THE DEVELOPMENT OF A NUTRIENT PROFILING MODEL ASSESSING HEALTHFULNESS OF PACKAGED FOODS FOR ADULTS IN THE LOW-INCOME CONTEXT OF SOUTH AFRICA

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Abstract

Background: South Africa is facing high, and increasing levels of overweight, obesity and nutrition-related non-communicable diseases. These conditions have been linked to poor health outcomes that disproportionately affect the poorest, and place an undue burden on the health system and South African economy. The proliferation of ultra-processed products (UPPs) is in part to blame for this.

Aim: To assess dietary intake and UPP consumption amongst low-income adults in South Africa, and to develop and test a nutrient profiling model (NPM) assessing healthfulness of foods available and consumed by adults in the low-income context of South Africa to the extent that it provides the potential to underpin a front-of-package warning label system.

Methods: Following an evidence-informed process, an NPM that identifies unhealthy products high in nutrients of concern to limit was developed using nutritional composition data from a secondary cross-sectional analysis of the 6747 packaged foods available in South African supermarkets in 2018. The suitability of the NPM was tested by applying the proposed model to the South African packaged food supply, alongside three existing NPMs developed for similar purposes. Household data, a 1-day 24-hour dietary recall and retail food outlet types were analysed from two secondary cross-sectional studies including 2521 low-income adults (18-50 years) residing in Langa, Khayelitsha and Mount Frere in South Africa. Compliance with WHO dietary guidelines and UPP consumption trends were evaluated. Products subject to warning labels using the criteria of the proposed NPM were evaluated. Alignment between UPP consumption and products subject to warning labels was assessed.

Results: Three quarters (75.6 %) of the packaged foods included in this study are ultra-processed. Additionally, 39.4 % of the mean dietary intake of low-income adults is ultra-processed. Most participants were within the acceptable WHO guideline range for saturated fat (80.4 %), total fat (68.1%), sodium (72.7 %) and free sugar (57.3 %). Only 7.0 % of all participants met the WHO guideline for fruit and vegetables, and 18.8 % met the guideline for fibre. Those within the highest quartile of share of energy from UPPs were the highest energy consumers overall and consumed statistically higher amounts of unhealthy dietary components to limit compared to low UPP consumers. Findings from the step-wise NPM development process indicated that an NPM that identifies unhealthy foods to restrict is most appropriate for South Africa. The proposed NPM assesses packaged foods that contain any added saturated fat, added sodium, free sugar or non-sugar sweetener, and consistently identifies unhealthy packaged foods and beverages that are high in saturated fat, sugar, sodium or contain any non-sugar sweetener. When applying the proposed NPM

to the dietary intake of low-income adults in South Africa 92.0 % of the sample reported consuming at least one product on the previous day that would carry a warning label. On average, 38.1 % of energy from foods reported consumed came from products that would be subject to warning labels. High UPP consumers obtained 12 times more energy from warning label products than low UPP consumers. Among high UPP consumers, 79.1 % of daily sodium, 60.9 % daily sugar and 55.6 % of daily saturated fat intake was attributable to warning label products. Low UPP consumers had significantly lower values at 32.4 %, 22.1 % and 8.1 %, respectively. Warning label products were predominately purchased from supermarkets or informal spaza stores.

Conclusion: Low-income South Africans are consuming energy dense UPPs. The proposed NPM is fit-for-purpose and suitable for use in restrictive food policy in South Africa. It can be used to underpin country-level food policies, such as for the criteria to identify unhealthy products that should be taxed, carry front-of-package warning labels, or should not be marketed. These policies have the potential to support the fight against obesity and non-communicable diseases in the country.

Declaration

I declare that *The development of a nutrient profiling model assessing healthfulness of packaged foods for adults in the low-income context of South Africa* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full Name: Tamryn Caron Frank Date: 10.11.2022

Signature: 

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Acronyms

Acronym	Full Phrase
BMREC	Biomedical Research Ethics Committee
COVID-19	Coronavirus disease 2019
CAM	Chile adjusted model
CWO	Chilean Warning Octagons
FAO	Food and Agriculture Organisation
FCT	Food composition table
FoPL	Front-of-package labelling
FZANZ	Food Standards Australia New Zealand
HIV	Human immunodeficiency virus
HPL	Health Promotion Levy
HPL study	Associations of the implementation of the South African Health Promotion Levy (HPL) with dietary intake and consumption of sugar sweetened beverages in adults aged 18-39 years living in Langa study
HNC	Health and nutrition claims
HSREC	Humanities and Social Science Research Ethics Committee
LMICs	Low- and middle-income countries
MRC	Medical Research Council
NCDs	Non-communicable diseases
NDoH	National Department of Health
NPM	Nutrient profiling model
NSS	Non-sugar sweetener
PAHO	Pan America Health Organisation
ROFE study	Researching the obesogenic food environment, its drivers and potential policy levers in South Africa and Ghana study
SA	South Africa
SADHS	South African Demographic and Health Survey
SANHANES	South African National Health and Nutrition Examination Survey
UNICEF	United Nations Children's Fund
UPP	Ultra-processed product
UWC	University of the Western Cape
WHO	World Health Organisation

Definitions

Word/Phrase	Definition
Dietary diversity score	The dietary diversity score measures the average number of food groups consumed in the past 24 hours (from a total of 12 possible food groups) to identify how diverse the diet is (Labadarios, Mchiza, et al., 2011).
Food environment	The food environment is defined as the interface between the wider food system and how people acquire food. It consists of two domains, the external food environment, and the personal food environment. These domains are interrelated in terms of physical, socio-cultural and economic domains (Turner et al., 2017).
Nova classification system (note Nova is not an acronym)	The Nova classification system is a food classification system with four food categories that takes the extent, nature and reason for processing into account when categorising foods and beverages. The four groups are unprocessed or minimally processed foods; processed culinary ingredients; processed foods; or ultra-processed products (Monteiro et al., 2016, 2017).
Nutrient profiling	'The science of categorising foods based on their nutritional composition, for reasons related to preventing disease and promoting health'(World Health Organization (WHO), 2011)
Nutrients of concern to limit	For the purpose of this thesis nutrients of concern to limit or restrict include those known to play a role in the development of obesity and/or diet-related non-communicable diseases. These includes energy, saturated fats, trans fats, free or added sugar, sodium, non-sugar sweetener and ultra-processed products. In this document, when referring to foods that contain these nutrients of concern to limit, the term unhealthy food is used.
Nutrients to encourage	For the purpose of this thesis nutrients encourage include those known to play a protective role in the prevention of obesity and/or diet-related non-communicable diseases. These includes fruits, vegetables, nuts, legumes, fibre and wholegrains. In this document, when referring to foods that contain these nutrients to encourage, the term healthy food is used.
Nutrition transition	The nutrition transition is a change in dietary intake patterns and nutrient consumption of a population due to a change in lifestyle because of urbanisation and acculturation as a result of economic and social development (Vorster, Kruger, & Margetts, 2011). It is defined by five stages that populations undergo. The rate of progression from one stage to the next is non-linear, and not always the same within different sub-populations in the same country. It is possible to progress slowly, or quickly from one stage to another, and to skip certain stages. The stages are defined as: 1) Collecting food where low levels of fertility and low life-expectancy are observed; 2) Famine where nutritional deficiencies emerge and there is high fertility, high maternal and child mortality and a low life expectancy; 3) Receding famine where mortality rates slowly start to decline, but stunting and maternal and child deficiencies are present; 4) Chronic disease where obesity and nutrition-related NCDs emerge with increased life expectancy but also increased disability years; and 5) Behavioural

