Intervention: Diet and PA This was implemented by the intervention schools that were also given a toolkit containing teachers' manual, curriculum manual, a resource box and PA resource bin (HealthKick).	Duration: 3 years			√	Physical fitness levels and PA-related knowledge, attitudes and behaviours.	Socioecological theory	Weak
Ghamman et al. 2017 [32]	Design: Quasi-experiment Setting: 17 schools in Sousse, Tunisia Participants: 4003 children in grades 7 and 9 Age: 11–16 years Boys/girls: 1933/2070	Intervention: Diet and PA Educational events were organised at least three times in a school year for children, parents and teachers. Classroom sessions were organised by teachers and consisted of interactive lessons of healthy eating, the benefits of regular PA, and ways to incorporate PA into usual activities. After-school soccer games were organised both within and between the schools to encourage PA. Programmes were delivered by student leaders, project team and teachers ("Together in Health").	Duration: 3 years Follow-up: 1 year	√	√	√	Weight status, PA, screen time behaviours, fruit and vegetable intake and fast food intake.	No	Weak

NR: not reported; RCT: randomised controlled trial; BMI: body mass index; BMI z-scores: body mass index z-scores; PA: physical activity; [a] these two studies evaluated the same intervention (HealthKick) with different outcomes measures; SES: socioeconomic status (defined as quintile 1 and 2 vs. quintile 3 schools); RCT: randomised control trial.

3.1.3. Intervention Outcomes and Measures

Two studies [24,27] evaluated PA-related outcomes only, three anthropometric outcomes only [29,31,33], two nutrition- and PA-related outcomes [26,28,30], one nutrition and anthropometric outcomes [25], two nutrition, PA, and anthropometric outcomes [32].

3.1.4. Theoretical Basis of Intervention

The majority of the interventions were not theory based, except for three studies from South Africa. Socioecological theory guided the development of two [24,25], while one was based on social cognitive theory and the theory of planned behaviour [28].

3.2. *Methodological Quality of the Included Studies*

The overall methodological quality of the included studies is presented in Table 1 (details can be found in the online supplementary Table S3). Nine out of the ten studies were categorised as weak and one of high quality [28]. The weak ratings were mainly due to missing information; the authors did not describe the components under consideration in most instances. For example, five studies each were rated either weak or moderate based on selection bias and only one of the four randomised controlled studies described method of randomisation [28]. The drop-out rates, reported by five studies [26,28,30,31,33] were between nil and 30.8%. Information on blinding of assessors to the allocation of treatments in the RCTs and confounding were mostly missing in the studies.

3.3. *Main Findings of Interventions*

3.3.1. Weight Status

The main findings of the interventions are presented in Table 2. Six studies evaluated changes in body composition [25,29–33] and the results were mixed. Of these, three reported statistically significant effects in favour of the intervention groups [31–33], while observed changes were not significant in the other two studies [25,29]. It should be noted that two [31,33] of the studies targeted overweight/obese children. Regaieg and co-workers [33] reported a statistically significantly decrease in BMI of children in the intervention group compared to those in the control group (-0.6 kg/m^2, $p < 0.001$). In addition to targeting obese children, this was a small sample size. Maatoug and colleagues [31] reported a statistically significant decrease in BMI z-score in the post-intervention and follow-up (-0.13, $p < 0.001$ and -0.34, $p < 0.001$ respectively) in the overweight/obese children exposed to the intervention compared to those in the control group. In another study [32], overweight prevalence was significantly reduced in the intervention group (-2.0%, $p = 0.036$) but not the controls (-1.0%, $p = 0.602$). On the contrary, two studies did not observe beneficial effects of the intervention on weight status [25,29].

Table 2. Summary of results of school-based interventions targeting nutrition and physical activity, and body weight status of children in African countries.