	change where there are reduced nutrition-related NCDs, extended healthy aging and reduced obesity (Popkin & Ng, 2022).
Primary data analysis	Analysis of data to examine the hypothesis of the original study protocol, by members of the team that originally collected the data (Cheng & Phillips, 2014).
Processed food	Foods that contain added sugars, fats, oils, or salts; and are no longer in their naturally occurring form (Pan American Health Organization & WHO, 2016).
Random sampling	Random sampling is a sampling technique used to ensure that a study sample is representative of the study population. The researcher controls the sampling process; however, the researcher has no control over exactly which individuals are selected as the study sample (they are included by chance) (Joubert & Ehrlich, 2007).
Secondary analysis of existing data	Any additional analysis done on collected data, regardless of whether or not the person was involved in primary data collection (other than analysis by the primary research team for the purpose to answer the study's original research question, which is primary data analysis) (Cheng & Phillips, 2014).
Structural	According to the Oxford English Dictionary "Relating to or forming part of the building or other item'" or "Relating to the arrangement of and arrangements between the parts or elements of a complex whole, e.g. there have been structural changes in the industry." For the purpose of this document "structural" will refer to the second definition of the term (*Oxford Dictionary of English*, 2015).
Study population	The study population is the entire group of people that the study aims to gather information from and draw conclusions about (Joubert & Ehrlich, 2007).
Study sample	The study sample is the group of participants selected (either randomly or otherwise) to participate in a study. They are selected from the study population. For descriptive and cross-sectional studies the study sample should be representative of the study population (Joubert & Ehrlich, 2007).
Ultra-processed products	Ultra-processed products (also referred to as ultra-processed foods) is a term used in the Nova classification system describes foods that contain minimal whole foods and refers to "*formulations mostly of cheap industrial sources of dietary energy and nutrients plus additives, using a series of processes*" (Monteiro et al., 2016, 2017).

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CHAPTER 1: Introduction

This introductory chapter begins with a problem statement, providing the rationale behind undertaking this research. This is followed by the project aim and objectives, and then the significance of the study is discussed. The chapter ends by providing an overview of all of the thesis chapters.

1.1 Problem statement

The world is facing an obesity pandemic (Abarca-Gómez et al., 2017; Bodirsky et al., 2020; Food and Agriculture Organization & World Health Organization, 2018). Coupled with this, rates of non-communicable disease (NCD) morbidity and mortality are increasing dramatically (Bigna & Noubiap, 2019; Botha & Vermund, 2022; Ghebreyesus, 2018). As more countries move towards the nutrition-related NCD phase of the nutrition transition, they are departing away from traditional eating patterns towards an increased consumption of ultra-processed products (UPPs) (Popkin & Ng, 2022). This proliferation of UPPs has played a pivotal role in nutrition-related NCD morbidity and mortality trends (Baker et al., 2020; X. Chen et al., 2020; Neri et al., 2022; Paula, Patriota, Gonçalves, & Pizato, 2022; Srour et al., 2020; Wang, Du, Huang, & Xu, 2022).

The global state is mirrored in South Africa. Recent years have seen levels of overweight and obesity increasing, particularly amongst South African women (Mbogori, Kimmel, Zhang, Kandiah, & Wang, 2020). South African children are expected to have the tenth highest level of obesity, globally, by 2030 (Lobstein & Brinsden, 2019). Nutrition-related NCDs, such as diabetes and hypertension are fast becoming the most burdensome on our health system (Botha & Vermund, 2022; Roomaney, van Wyk, Turawa, & Pillay-van Wyk, 2021; Statistics South Africa, 2017) and inflict significant economic costs and human suffering on individuals and their families. The treatment of NCDs places a high out-of-pocket financial burden on individuals and households (Kazibwe, Tran, & Annerstedt, 2021). There are also other costs borne by South African individuals and families such as reduced ability to work and earn an income due to obesity and NCDs (Lawana, Booysen, & Tsegaye, 2020). With a third of the adults in South Africa unemployed and more than half of the population living in poverty (Samodien, Abrahams, Muller, Louw, & Chellan, 2021; Statistics South Africa, 2022; World Bank, 2021) this paints a dire picture for the health and economic outcomes of the most vulnerable in the country.

The food environment within the country is rapidly changing, with multinational food corporations accounting for the majority of the market share (Haggblade et al., 2016). Foods are eaten away from home more frequently, with fast-food options increasing. Studies in South Africa have shown that UPPs that are cheap, filling and tasty, but not necessarily nutritious or healthy, are preferred and are the food of choice for many (Haggblade et al., 2016; Jacobs et al., 2022; Statistics South Africa, 2015; Temple & Steyn, 2011). Conversely, the high cost and limited availability of healthy foods makes healthy options unattainable for most of the population, with 65 % of South Africans unable to afford a healthy diet (FAO, IFAD, UNICEF, WFP, & WHO, 2022). As a result of this changing food environment, levels of overweight, obesity and NCDs are increasing (Mbogori et al., 2020), and the poorest and most vulnerable in the country bear the brunt of poor health and economic outcomes (Kazibwe et al., 2021; Samodien et al., 2021). If urgent efforts are not made to transform the failing obesogenic food environment, the health and wellbeing of the South African population will deteriorate further.

Comprehensive food policies have the potential to substantially change the food environment and improve diets, particularly amongst lower-income people in South Africa. The best policies are those that create positive changes in the food, social and information environments, whilst simultaneously addressing inequalities (Bodirsky et al., 2020; Haggblade et al., 2016; Hawkes et al., 2015). Policy level interventions to achieve this include policies that promote healthier food choices, such as marketing restrictions, restricting unhealthy foods from the school food environment, unhealthy food taxes and front-of-package labeling (FoPL) (Food and Agriculture Organization & World Health Organization, 2018; Hawkes et al., 2015). In order to operationalise these policies, one must be able to categorise foods as “unhealthy” or “healthy”. Nutrient profiling models (NPMs) are an appropriate tool for this, and can underpin policies, by identifying foods to be regulated (M. Rayner, Scarborough, & Kaur, 2013; M. Rayner, Scarborough, & Lobstein, 2009).

1.2 Research question, aim and objectives

1.2.1 Research question

How can a nutrient profiling model be developed to the extent that it will contribute to assessing the healthfulness of packaged foods and diets of adults in the low-income context of South Africa?

1.2.2 Aim

To develop a nutrient profiling model assessing healthfulness of foods available and consumed by adults in the low-income context of South Africa to the extent that it will provide the potential for a front-of-package warning labelling system.

1.2.3 Objectives

1. Evaluate the alignment of the Nova food classification system and the WHO dietary guidelines in assessing dietary intakes of low-income adults in South Africa
   1.1. Critically evaluate the adequacy of the diet of low-income adults in South Africa based on the WHO recommended dietary intake guidelines and the Nova food classification system
   1.2. Identify the types of food outlets that various food categories are commonly purchased from
2. Propose a suitable nutrient profiling model to identify packaged foods high in critical nutrients in South Africa
   2.1. Use an evidence-informed approach to develop a suitable nutrient profiling model
   2.2. Compare this model to three other models used in low and middle-income countries, to strengthen the proposal
3. Apply the proposed nutrient profiling model to the diets of low-income adults in South Africa to demonstrate the potential impact of this model if used in a simplified front-of-package labelling system to identify nutrients of concern
   3.1. Using information from the dietary intake of individuals of low-income adults in South Africa, assess the proportion of the diet that could be included in a simplified nutrient information labelling system
   3.2. Using the nutrient profiling model identified in objective two, analyse whether diets identified as highly processed (in objective one) are more likely to contain more nutrients of concern in comparison to minimally processed diets

1.3 Significance of study

Limited work has been undertaken in South Africa to explore effective policy interventions to change the external food environment and support healthy food preferences among South Africans, particularly among those with lower access to resources. This PhD thesis provides the first assessment of UPP intake amongst low-income South Africans using 24-hour recall dietary intake data and the Nova classification system, as well as the types of stores that UPPs are being purchased from. The

Nova food classification system is a recognised tool that can be used in public health policy for the development of guidelines that describe dietary patterns by the level of processed food consumption (Kelly & Jacoby, 2018; O'Halloran et al., 2017) and categorises foods and beverages into four groups based on their level of processing (Monteiro et al., 2016, 2017). This study provides important contextual information on the food environment in South Africa, by proving a baseline assessment of UPP consumption amongst low-income adults living in South Africa, as well as evaluating compliance to WHO-set guidelines for the prevention of chronic diseases. In a country where 55 % of the population lives in poverty this is especially important as low-income South Africans are disproportionately affected by the proliferation of UPPs. They carry a larger economic burden in terms of healthcare costs and lost productivity as a result of nutrition-related NCDs, and are most vulnerable to the price of food, making purchasing decisions based on price rather than health outcomes. This means that the UPP food industry, if left unregulated, has an ideal target market in low-income consumers who gravitate towards price-based marketing strategies.

A starting point for regulating the UPP food environment in South Africa is to develop and implement an NPM that can serve as the foundation for various other food policies. In doing so, it is important consider the resource-limited setting of a LMIC like South Africa. If effective regulations are to be put in place, they need to be easy to implement, require minimal resources to enforce and should not be too costly. This study aims to develop a suitable NPM that can be used to underpin evidence-informed national nutrition policies in South Africa that are designed to influence the external food environment. An evidence-informed NPM can be used effectively in numerous restrictive food policies to inform the classification of unhealthy foods that contain nutrients of concern to limit (hereafter "unhealthy foods"). These policies, such as front-of-package warning labelling that warns against foods high in unhealthy nutrients, or a policy that restricts foods with warning label from being marketed, or sold on school premises can in turn potentially result in a decreased consumption of UPPs, and thus potentially a reduced incidence of obesity and nutrition-related NCDs in South Africa, which will improve the health and wellbeing of low-income South Africans.

1.4 Overview of this thesis

This is a thesis by publication, which is presented in the format of five chapters. The first, introductory chapter provides the problem statement, and aims and objectives of the study. Chapter two provides a literature review of relevant research, and the research methodology is discussed in chapter three.

Chapter four provides the research findings of this thesis, in the form of four journal articles. Two of the articles have been published in peer-reviewed journals, and two have been submitted to journals, and are currently under peer-review. The final chapter, chapter five, provides a summary of the main research findings and the implications thereof for future research.

Papers embedded in the thesis:

1. Frank T., Ng S.W., Lowery C.M., Thow A.M., Swart E.C. 2022. Dietary intake of low-income adults in South Africa: Ultra-processed food consumption a cause for concern. Submitted to Public Health Nutrition on 26.08.22 (currently under review).
2. Frank T., Thow A.M., Ng S.W., Ostrowski J., Bopape M, Swart E.C. 2021. A fit-for-purpose nutrient profiling model to underpin food and nutrition policies in South Africa. Nutrients, 13, 2584. doi: 10.3390/nu13082584
3. Frank T, Ng S.W., Miles D.R., Swart E.C. 2022. Applying and comparing various nutrient profiling models against the packaged food supply in South Africa. Public Health Nutrition 25(8), 2296-2307. doi: 10.1017/S1368980022000374
4. Frank T., Thow A.M., Swart E.C., and Ng S.W. 2022. The potential effect of a front-of-package warning label for low-income adults in South Africa. Submitted to PLoS ONE on 19.10.22 (currently under review).

I was responsible for the overall conceptualisation of the project, as well as the methodology, data curation, data analysis and data visulisation, and writing the manuscripts. My supervisors provided guidance throughout the process in the form of both oral and written input. All contributions to manuscripts made by co-authors are provided in Chapter four, in the introductory section for each manuscript.

CHAPTER 2: Literature Review

I begin this literature review by exploring the nutrition-related health crisis that the world is facing. I examine the rising rates of obesity and nutrition-related NCD diseases and the economic implications of this, as well as the interplay between the Coronavirus disease 2019 (Covid-19), nutrition, and health. After exploring the global context, I will explore the nutrition-related health crisis in South Africa, to better understand the context within the country.

Following this, the literature review moves on to examine the root causes of this nutrition-related health crisis, exploring how the food landscape has evolved through the nutrition transition, and the role that UPPs have played in influencing the course of the nutrition transition.

In order to bring about meaningful change, that also addresses inequalities, policies that promote a healthy food environment for all are then explored. One particular strategy, that is used to underpin food policies to promote healthier food environments around the world is explored in detail, this is nutrient profiling. The process followed to develop a nutrient profiling model is discussed, and through the example of a front-of-package warning label, the potential of nutrient profiling to be used in food policy in South Africa is explored.

2.1 The state of food and nutrition security: A nutrition-related health crisis

Unbalanced diets high in UPPs, added sugar, salt, trans- and saturated fats have been extensively associated with metabolic disorders and increased risk for chronic NCDs (such as cardiovascular disease, type two diabetes, hypertension and some cancers) (X. Chen et al., 2020; Hall et al., 2019; Neri et al., 2022; Paula et al., 2022; Srour et al., 2020; Wang et al., 2022). This is reflected in the leading cause of death worldwide, ischaemic heart disease (Barquera et al., 2015; World Health Organization, 2019b). Unhealthy diets now account for more deaths than tobacco and alcohol combined (Food and Agriculture Organization & World Health Organization, 2018). This is in part due to the nutrition transition, with changing lifestyle and food systems (Barquera et al., 2015). Although the nutrition transition occurs unevenly across different geographies and subpopulations and even within a country, much of the world is in the stage of the transition where nutrition-related

NCDs are increasing at a rapid rate (Popkin & Ng, 2022). Globally there has been a shift away from traditional diets and an increased consumption of unhealthy, refined foods (May, 2018; Popkin, Adair, & Ng, 2012; Popkin & Ng, 2022). Less healthy food components, such as fibre, fruits and vegetables, nuts and wholegrains, that are protective, and preventative in developing poor health outcomes are being consumed (Murray et al., 2020). Although there has been an increase in obesity and nutrition-related NCDs, undernutrition still remains problematic, with the double burden of malnutrition being especially prevalent in low- and middle-income countries (LMICs). Globally, obesity amongst adults has a prevalence of 13.1 %, and stunting in children under five a prevalence of 22 %. Often undernutrition in the form of stunting in children coexists with over-nutrition in the form of obesity in adults in the same households (FAO et al., 2022; Harper et al., 2022). The 2018 United Nations interagency task force on NCDs report highlighted the fact that malnutrition, due to unhealthy diets, is one of the greatest global concerns currently (Food and Agriculture Organization & World Health Organization, 2018).