Reference and Outcome	Change Over Time in I and C and I vs. C					Intervention Effects as Reported in Primary Studies	Main Findings
	ΔI	ΔC	*p*-Value	ΔI–ΔC	*p*-Value		
Naidoo et al., 2009 [26] †							PA and sports participation increased significantly post-intervention ($p < 0.05$). Healthy food and drinks choices were available.
Number of sports participated in (average)	10.0 *						
PA > 5 times/week after school (%)	20.0 *						
Boys							
Sit ups	+2.0						
Sit and reach (cm)	+0.29						
Standing broad jump (m)	+1.0						
BMI (kg/m^2)	+0.8						
Girls							
Sit ups	+1.0						
Sit and reach (cm)	+0.89						
Standing broad jump (m)	+0.0						
BMI (kg/m^2)	+0.65						
Draper et al., 2010 [27]							Intervention improved self-efficacy for PA in the experimental group but not the controls ($p < 0.05$). PA knowledge improved in both the intervention and control groups. There was no effect on overall physical fitness scores. However, significant effects on sit and reach ($p < 0.001$), sit ups ($p < 0.02$), and shuttle run ($p < 0.0001$) between intervention and control groups were reported. Weight of children in the intervention significantly decreased, while change was reported for height.
Sit and reach (cm)	+4.40	−10.50	<0.001				
Sit ups (in 30 s)	+1.80	+0.30	<0.02				
Shuttle run (seconds)	−2.30	+1.40	<0.0001				
Long jump (cm)	+9.70	+14.6	NS				
Ball throw (m)	−1.10	+0.10	NS				
PA self-efficacy	+0.30	−0.01	<0.05				
PA knowledge	+0.56	+0.47	NS				
Harrabi et al., 2010 [30]							Nutrition knowledge and intention improved significantly in the intervention compared to the control group. The percentage of children with increased intake of fruits and vegetables increased in both groups, although significant in the controls. PA intention ($p < 0.001$) and behaviour ($p < 0.001$) improved in the intervention group. No significant differences in BMI in both groups.
What to eat for breakfast (%)	+25.1	+1.2		+22.9	0.0001		
Intention to eat breakfast (%)	+8.2	+2.9		+7.3	0.0001		
Fruit and vegetable intake ≥ 5 times/day (%)	+10.1	+9.6		−2.5	NS		
Intention to engage in PA daily (%)	+9.1	+1.7		+3.5			
PA duration ≥ 30 min for at least six days a week (%)	+18.4	+9.7		−1.0	0.0001		
Jemmott et al., 2011 ª [28]							More participants in health-promotion intervention than controls met 5-a-Day fruit ($p = 0.003$) and vegetable ($p = 0.0001$) intake, and PA guidelines ($p = 0.0001$). Health-promotion knowledge, attitude and intention increased (all $p < 0.0001$) in the intervention group.
Fruit and vegetable intake ≥ 5 times/day in the past 30 days (5-a-Day) (%)	+2.83	−5.70			0.008	+0.16	
Mean servings of fruit per day in the past 30 days	+0.49	+0.33			0.003	+0.19	
Mean servings of vegetables/day in the past 30 days	+0.98	+0.17			0.0001	+0.24	

Table 2. *Cont.*

Reference and Outcome	Change Over Time in I and C and I vs. C					Intervention Effects as Reported in Primary Studies	Main Findings
	ΔI	ΔC	*p*-Value	ΔI–ΔC	*p*-Value		
Meeting PA guidelines in the past 7 days (%)	+7.10	+7.10			0.0001	+0.27	
Health knowledge	+3.48	+1.38			0.0001	+1.03	
Attitude toward health-promoting behaviour	+1.14	+0.69			0.0001	+0.89	
Intention for health-promoting behaviour	+1.02	+0.54			0.0001	+0.81	
Monyeki et al., 2012 [29]							Non-significant decreasing trends in BMI and percentage body fat ($p = 0.32$) in intervention group, whereas BMI tended to be stable with an increasing percentage body fat by age in the control group.
Body fat at age 12 y (%)	−0.32	+1.62	NS				
Body fat at age 13 y (%)	−1.03	+2.31	NS				
Regaieg et al., 2013 [33]							Significant decreases in BMI, FM and waist circumference in intervention ($p < 0.001$). In the controls, a non-significant increase ($p = 0.11$) in waist circumference was observed. There were increases in FFM in both groups, but this was higher in the intervention.
Weight (kg)	+0.70	+2.60	<0.001				
BMI (kg/m^2)	−0.60	+0.50	<0.01				
FM (%)	−4.30	−0.20	<0.01				
Waist circumference (cm)	−1.70	+0.70	<0.001				
Maatoug et al., 2015 [31]							BMI z-score decreased significantly from pre-intervention to post-intervention and from post-intervention to 4-mo follow-up in the intervention group. In the control group, BMI z-score decreased significantly from pre- to post- intervention but nor from post- to follow-up.
BMI (kg/m^2)	+0.25	+0.49 ***					
BMI z score	−0.13 ***	−0.18 ***					
De Villiers et al., 2016 [a] [25]							Nutrition knowledge ($p = 0.011$) and self-efficacy ($p = 0.039$) significantly improved in the intervention group as compared with the controls. The intervention did not improve nutrition behaviour ($p = 0.743$) nor weight status of the children.
Nutrition knowledge	+2.52	+0.60				+1.92 **	
Nutrition behaviour	−0.52	−0.60			NS	+0.09	
Self-efficacy	+0.36	−0.35				+0.71 *	
Overweight (%)	+1.00	+1.00					
Obesity (%)	−4.00	+7.00					
Uys et al., 2016 [a] [24]							Intervention did not improve overall physical fitness and determinants of PA behaviour. PA knowledge improved in both intervention ($p < 0.005$) and control (($p < 0.001$) groups. Additionally, improvement was only observed in the sit-ups score of children in the intervention group ($p < 0.05$).
PA knowledge						−0.48 *	
PA behaviour						−0.44	
PA self-efficacy						−0.38	
Sit and reach (cm)						−1.29	
Sit ups (in 30 s)						+1.62 *	
Shuttle run (seconds)						+3.32	
Long jump (cm)						−5.75	

Table 2. *Cont.*

Reference and Outcome	Change Over Time in I and C and I vs. C					Intervention Effects as Reported in Primary Studies	Main Findings
	ΔI	ΔC	*p*-Value	ΔI–ΔC	*p*-Value		
Ghamman et al., 2017 [32]							Overall, higher proportion of children ($p = 0.010$), boys ($p = 0.021$) and those ≥ 14 years ($p = 0.004$) in the intervention group met the recommended daily PA post-intervention, whereas, in the controls, an increase was observed only at follow-up ($p = 0.023$). Further, more children in the intervention group reported eating five fruits and vegetables daily ($p = 0.02$). Overweight prevalence reduced in the intervention group ($p = 0.036$).
Fruit and vegetable intake ≥ 5 times/day (%)	+3.2 *	−5.2 **					
Fast food consumption ≥ 4 times/week (%)	−0.8	+5.1 ***					
Meeting recommended PA (%)	−3.6 *	+0.1					
Weekday screen time > 2 hr/day (%)	+1.4	−2.1					
Weekend screen day > 2 hr/day	−0.1	−7.0 ***					
Prevalence of overweight (%)	−2.6 *	−1.0					

NS: not significant; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; [a]: adjusted beta estimates for baseline prevalence; FM: fat mass; FFM: fat free mass; PA: physical activity; BMI: body mass index; BMI z-score: body mass index z-score; hr: hour; I: intervention; C: control; IE: intervention effects; ΔI: change in intervention; ΔC: change in control; ΔI–ΔC: difference between change in intervention and control; [‡]: no controls, change in intervention are presented by gender.