2.1.1 The obesity and non-communicable disease pandemic

Globally, obesity levels are rising (Afshin et al., 2017; UNICEF, WHO, & World Bank, 2018). In the past 40 years rates have doubled in at least 70 countries (Afshin et al., 2017). Amongst adults, two billion are overweight, and 672 million are living with obesity (Abarca-Gómez et al., 2017). It is estimated that by 2050, 45 % of the global population will be overweight, and 16 % will be living with obesity (Bodirsky et al., 2020). Levels of childhood obesity are also increasing. A multinational study monitoring childhood obesity over the past four decades has found a steady rise in the levels of childhood obesity globally (Abarca-Gómez et al., 2017). This has implications in terms of increased risk for developing nutrition-related NCDs in these individuals as adults (Bauman, Rutter, & Baur, 2019). NCDs are the leading cause of death worldwide, responsible for 70 % of all global deaths (Bigna & Noubiap, 2019; Botha & Vermund, 2022; Ghebreyesus, 2018), although the majority of these deaths occur in LMICs (Ghebreyesus, 2018). In Africa, and Sub-Saharan Africa this nutrition crisis is pronounced, and obesity rates are rising at alarming rates (May, 2018; UNICEF et al., 2018). Some high-income countries are seeing a plateau in obesity rates (Bauman et al., 2019), however, no country has been successful in decreasing obesity levels (Food and Agriculture Organization & World Health Organization, 2018).

NCD treatment places a tremendous economic burden on governments and societies. Treatment costs are high, and NCDs result in reduced labour productivity and low earning potential (Food and Agriculture Organization & World Health Organization, 2018). The global cost of NCDs (mainly cardiovascular disease) was US$7 trillion between 2011 and 2015 (Zoghbi et al., 2014), and between 2011 and 2025 it is estimated that NCDs will result in a US$47 trillion loss in global gross domestic product (Ghebreyesus, 2018). Added to this, the annual cost of obesity is equivalent to 2.8 % of the global gross domestic product (US$2 trillion) per year (Richard et al., 2014). The healthcare cost implications of not addressing obesity are often overlooked by those in power (Jackson-Morris, Nugent, Ralston, Barata Cavalcanti, & Wilding, 2020). However, it is vital to understand that obesity not only affects mortality; it also creates a massive economic burden through higher healthcare costs and increased disabilities, reduced productivity and earlier retirement (Shekar & Popkin, 2020). Additionally, the treatment of NCDs place a high out-of-pocket financial burden, especially on individuals and households in LMICs (Kazibwe et al., 2021). Fighting for obesity prevention makes sense from a budgetary perspective, as it is a budget-saving measure (Shekar & Popkin, 2020). Unfortunately, there is a long history of the UPP industry undermining political efforts to address obesity, in order to protect their own corporate interests (Milsom, Smith, Baker, & Walls, 2021). Going forward, concerted obesity-prevention interventions need to be supported and strengthened (Jackson-Morris et al., 2020; Milsom, Smith, Baker, & Walls, 2021).

2.1.2 Covid-19, nutrition and health

Obesity is known to worsen the outcome of infectious diseases (Gong, Bajwa, Thompson, & Christiani, 2010; Huttunen & Syrjänen, 2010, 2013; Louie et al., 2011), as has been highlighted recently in the higher mortality and morbidity rates among COVID-19 patients living with obesity (Luzi & Radaelli, 2020; Malavazos, Corsi Romanelli, Bandera, & Iacobellis, 2020; Popkin, Corvalan, & Grummer-Strawn, 2020). This interaction between obesity and COVID-19 can be considered a syndemic (White, Nieto, & Barquera, 2020) as the two conditions interact negatively with each another, resulting in more severe illness and greater complications (White et al., 2020). Obesity is also linked to NCDs which are in themselves risk factors for COVID-19, including type 2 diabetes, hypertension and dyslipidaemia (Popkin et al., 2020).

Besides the immediate effects of COVID-19 on morbidity and mortality, the impact that the virus has had on the health system, economics and the food environment could also unintentionally worsen

NCDs and exacerbate all forms of malnutrition (Headey et al., 2020; Popkin et al., 2020). Many have lost jobs and income, with the poor being worst affected. LMICs, in particular, are seeing the effects of COVID-19 on nutrition (United Nations, 2020).

To prevent a repeat of the COVID-19 pandemic, urgent action is needed to create a healthier food environment (White et al., 2020) and reduce the risk of repeated vulnerability in the years to come (Jackson-Morris et al., 2020). The reality is that if the obesity pandemic had been addressed earlier, the COVID-19 complications would have been less severe (White et al., 2020). Decades of policy inaction, together with poor funding of obesity-prevention strategies, have resulted in elevated obesity levels which have left the global population less able to fight off the effects of COVID-19 (Jackson-Morris et al., 2020). This pandemic is a tipping point and a lesson to the world.

2.1.3 Overview of the nutrition and health situation in South Africa

South Africa is classified as an upper-middle income country, with a population of 57 million people and 66 % of the population living in urban areas (Mbogori et al., 2020). Although South Africa is one of the wealthiest nations in Africa, wealth is unequally distributed (Mbogori et al., 2020), and it is the country has the highest Gini-coefficient in the world (World Bank, 2022). Approximately 55 % of all South Africans, and 60 % of children in South Africa live in poverty (Samodien et al., 2021; World Bank, 2021). Sixty-five percent are unable to afford a healthy diet (FAO et al., 2022).

Compared to other African countries (Kenya, Ghana and Malawi), South Africa has the highest overweight and obesity to underweight ratio; with an obesity prevalence rate 5.6 times higher than the prevalence of underweight. Amongst adults, 51.9 % of the population are living with overweight or obesity, and 4.8 % are underweight (Mbogori et al., 2020). Multimorbidity is common amongst South African adults, with hypertension, diabetes, human immunodeficiency virus (HIV) and tuberculosis being the most prevalent diseases (Roomaney, van Wyk, Cois, & Pillay-van Wyk, 2022; Roomaney et al., 2021). The 2012 South African National Health and Nutrition Examination Survey (SANHANES) reported that South Africa is undergoing a transition from infective diseases to NCDs, with increasing levels of obesity (Shisana et al., 2013). This was confirmed by the 2016 South African Demographic and Health Survey (SADHS), which found the prevalence of overweight or obesity to be at 68 % amongst women, and at 31 % for men; as well as an increasing prevalence of hypertension, overweight and obesity since 1998. One in five women was living with severely

obesity, placing them at greater risk for NCDs (Statistics South Africa, 2017). The prevalence of overweight and obesity amongst children under five is 13.3 % in South Africa, and has slowly, but steadily increased over the past 18 years (Mbogori et al., 2020). In 2020, NCDs were estimated to be responsible for 27 % of deaths in South Africa. This is a 4 % increase in mortality rate due to NCDs over the space of 15 years (Botha & Vermund, 2022). Overweight and obesity prevalence is increasing more rapidly than levels of underweight are declining, and stunting levels remain high in children under five, at 27.4 % (Mbogori et al., 2020). Over 70 % of stunted children in South Africa live in a household with an overweight or obese adult (Harper et al., 2022). Dietary diversity is low in the country (Faber, Wenhold, & Laurie, 2017; Madlala et al., 2022), and there is a high prevalence of micronutrient deficiencies amongst South African adults (Mchiza et al., 2015). This combination of obesity, undernutrition and micronutrient deficiencies creates a triple burden of malnutrition in the country.

Numerous studies have found that the many households in South Africa do not have an adequate income to allow for purchasing of wholesome, nutritious food (Labadarios, Mchiza, et al., 2011; Shisana et al., 2013; Statistics South Africa, 2015; Temple & Steyn, 2011), and households with lower income have poor dietary diversity (Sambo, Oguttu, & Mbombo-Dweba, 2022). High food prices of fruits and vegetables, as well as limited availability of healthy options in townships and poorer urban centres is thought to be the cause of this (Mchiza et al., 2015). Energy-dense foods such as sugar, fat and refined cereals are cheap sources of energy (Temple & Steyn, 2011). Food insecure individuals are more likely to make food choices based on what is most affordable and convenient, which negatively affects their dietary intake quality (Wiles, 2022). On average the cost of a healthy diet is 69 % more than the unhealthy alternative in South Africa (Temple & Steyn, 2011) and as a result a healthy, nutritious diet is unaffordable for most South Africans, with 65 % of South Africans unable to afford a healthy diet (FAO et al., 2022).