3.3.2. Physical Fitness, and PA Knowledge, Attitudes, Intentions and Behaviours

Six studies evaluated physical fitness, PA knowledge, attitudes, and behaviours [24,26–28,32]. In one study, [26], PA and sports participation increased significantly. This study did not have a control group; however, the number of sports activities that children participated in for at least five times per week increased from 35% to 55% after the intervention ($p < 0.05$). In other studies, more children met the recommended PA guidelines [28,32]. In the study by Jemmott and colleagues [28] for instance, the intervention resulted in significantly more participants meeting PA guidelines in the past seven days compared with controls (odds ratio = 1.56 ((95% confidence interval (CI): 1.29, 1.89)). Ghamman and colleagues [32] reported beneficial effects of the intervention in boys ($p = 0.021$) and older children ($p = 0.004$). For the studies that measured physical fitness, no overall effects were observed on the scores [24,27]. PA self-efficacy [27], knowledge, attitudes and intention improved significantly in children in the intervention but not in the controls [28].

3.3.3. Nutrition Knowledge, Attitudes, Self-Efficacy and Behaviours

Five studies assessed changes in nutrition knowledge, attitudes, self-efficacy and intentions scores, and dietary behaviours including fruit and vegetable intake, fast food intake, and consumption of carbonated drinks [25,26,28,30,32]. Two studies reported statistically significantly increase in the number of participants in the intervention group that met the recommended intake of fruits and vegetables compared with those in the controls. Jemmot et al. [28] reported that children in the intervention group were 1.30 times more likely to meet the recommended intake of fruits and vegetables compared to those in the controls (95% CI: 1.07, 1.58. Likewise, Ghammam [32] found that more children in the intervention groups (+3.2%, $p = 0.026$) met the recommended intake of fruits and vegetables compared with the those in the controls (−5.5%, $p = 0.001$). No significant effects were observed in one study [30]. Moreover, De Villiers [25] did not observe overall significant effects on dietary behaviour. Furthermore, significant improvements were reported in nutrition knowledge, self-efficacy, attitudes and intention in the intervention groups in other studies [25,28,30].

4. Discussion

The present systematic review aimed to summarise the available evidence on school-based interventions to prevent childhood overweight/obesity within the African context. A total of ten studies were evaluated. These studies were generally of low methodological quality. The majority of the studies focused on nutrition and physical activity, while a few targeted body composition indices. Moreover, the programme development of the majority of these interventions were not theory based. The results of the effectiveness of these interventions were inconsistent: three of five studies that evaluated weight status, three of six that reported physical activity outcomes, and four of six reporting on nutrition-related outcomes found beneficial effects of the interventions. We are however unable to make definite statements about the overall effectiveness and quality of evidence due to the limited number and heterogeneous outcomes across studies.

These findings highlight the paucity of high-quality, theory based interventions to mitigate the effects of overweight and obesity, and energy-related behaviours among African children. A considerable body of evidence suggests that multicomponent school-based interventions that target PA, dietary behaviours, sedentary behaviours, and the environments are more likely to be effective in children and adolescents compared with single component interventions [15–18,34]. Given the multi-faceted nature of overweight and obesity, it is not surprising that programmes that target individual behaviours and the obesogenic environments simultaneously are promising. Additionally, these behaviours tend to cluster so that any successful intervention should consider both ends of the energy balance equation. Contrary to the aforementioned studies, the present study found inconsistent results from the multicomponent programmes. It is worth noting that of the single component interventions, positive effects were reported in a small sample of children who were overweight and obese which may not have enough power.

The importance of theoretical frameworks in childhood obesity interventions have been highlighted [35]. In the present review, only three of the ten included studies were theory-based interventions. While one reported beneficial effects in favour of the intervention groups in all the measured outcomes, results from the other two were inconsistent. Some beneficial effects were equally reported in the studies that did not apply theories. Documented evidence indicates that duration of interventions may have an overall impact on adiposity, dietary, and PA behaviours [17–19]. Kamath et al. [19] showed that intervention trials with longer duration (>6 months) and post-intervention outcomes tended to yield marginally larger effects. Results from a systematic review [18] showed that studies that reported significant effects were implemented over a longer period compared to those that did not report significant effects. Waters et al. [17] reported that interventions that lasted longer significantly decreased the prevalence of overweight/obesity in preschool children and children aged 6–12 years. The results from the present study are inconsistent; of the studies that lasted >1 year, four yielded statistically significant intervention outcomes, while two were not significant.

The majority of these interventions were designed to improve dietary and PA activity behaviours by targeting the children. The limited successes of many well-intended behavioural interventions have been attributed to changing behaviours without corresponding changes in the obesogenic environments such as the home, school policies and programmes, advertising, and the community. For school children, the family or home environment is one key setting to target for successful and sustainable interventions. Parents play an influential role in promoting healthy dietary and physical activity behaviours of the children by not only parental practices and rules, but also by providing the supportive environment for these behaviours as well as serving as positive role models [36–38]. Parental involvement in school-based health interventions in developed countries is well documented [14,39–41]; however, in Africa, there is a paucity of published studies. While there has been considerable interest in parental involvement in school-based obesity interventions, the evidence for programme effectiveness is unclear. Results from one systematic review were inconclusive [39]; however, other studies found positive effects with parental engagements [40,41]. In the present review, one study attempted to involve parents by organising meetings but the turnout was [25]. Another study reported parental involvement through a homework approach [28]. Although this study was effective, no conclusions could be made based on the available evidence.

The results of the present systematic review should be interpreted cautiously. The paucity of studies in Africa is a major limitation; all the studies included in this systematic review were conducted in two African countries and hence the findings could not be generalised to the entire continent. It is possible some relevant studies that were not indexed in the targeted databases were missed in the review process. However, efforts were made to contact key experts across and outside Africa for the existence of relevant studies among African schoolchildren. Additionally, multiple reviewers were involved in the review and interpretation of the results. The methodological quality of the studies was low. Generally, important information such as selection bias, confounding, blinding, reliability, and validity of data collection tools were either missing or not clearly reported. Two of the included studies, however, made references to implementation details elsewhere [24,25]. It should be noted that none of the studies reported adverse effects of the interventions. Moreover, except for body composition and physical fitness, all outcomes relied on self-reports. Reliance on self-reports by children may be subject to recall bias and social desirability, thereby affecting the reliability and accuracy. Furthermore, given that most of the included studies were non-randomised, blinding of participants, data collectors and intervention assessors was not possible. In addition, two studies reported a high attrition rate. Those in the intervention have a high probability of completing the study and may have contributed to the reported effectiveness in the interventions. Meta-analysis was not possible given that the included studies were heterogeneous.

Despite these limitations, this is one of the first systematic reviews of the literature of school-based interventions in the African context. A further strength was the use of the "Effective Public Health Practice Project quality assessment tool for quantitative studies" to assess the quality. While the effectiveness and the evidence from this systematic review may be limited, these broadly agree with the available literature [14,18,19]. The result of this study has research and public health implications. Given the increasing trends of obesity in African children and the limited studies on prevention efforts in the school settings, this study demonstrates the need for further intervention efforts across African countries. There is a need to explore the possibility of rigorous, large, multi-site, well-designed, and theory-driven interventions, with harmonised methodologies and parental involvement. Furthermore, researchers should consider incorporating formative research prior to implementation, as well as integrating interventions into already existing healthy lifestyle school programmes (regular school curricula) and structures to ensure maximum reach, sustainability and effectiveness. Fortunately, in line with the recommendations by World Health Organization (WHO) [42], many African countries have detailed policy initiatives spanning the family, school, the community, and the food and beverage industry. Some of the initiatives targeting educational settings include the creation of healthy food environments in schools and child-care settings by restricting marketing of unhealthy foods and beverages. Additionally, these settings are to provide adequate facilities on school premises and in public spaces for PA during recreational time for all children. It is expected that governments provide the needed resources for the implementation and evaluation of these policy interventions across Africa.

5. Conclusions

Overweight and obesity are emerging public health issues among African school children. Given the dearth of studies on school-based obesity interventions and the inconsistent results, definite conclusions about the overall effectiveness could not be made. This study has identified research gaps in the childhood obesity literature in Africa and strengthened the need for further studies. Future studies should focus on objective measures of body composition in addition to targeted energy related behaviours. The findings of such interventions would contribute valuable data which will inform policy.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/12/1/95/s1. Table S1: Search Strategy PubMed; Table S2: PRISMA checklist; Table S3: Quality of included studies.