Overweight, obesity and NCDs are overwhelming the public health care system in South Africa, and placing a massive burden on it (Boachie, Thsehla, Immurana, Kohli-Lynch, & Hofman, 2022). A cost of illness study undertaken in 2018 to estimate the direct medical costs of type 2 diabetes in South Africa estimated that, should all cases (both diagnosed and undiagnosed) be treated, the annual treatment and management costs of the disease would be ZAR 21 800 million. This is equivalent to approximately 12 % of the entire country's 2018 health budget. Due to increasing prevalence of the disease, the treatment costs are estimated to increase to ZAR 35 100 million by 2030 (Erzse et al., 2019). The annual direct healthcare treatment costs due to overweight and obesity in 2020 was

estimated at ZAR 33 194 million; which is 0.7 % of the country's gross domestic product; or 15 % of the annual healthcare costs. This includes, amongst others, the cost of treating diabetes (ZAR 19 861 million), cardiovascular disease (ZAR 8 874 million), and cancers (ZAR 352 million) (Boachie et al., 2022). If nothing changes, the cost of obesity is estimated to account for 2.6 % of South Africa's gross domestic product by 2060 (Okunogbe, Nugent, Spencer, Ralston, & Wilding, 2021).

Increasing levels of overweight and obesity place strain on the economic potential of the country, due to increased health costs and productivity losses through illnesses resulting in absenteeism and premature mortality (Boachie et al., 2022). Preventative public health policies are urgently required to reduce the prevalence and incidence of overweight, obesity and NCDs in South Africa (Boachie et al., 2022).

2.2 The nutrition transition and the role that ultra-processed products have played in a changing food environment

Over the past 50 years the manner in which food is produced, distributed and marketed has changed drastically (Ambikapathi et al., 2022). Although food security has improved, economic development has driven a shift in food preferences, resulting in the nutrition transition (Imamura et al., 2015; Popkin, 1997). The displacement of traditional eating patterns with highly refined, ready-to-eat UPPs excessive in fats, sugar and salt and low in fibre is known as the nutrition transition (Moubarac, Parra, Cannon, & Monteiro, 2014; Nnyepi, Gwisai, Lekgoa, & Seru, 2015). This is a global phenomenon, that is occurring at different rates around the globe, and does not always occur in a linear manner amongst different sub-populations within a country (Popkin & Ng, 2022). The transition is synonymous with industrialisation, urbanisation and demographic shifts; which collectively contribute to an increased prevalence of nutrition-related NCDs (Nnyepi et al., 2015).

Throughout the world, countries are finding that the increased consumption of UPPs is synonymous with a significant increase in the amount of refined carbohydrates, total and saturated fats, free sugars and sodium consumed; as well as a decrease in the intake of protein and fibre (Louzada et al., 2018; Martínez Steele, Popkin, Swinburn, & Monteiro, 2017; Monteiro, da Costa Louzada, et al., 2018; Moubarac, Batal, Louzada, Martinez Steele, & Monteiro, 2017). A high intake of UPPs is a risk factor for obesity and nutrition-related NCDs (Fiolet et al., 2018; Mendonça, Lopes, et al., 2016; Monteiro,

Moubarac, et al., 2018), and increased sugar and refined carbohydrate intake have been significantly, and consistently linked to an increase of NCDs over time (Pressler et al., 2022). A nineteen country study found a direct association between the prevalence of obesity and the availability of UPPs and beverages in households (Monteiro, Moubarac, et al., 2018). The prevalence of UPP consumption is common in high-income and LMICs alike, (Monteiro et al., 2016; Monteiro, Moubarac, Cannon, Ng, & Popkin, 2013) although consumption rates of processed foods are increasing most rapidly in LMICs (Stuckler, McKee, Ebrahim, & Basu, 2012). Traditionally, NCDs were uncommon amongst populations following non-western traditional lifestyles and diets. As dietary patterns changed with the progression of the nutrition transition, nutrition-related NCDs such as cardiovascular disease, diabetes, cancer and obesity have become prevalent (Pressler et al., 2022).

2.2.1 The nutrition transition

The nutrition transition is defined by five stages that populations undergo. The rate of progression from one stage to the next is non-linear, and not always the same within different sub-populations in the same country. It is possible to progress slowly, or quickly from one stage to another, and to skip certain stages. The stages are defined as: 1) Collecting food where low levels of fertility and low life-expectancy are observed; 2) Famine where nutritional deficiencies emerge and there is high fertility, high maternal and child mortality and a low life expectancy; 3) Receding famine where mortality rates slowly start to decline, but stunting and maternal and child deficiencies are present; 4) Chronic disease where obesity and nutrition-related NCDs emerge with increased life expectancy but also increased disability years; and 5) Behavioural change where there are reduced nutrition-related NCDs, extended healthy aging and reduced obesity (Popkin & Ng, 2022).

Globally, many countries are advancing in the nutrition transition, moving away from a pattern of undernutrition towards one of obesity and nutrition-related NCDs (Popkin & Ng, 2022). This is because the food environment is changing, with a steady rise in the production and consumption of UPPs throughout the world (De Vogli, Kouvonen, & Gimeno, 2014; Monteiro et al., 2013; Stuckler et al., 2012). This proliferation of UPPs and the changing food environment undermines dietary patterns based on fresh, unprocessed ingredients (Monteiro & Cannon, 2012; Moodie et al., 2013). The advancing nutrition transition has resulted in the increasing displacement of healthy food consumption with unhealthy empty calorie alternatives, that are energy-dense, and high in sodium, saturated fat and sugar (Bodirsky et al., 2020; Mbogori & Mucherah, 2019).

The food environment can be seen as the part of the food system where people make choices about food acquisition, preparation and consumption. It plays an important role in guiding peoples food choices, and as a result, their nutritional health (High level panel of experts on food security and nutrition, 2017). It influences food choices that are made, through both the external-, and the internal food environment. External factors that influence food choice are the availability and prices of food, how foods are marketed and regulated, as well as the food geography in terms of what types of stores are available for purchasing foods at, the quality of the foods and what foods are available for selection. One's personal food environment include aspects such as convenience, accessibility to get to the market place, purchasing power and desirability of certain foods (Turner et al., 2018).

Throughout the world, economic development has driven a shift in food preferences, resulting in the nutrition transition (Popkin, 1997). The commercial determinants of obesity, including the actions of "big food" companies that drive the obesogenic food environment need to be addressed (Kickbusch, Allen, & Franz, 2016). Underlying drivers of consumption of unhealthy food and beverages include free-trade agreements, food-sector specific foreign direct investment, market saturation by transnational companies, market regulations and protections and a large percentage of retail space owned by a small number of large companies (Stuckler et al., 2012). Free trade agreements result in countries being unable to place market restrictions on the import of unhealthy foods, or non-tariff measures such as bans, quotas, licensing or other restrictions (Ronald, Katia, & Raphael, 2011). The food industry makes use of factors that are known to influence food preferences towards their products. Confectionery and snack foods are, for example, developed with the innate preference towards energy density and sweetness in mind (Hawkes et al., 2015). These UPPs are widely available, low in cost and aggressively marketed (Swinburn et al., 2011). Food companies sometimes provide large packaged portion sizes which encourage children to eat more than necessary to satisfy their appetite. Over time this becomes normalised, and in turn preferred. Branded food products are preferred above identical foods or drinks in plain packaging in children who watch more television (and are exposed to more adverts). The food industry uses this to create or enhance food preferences. In particular, companies have focused on low- and middle-income countries to form new preferences and habits by making their products extensively available and relatively affordable (Hawkes et al., 2015).

Since the entry of large transnational food corporations (or "big food") into LMICs in the global south there has been a displacement of traditional dietary patterns and changing food systems (Monteiro &

Cannon, 2012). Consumption habits and choices are continually shifting towards unhealthy processed products due to the price, food type, availability and marketing strategies employed by large corporations (G. Rayner, Hawkes, Lang, & Bello, 2006). LMICs are experiencing the most rapid growth in the consumption of processed foods and soft drinks. LMICs, including South Africa, already have a heavy presence of multinational corporations, with at least one of the two market leaders in LMICs being a multinational corporation (Stuckler et al., 2012). Unfortunately, these UPPs are highly profitable for companies as they have low production inputs, a high retail value and an extended shelf-life. As a result, there is a large monetary incentive for companies to increase sales of these products (Stuckler et al., 2012).

2.2.2 The proliferation of ultra-processed products

The evidence warning against the consumption of UPPs is growing as can be seen in the common theme amongst different healthy diets: consume a diet that is minimally processed (Katz & Meller, 2014). Numerous studies associate the consumption of UPPs with obesity and related NCDs like hypertension, diabetes, dyslipidemia and certain cancers (Canella et al., 2014; Fiolet et al., 2018; Hall et al., 2019; Julia et al., 2018; Louzada et al., 2015; Mendonça, Lopes, et al., 2016; Mendonça, Pimenta, et al., 2016; Poti, Braga, & Qin, 2017). Although it is evident that the nutrition transition has been spurred on by the proliferation of UPPs there remains inadequate information about intake in some populations, particularly in LMICs where collected dietary intake data does not provide sufficient information about UPPs consumed (Walls, Johnston, Mazalale, & Chirwa, 2018). As UPP consumption can be harmful to health it is important to examine UPP intake when assessing dietary patterns and health of individuals and populations (Moubarac et al., 2014).

UPP is a term used in the Nova classification system (note Nova is not an acronym) to refer to products that contains minimal whole foods and refers to “formulations mostly of cheap industrial sources of dietary energy and nutrients plus additives, using a series of processes” (Monteiro et al., 2017). The Nova food classification system categorises foods and beverages into four groups based on their level of processing. The four groups are: 1) unprocessed or minimally processed foods; 2) processed culinary ingredients; 3) processed foods; and 4) UPPs (Monteiro et al., 2016, 2017). UPPs are typically refined foods, high in nutrients known to negatively affect health (sodium, saturated and trans fats, and added sugars) and are energy dense (Poti et al., 2017). It must be noted that there are some benefits to food processing, as it enhances taste and palatability, prolongs shelf-life, ensures

good quality and improves transportability (Stuckler & Nestle, 2012). However, advances in industrial food processing capabilities has resulted in using chemical synthesis to create foodstuffs from extracted foods (Monteiro et al., 2013; Moodie et al., 2013). These high-energy, low nutritional quality foodstuffs are usually made from cheap ingredients and additives, but are very palatable and convenient (Monteiro et al., 2013; Stuckler & Nestle, 2012). They can be identified by their ingredient list, which usually includes little to no intact foods as well as various additives (Moodie et al., 2013). They are designed to be convenient, enjoyed by consumers as they are very palatable and are often sold in large portions that are widely marketed (Moodie et al., 2013). Due to their highly palatable, convenient and affordable nature, UPPs are designed to displace other foods (Monteiro et al., 2017). Their longer shelf life makes them readily available, and as they are cheap, filling and tasty and ready-to-eat they are popular consumption choices (Monteiro et al., 2017, 2013; Stuckler & Nestle, 2012).

Besides the concerns for population health outcomes that UPPs are causing, there are also concerns that the changing food environment will have a negative impact on environmental health and sustainability. If eating patterns continue to move in the direction of excessive consumption of empty calorie UPPs the increasing inputs required to manufacture these products will result in a strain on the environment due to increased greenhouse gas emissions, excessive water usage, unsustainable land use and decreased biodiversity (Bodirsky et al., 2020).

2.2.3 The nutrition transition in South Africa

Overweight and obesity rates have been steadily increasing in Africa since the late 1990s (Mbogori et al., 2020). And, although Sub-Saharan Africa was the last global region to undergo the nutrition transition, it is now advanced in parts of the region (Haggblade et al., 2016; Nnyepi et al., 2015). In South Africa, the nutrition transition can be described as advanced, with increasing levels of nutrition-related NCD morbidity and mortality (Popkin & Ng, 2022), as is evident by the changing diet, rising levels of urbanisation, and increasing rates of overweight, obesity and NCDs in the country (Haggblade et al., 2016).

Compared to other African countries with a lower gross domestic product than South Africa, and less people residing in urban areas (Malawi, Ghana and Kenya), South Africa has had the largest shift from under- to over-nutrition, and the highest rates of overweight and obesity. These findings align with expected health outcomes of an advancing nutrition transition (Mbogori et al., 2020). In South

Africa, 90 % of the food consumed has undergone at least some processing, and 55 % is highly processed (including breads, sweets, sugar sweetened beverages, canned foods, processed meats). Sugar intake is estimated to be 90 kg/person/year (Haggblade et al., 2016). South Africa has a long food manufacturing history with large presence of multinational food corporations. Ten companies account for more than 50 % of packaged food sales in South Africa, and supermarkets are increasing, accounting for two-thirds of retail food sales in the country (Haggblade et al., 2016).

A carbohydrate-based diet with low nutrient density is frequently consumed in South Africa (Armstrong, Lambert, & Lambert, 2011; Temple & Steyn, 2011). In 2012, the SANHANES-1 found the national dietary diversity score to be at 4.2, with urban households having a higher score than rural households (Shisana et al., 2013). Although urban households have a higher dietary diversity score, (Labadarios, Mchiza, et al., 2011) the types of food they are eating are often non-nutritious and do not impact positively on a healthy dietary intake (Battersby, 2012). A newly published study amongst 792 black women from Soweto found ultra-processed foods contributed between 44.8 % to 47.9 % of daily energy intake (Jacobs et al., 2022). In South Africa, communities make use of formal, regulated supermarkets and/or more informal, less regulated fast food outlets and small shops (spazas) to purchase their food (Steyn, Nel, Parker, Ayah, & Mbithe, 2012). The urban poor are reliant on purchasing food at market places as their main food source (Battersby, 2017).

Although the current stage of the nutrition transition in South Africa with high rates of nutrition-related NCDs reflects a similar stage to much of the rest of the world, there remains hope that the course of the nutrition transition can change direction, both in South Africa and globally, towards transitioning into a phase with a reduction in nutrition-related NCDs, reduced obesity and improved disease prevention resulting in longer, healthier lives (Popkin & Ng, 2022).

2.3 How to bring about change? Policies that promote a healthier food environment

Existing food policies have been unsuccessful at shifting the course of the nutrition transition (Bodirsky et al., 2020). Part of the reason for this failure is that individuals are often blamed for the failure in obesity prevention, and as a result existing policies have focused on the individual. However, the pivotal role that the external food environment plays in creating an obesogenic food

environment is often forgotten (Rodgers, Woodward, Swinburn, & Dietz, 2018). When energy-dense, hyper-palatable, convenient UPPs that are high in nutrients of concern linked to poor health outcomes are readily available at a low cost in the food environment this influences food choices negatively (Monteiro et al., 2013; Popkin et al., 2012). A restructuring of the food system is needed (Bodirsky et al., 2020), as individual behavioural interventions are unlikely to result in a change in dietary consumption patterns on a population level. Attention should be given to the food environment and food systems instead (Monteiro, da Costa Louzada, et al., 2018). In order to curtail the global obesity and NCD pandemic effective and well-designed policies must aim towards making healthy food choices both the easy and the preferred choice (Hawkes et al., 2015).