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References

1. Ng, M.; Fleming, T.; Robinson, M.; Thomson, B.; Graetz, N.; Margono, C.; Mullany, E.C.; Biryukov, S.; Abbafati, C.; Abera, S.F.; et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet* **2014**, *384*, 766–781. [CrossRef]
2. UNICEF; World Health Organization; World Bank Group. *Levels and Trends in Child Malnutrition*; eSocialSciences: London, UK, 2016; pp. 1–8.
3. Adom, T.; Kengne, A.P.; De Villiers, A.; Puoane, T. Prevalence of overweight and obesity among African primary school learners: A systematic review and meta-analysis. *Obes. Sci. Pract.* **2019**, *5*, 487–502. [CrossRef]
4. Reilly, J.J. Health consequences of obesity. *Arch. Dis. Child.* **2003**, *88*, 748–752. [CrossRef]
5. Noubiap, J.J.; Essouma, M.; Bigna, J.J.; Jingi, A.M.; Aminde, L.N.; Nansseu, J.R. Prevalence of elevated blood pressure in children and adolescents in Africa: A systematic review and meta-analysis. *Lancet Public Health* **2017**, *2*, e375–e386. [CrossRef]

6. Agyemang, C.; Redekop, W.K.; Owusu-Dabo, E.; Bruijnzeels, M.A. Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. *BMC Public Health* **2005**, *5*, 114. [CrossRef]
7. Salman, Z.; Kirk, G.D.; DeBoer, M.D. High Rate of Obesity-Associated Hypertension among Primary Schoolchildren in Sudan. *Int. J. Hypertens.* **2011**, *2011*, 629492. [CrossRef]
8. Harrabi, I.; Bouaouina, M.; Maatoug, J.; Gaha, R.; Ghannem, H. Prevalence of the metabolic syndrome among urban schoolchildren in Sousse, Tunisia. *Int. J. Cardiol.* **2009**, *135*, 130–131. [CrossRef]
9. Jmal, L.; Jmal, A.; Abdennebi, M.; Feki, M.; Boukthir, S. Prevalence of Metabolic Syndrome in Tunisian Overweight and Obese Children. *Tunis. Med.* **2019**, *97*, 133–139.
10. Jamoussi, H.; Mahjoub, F.; Sallemi, H.; Berriche, O.; Ounaissa, K.; Amrouche, C.; Blouza, S. Metabolic Syndrome in Tunisian Obese Children and Adolescents. *Tunis. Med.* **2012**, *90*, 36–40.
11. Zeelie, A.; Moss, S.J.; Kruger, H.S. The relationship between body composition and selected metabolic syndrome markers in black adolescents in South Africa: The PLAY study. *Nutrition* **2010**, *26*, 1059–1064. [CrossRef]
12. Munthali, R.J.; Kagura, J.; Lombard, Z.; Norris, S.A. Childhood adiposity trajectories are associated with late adolescent blood pressure: Birth to twenty cohort. *BMC Public Health* **2016**, *16*, 665. [CrossRef]
13. Reilly, J.J.; Kelly, J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: Systematic review. *Int. J. Obes.* **2011**, *35*, 891–898. [CrossRef]
14. Brown, T.; Summerbell, C. Systematic review of school-based interventions that focus on changing dietary intake and physical activity levels to prevent childhood obesity: An update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. *Obes. Rev.* **2009**, *10*, 110–141. [CrossRef]