As the poorest are most harshly impacted by the financial and health burden created by the obesity and NCD pandemic interventions that address inequality need to be considered in policy formation. Comprehensive, solidly designed food policies have the potential to substantially improve diets at a local, national and international level. These benefits are not only for a select few, but also reach disadvantaged, lower socio-economic groups. The best policies are those that create positive changes in the food, social and information environments, and promote equity (Hawkes et al., 2015). Recent recommendations have been made that policy measures to bring about change should aim to address undernutrition, obesity and environmental sustainability (Bodirsky et al., 2020). Within the budgetary constrained setting of Sub-Saharan Africa policy interventions that have been identified as most appropriate to address the nutrition transition include, but are not limited to, fiscal policies and regulations to limit availability of unhealthy foods such as through front-of-package labelling, taxation of unhealthy food and subsidizing of healthy alternatives (Haggblade et al., 2016). NCD interventions and policies have the potential to be cost-effective and feasible to implement in all settings (Ghebreyesus, 2018). By making use of the theory of change, there are four key types of policies to support healthy diets for obesity prevention as described below (Hawkes et al., 2015).

First, policies that focus on interventions that provide a supportive environment for healthy preference learning should be implemented. These policies need to be aimed towards creating a supportive environment that creates positive changes amongst young children (Hawkes et al., 2015). As children learn taste preferences from a young age, this creates a positive acceptance of healthy foods from a young age (Olsen, 2019). Additionally, as stunting occurs at a young age and prevails across the life course, the earlier that changes are implemented the more likely long-term improved health outcomes are (Harper et al., 2022). This is especially relevant in the context of a country like South Africa that

suffers from the double-burden of malnutrition, with stunting and obesity occurring in the same households across different generations (Harper et al., 2022; Mbogori et al., 2020).

Second, there should be a focus on interventions that overcome barriers to healthy food choices. A lack of information, inadequate time, and insufficient social support are barriers that prevent the selection of healthy food choices, and a low socio-economic standing prevents access to and affordability of foods. Policies need to break these barriers and empower people to make healthy choices (Hawkes et al., 2015). In the context of South Africa, with high level of inequality (Samodien et al., 2021; World Bank, 2022) it is essential to consider interventions that can promote improved equity in the country. For instance, a study assessing a private health insurance programme in South Africa found that subsidising the price of healthy fruits and vegetables may be effective in improving diets (An, Patel, Segal, & Sturm, 2013). Studies elsewhere around the world have proposed that subsidisation of the cost of healthy foods for low-income people, together with taxation and front-of-package labelling of unhealthy foods and beverages could be an effective way to overcome socio-economic barriers and promote equity (Caro, Valizadeh, Correa, Silva, & Ng, 2020; Ni Mhurchu et al., 2015; Valizadeh, Popkin, & Ng, 2022).

Third, interventions that encourage people to evaluate current unhealthy food preferences can be effective in improving the food environment. Policies that influence consumers to reassess their choices and nudge them towards the selection of healthier options through changes in availability, price or presentation of foods (or choice architecture) are important (Cecchini & Warin, 2016; H.-J. Chen et al., 2017; Hawkes et al., 2015). For instance, implementing fiscal policy measures that result in increased prices of unhealthy foods is increasingly seen as an effective, low-cost strategy for reducing consumption of UPPs as part of the approach to address obesity and related NCDs (Stuckler et al., 2012; Thow, Downs, & Jan, 2014; World Health Organization, 2015b). In behavioural economics the nudge theory suggests that people can be influenced to make food selections that support health preferences over the long-haul rather than that gratify an unhealthy short-term preference for taste. This is achieved by adjusting the way food is presented and priced (Aschemann-Witzel et al., 2013; Hawkes et al., 2015). Based on conventional economic theory, as food prices rise individuals are less likely to choose more expensive foods; especially when a satisfactory alternative item is available (Hawkes et al., 2015). An example of this is the excise tax on sugary beverages in South Africa (the Health Promotion Levy) which was introduced in April 2018 (South African Revenue Services, 2018). While a tax policy may be income-regressive (meaning it places a higher burden on those with a lower income), it is progressive from a health standpoint, particularly if the

tax revenues are used towards supporting health among low-income populations (Hofman, Stacey, Swart, Popkin, & Ng, 2021). Health taxes and price policies are appropriate and feasible tools to reduce the negative health and economic impacts of obesity and NCDs (Ghebreyesus, 2018).

Fourth, there should be a focus on interventions that trigger a positive food system response. Effective policies result in positive feedback responses in other areas of the food system as it is a dynamic, interdependent system (Hawkes et al., 2015). This has been observed in the United States of America since the implementation of a energy-labelling policy in chain retail stores and chain restaurant. The energy content of foods has declined since this policy has been implemented (Bleich, Wolfson, & Jarlenski, 2015; Grummon et al., 2021; Petimar et al., 2021). In South Africa, since the introduction of the Health Promotion Levy, the beverage industry has reformulated products to contain less sugar in order to be exempt from taxation (Essman et al., 2021; Stacey et al., 2019). As a result, consumers reap benefit from these policies without actively making any changes to their purchasing or consumption habits.

As levels of obesity continue to rise in Africa (and South Africa) a shift away from policies that only focus on undernutrition is required, towards a focus on the double-burden of malnutrition. It is important that future policies include a focus on the prevention of obesity and related NCDs (Mbogori et al., 2020).

2.4 Nutrient profiling models and their role in underpinning policy interventions

There are no universally accepted criteria to identify foods as healthy or unhealthy. This makes it difficult to implement policies or regulations regarding the health status of foods, as clear criteria are required for effective implementation. Nutrient profiling can serve as a solution, as it is an accepted scientific method to identify and categorise food based on the level of health according to nutritional composition (M. Rayner et al., 2013, 2009; Scarborough, Rayner, & Stockley, 2007). An NPM (or system) has many uses, and countries throughout the world are developing and adopting NPMs to use in policies for the regulation of food labels and to restrict marketing (Labonté et al., 2018; Lobstein & Davies, 2009; Poon et al., 2018; M. Rayner et al., 2009; M. Rayner, Scarborough, & Stockley, 2004). NPMs can be used in both policies that focus on packaged foods that are sold in

supermarkets and other stores, as well as prepared foods sold in the food service sector, such as foods at fast food outlets. For the purposes of this thesis, the focus is on NPMs used for packaged foods.

In LMICs, the implementation of NPMs has been slow, possibly due to limited resources and a lack of data that is required to underpin the development of NPMs within these countries (Bell, Colaiezzi, Prata, & Coates, 2017; Naseri, Thow, Reeve, Martyn, & Bollars, 2018; Pitt et al., 2016). However, there is a need for stronger, evidence-informed policies to promote health and prevent NCDs in LMICs (Naseri et al., 2018). Using one nutrient profiling system in various country-level policies can reduce confusion by ensuring a consistent food promotion approach and also reduce the administrative burden (Sacks et al., 2011).