15. Bleich, S.N.; Vercammen, K.A.; Zatz, L.Y.; Frelier, J.M.; Ebbeling, C.B.; Peeters, A. Interventions to prevent global childhood overweight and obesity: A systematic review. *Lancet Diabetes Endocrinol.* **2018**, *6*, 332–346. [CrossRef]
16. Verstraeten, R.; Roberfroid, D.; Lachat, C.; Leroy, J.L.; Holdsworth, M.; Maes, L.; Kolsteren, P.W. Effectiveness of preventive school-based obesity interventions in low- and middle-income countries: A systematic review. *Am. J. Clin. Nutr.* **2012**, *96*, 415–438. [CrossRef]
17. Waters, E.; de Silva-Sanigorski, A.; Burford, B.J.; Brown, T.; Campbell, K.J.; Gao, Y.; Armstrong, R.; Prosser, L.; Summerbell, C.D. Interventions for preventing obesity in children. *Cochrane Database Syst. Rev.* **2011**. [CrossRef]
18. Dobbins, M.; Husson, H.; Decorby, K.; RL, L. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst. Rev.* **2013**. [CrossRef]
19. Kamath, C.C.; Vickers, K.S.; Ehrlich, A.; Mcgovern, L.; Johnson, J.; Singhal, V.; Paulo, R.; Hettinger, A.; Erwin, P.J.; Montori, V.M. Behavioral Interventions to Prevent Childhood Obesity: A Systematic Review and Metaanalyses of Randomized Trials. *Clin. Rev.* **2008**, *93*, 4606–4615. [CrossRef]
20. Adom, T.; Puoane, T.; De Villiers, A.; Kengne, A.P. Protocol for systematic review of school-based interventions to prevent and control obesity in African learners. *BMJ Open* **2017**, *7*, e013540. [CrossRef]
21. Moher, D.; Shamseer, L.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A.; PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst. Rev.* **2015**, *4*, 1. [CrossRef]
22. Siegfried, N.; Clarke, M.; Volmink, J. Randomised controlled trials in Africa of HIV and AIDS: Descriptive study and spatial distribution. *BMJ* **2005**, *331*, 742. [CrossRef] [PubMed]
23. Effective Public Health Practice Project. *Quality Assessment Tool for Quantitative Studies*; Effective Public Health Practice Project: Hamilton, ON, Canada, 1998.
24. Uys, M.; Draper, C.E.; Hendricks, S.; De Villiers, A.; Fourie, J.; Steyn, N.P.; Lambert, E.V. Impact of a South African school-based intervention, HealthKick, on fitness correlates. *Am. J. Health Behav.* **2016**, *40*, 55–66. [CrossRef] [PubMed]
25. De Villiers, A.; Steyn, N.P.; Draper, C.E.; Hill, J.; Gwebushe, N.; Lambert, E.V.; Lombard, C. Primary school children's nutrition knowledge, self-efficacy, and behavior, after a three-year healthy lifestyle intervention (HealthKick). *Ethn. Dis.* **2016**, *26*, 171–180. [CrossRef]
26. Naidoo, R.; Coopoo, Y.; Lambert, E.; Draper, C. Impact of a primary school-based nutrition and physical activity intervention on learners in KwaZulu-Natal, South Africa: A pilot study. *S. Afr. J. Sport Med.* **2009**, *21*, 7–12. [CrossRef]

27. Draper, C.E.; De Kock, L.; Grimsrud, A.T.; Rudolph, M.; Nemutandani, S.; Kolbe-Alexander, T. Evaluation of a school-based physical activity intervention in Alexandra Township. *S. Afr. J. Sport Med.* **2010**, *22*, 12–19. [CrossRef]
28. Jemmott, J.B., III; Jemmott, L.S.; O'Leary, A.; Ngwane, Z.; Icard, L.; Bellamy, S.; Jones, S.; Landis, R.J.; Heeren, G.A.; Tyler, J.C.; et al. Cognitive-behavioural health-promotion intervention increases fruit and vegetable consumption and physical activity among South African adolescents: A cluster-randomised controlled trial. *Psychol. Health* **2011**, *26*, 167–185. [CrossRef]
29. Monyeki, M.A.; De Ridder, J.H.; Du Preez, S.M.; Toriola, A.; Malan, D.D.J. The effect of a ten month physical activity intervention programme on body composition of 9–13 year-old boys. *Afr. J. Phys. Health Educ. Recreat. Danc.* **2012**, *18*, 241–250.
30. Harrabi, I.; Maatoug, J.; Gaha, M.; Kebaili, R.; Gaha, R.; Ghannem, H. School-based Intervention to Promote Healthy Lifestyles in Sousse, Tunisia. *Indian J. Community Med.* **2010**, *35*, 94–99. [CrossRef]
31. Maatoug, J.; Fredj, S.B.; Msakni, Z.; Dendana, E.; Sahli, J.; Harrabi, I.; Chouikha, F.; Boughamoura, L.; Slama, S.; Farpour-Lambert, N.; et al. Challenges and results of a school-based intervention to manage excess weight among school children in Tunisia 2012–2014. *Int. J. Adolesc. Med. Health* **2015**, *29*. [CrossRef]
32. Ghammam, R.; Maatoug, J.; Zammit, N.; Kebaili, R.; Boughammoura, L.; Al'Absi, M.; Lando, H.; Ghannem, H. Long term effect of a school based intervention to prevent chronic diseases in Tunisia, 2009–2015. *Afr. Health Sci.* **2017**, *17*, 1137–1148. [CrossRef]
33. Regaieg, S.; Charfi, N.; Kamoun, M.; Ghroubi, S.; Rebai, H.; Elleuch, H.; Feki, M.M.; Abid, M. The effects of an exercise training program on body composition and aerobic capacity parameters in Tunisian obese children. *Indian J. Endocrinol. Metab.* **2013**, *17*, 1040–1045.
34. Brown, E.C.; Buchan, D.S.; Baker, J.S.; Wyatt, F.B.; Bocalini, D.S.; Kilgore, L. A Systematised Review of Primary School Whole Class Child Obesity Interventions: Effectiveness, Characteristics, and Strategies. *Biomed Res. Int.* 2016. [CrossRef] [PubMed]
35. Sharma, M. School-based interventions for childhood and adolescent obesity. *Obes. Rev.* **2006**, *7*, 261–269. [CrossRef]
36. Bauer, K.W.; Neumark-Sztainer, D.; Fulkerson, J.A.; Hannan, P.J.; Story, M. Familial correlates of adolescent girls' physical activity, television use, dietary intake, weight, and body composition. *Int. J. Behav. Nutr. Phys. Act.* **2011**, *8*, 25. [CrossRef]
37. McMinn, A.M.; Griffin, S.J.; Jones, A.P.; Van Sluijs, E.M.F. Family and home influences on children's after-school and weekend physical activity. *Eur. J. Public Health* **2013**, *23*, 805–810. [CrossRef]
38. Zecevic, C.A.; Tremblay, L.; Lovsin, T.; Michel, L. Parental Influence on Young Children's Physical Activity. *Int. J. Pediatr.* 2010, *2010*, 1–9. [CrossRef]
39. Lippevelde, W.; Van Verloigne, M.; Bourdeaudhuij, I.; De Brug, J.; Bjelland, M.; Lien, N.; Maes, L. Does parental involvement make a difference in school-based nutrition and physical activity interventions? A systematic review of randomized controlled trials. *Int. J. Public Health* **2012**, *57*, 673–678. [CrossRef]
40. Golan, M.; Crow, S. Targeting Parents Exclusively in the Treatment of Childhood Obesity: Long-Term Results. *Obes. Res.* **2004**, *12*, 357–361. [CrossRef]
41. Verjans-janssen, S.R.B.; Van De Kolk, I.; Van Kann, D.H.H.; Kremers, P.S.P.J.; Gerards, S.M.P.L. Effectiveness of school-based physical activity and nutrition interventions with direct parental involvement on children's BMI and energy balance-related behaviors—A systematic review. *PLoS ONE* **2018**, *13*, e0204560. [CrossRef]
42. World Health Organization. *WHO Report of the Commission on Ending Childhood Obesity*; World Health Organization: Geneva, Switzerland, 2016.