2.4.1 The need for an NPM to underpin mandatory food policies in the LMIC setting of South Africa

As discussed above, South Africa is facing an obesity crisis, with an increasing prevalence of nutrition-related NCDs like hypertension and diabetes (Statistics South Africa, 2017). The country is undergoing a nutrition transition (Abrahams, Mchiza, & Steyn, 2011; Mbogori et al., 2020) and the availability and consumption of harmful UPPs is increasing rapidly (Haggblade et al., 2016; Ronquest-Ross, Vink, & Sigge, 2015). With rising rates of obesity and NCDs and no progress being made to reduce or even stabilise the rates of increase, measures need to urgently be put in place to protect the South African population from the effects of harmful UPPs. NPMs can be used to underpin food policies intended to curb the proliferation of UPPs, such as using an NPM for the criteria to identify unhealthy foods that shouldn't be marketed to children, foods that should carry a front-of-package warning label or foods that should be restricted in the school food environment (Labonté et al., 2018).

Comprehensive, solidly designed food policies have the potential to substantially improve diets at a local, national and international level. The benefits of healthy eating policies are not only for a select few; also benefit disadvantaged, lower socio-economic groups (Hawkes et al., 2015). LMICs face a number of challenges in the food policy arena, as highlighted in an analysis of the food policy environment in low-income Pacific countries. Challenges include ensuring multi-sectoral collaboration, implementing proposed policies and following through with long-term commitments

to policy goals (Dodd et al., 2020). The implementation of policies that are underpinned by an NPM has been slow in LMICs, possibly due to limited resources and a lack of population-level nutritional data which is needed to support the development of NPMs in the countries concerned (Bell et al., 2017; Pitt et al., 2016; Reeve, Naseri, Martyn, Bollars, & Thow, 2018).

A starting point for regulating the UPP food environment in South Africa is to develop and implement an NPM that can serve as the foundation for various other food policies. In doing so, it is important consider the resource-limited setting of a LMIC like South Africa. If effective regulations are to be put in place, they need to be easy to implement, require minimal resources to enforce and should not be too costly.

2.4.2 Steps in the development of an evidence-informed nutrient profiling model

There are numerous different NPMs used in government regulations around the world (Labonté et al., 2018). In order to select a suitable, context-specific NPM to be used in food policy a stepwise approach needs to be followed (M. Rayner et al., 2004; Reeve et al., 2018; Scarborough et al., 2007). Following Rayner's internationally accepted approach in NPM development, there are seven steps that need to be followed (Scarborough et al., 2007). More recently, the WHO published guidelines on NPM development in the WHO draft guidelines on front-of-package labelling. It recommends six steps in the development or adaptation of an NPM (World Health Organization, 2019a).

The two recommended approaches have been combined into the following five steps (Scarborough et al., 2007; World Health Organization, 2019a) that can be used to develop a context-specific, fit-for-purpose NPM:

Step 1: Determining the purpose, and target population of the NPM;

Step 2: Selecting appropriate nutrients and other food components to include;

Step 3: Selecting a suitable NPM type, criteria and base;

Step 4: Selecting appropriate numbers and thresholds;

Step 5: Deciding on the process for validating the proposed NPM

It is important to note that although steps are presented as a stepwise process, they are in a practical sense interrelated and interdependent, with decisions made in one step affecting the decisions made in other steps (Verhagen & van den Berg, 2008).

2.4.3 The potential for and of a nutrient profiling model for food labelling policy in South Africa

NPMs can be used to underpin several inter-related food polices. For the purposes of this study, I focused on the potential for and of an NPM for front-of-package warning label policy in South Africa.

Appropriate nutrition information on packaged food labels is an important tool to promote healthy eating and inform nutrition-related policy (Graham, Orquin, & Visschers, 2012; Temple, 2020). A positive association between healthy eating and the use of nutrition labels has been found in several studies (Cecchini & Warin, 2016; Koen, Blaauw, & Wentzel-Viljoen, 2016). Front-of-package labelling could enable consumers to make healthier, informed food choices, (Carrad et al., 2016; Temple, 2020) over time assisting consumers to develop the competencies to make healthy food purchase choices (Aschemann-Witzel et al., 2013). On a public health level these changes could result in a significant saving in health costs and increase population health (Cecchini & Warin, 2016).

According to a 2016 review on the way forward regarding food labelling in South Africa front-of-package labelling is considered a low-cost and valuable tool that will assist South Africa to reach the goals of promoting health and wellness and preventing NCDs as set out in the *2013-2017 Strategic Plan for the prevention and control of NCDs* (Koen et al., 2016). Studies in South Africa have shown that consumers struggle to interpret current food labels with quantitative information, and some found different nutrition label formats to be confusing (Koen et al., 2016). Those with lower education levels are more likely to rank foods incorrectly (Hutton & Gresse, 2022), and unemployment, poverty, and food insecurity may impact the ability of consumers to understand labels (Xazela, Chinyamurindi, & Shava, 2019). South Africa has 11 official languages, and 12 % of the adult population are illiterate (Khuluvhe, 2021), which makes it difficult to convey information in an easily understood manner for all of the population. In South Africa there is not currently a standardised regulation regarding a food labelling system. Recently, a front-of-package warning label has been

developed specially for the South African context (Bopape et al., 2021). It has been tested against other front-of-package labelling formats, and amongst a nationally representative study sample was found to be the most effective labelling format for identifying unhealthy products in South Africa (Bopape et al., 2022).

The most recent food labelling regulation, "*Regulations pertaining to the labelling and advertising of foodstuffs (R146 of 2010)*" was implemented in 2010 (National Department of Health, 2010). Since then, a draft regulation was published, "*Draft regulations relating to the labelling and advertising of foods (R429 of 2014)*" (National Department of Health, 2014) that has not yet been promulgated. This regulation makes some recommendations, regarding a nutrient profiling model for regulating health and nutrition claims, and has also been validated for use in child-directed marketing restrictions (Wicks, Wright, & Wentzel-Viljoen, 2017, 2020). Although labelling regulations have yet to be implemented, South Africa has demonstrated that it can implement meaningful food and nutrition regulations. For example, in 2011 South Africa implemented trans-fat regulations, prohibiting foods that contain more than 2 g of trans fat per 100 g of fat (National Department of Health, 2011), in 2012 regulations on the use of sweeteners in food (National Department of Health, 2012), and in 2016 implemented mandatory limits in various processed foods regarding the upper limit of sodium permitted (Peters et al., 2017), and a sugary beverage tax, the Health Promotion Levy, was introduced in 2018 (South African Revenue Services, 2018).

The nutrition policy priorities in South Africa are emphasized in the National Department of Health's Strategy for the Prevention and Control of Obesity in South Africa 2015–2020: "*Create an enabling environment that supports the availability and accessibility of healthy food choices in various settings*". The strategy highlights the need for the development of norms and standards for sugar and fat content of ultra-processed foods, and also notes the importance of front-of-package labelling and the ethical marketing of food (National Department of Health, 2015). This document is currently under review, and an updated version is expected to be published in 2023, with extended focus on these key areas.

2.5 Conclusion

To move forward with improving the food environment and the health outcomes for low-income South Africans who are worst affected by the increasing prevalence of obesity and NCDs in the

country, a better understanding of ultra-processed food consumption in the country is required. Additionally, a well-researched, evidence-informed NPM that has the potential to underpin food policies that can address health in an equitable manner is urgently needed in the country.

CHAPTER 3: Methodology

The methodology chapter of the thesis has been divided into five sections. In the first section I discuss the theoretical and conceptual framework for this study. Thereafter, each study objective is discussed individually, and in the last section I discuss ethical considerations that are pertinent to all stages of the research.

Relevant throughout the methodology chapter is that secondary data analyses of two purposely selected studies was employed for data analyses in this study. The benefits of secondary analysis are gaining traction in the field of health research as it increases research efficiency (Cheng & Phillips, 2014).

The primary studies that served as data sources were "*Associations of the implementation of the SA Health Promotion Levy with dietary intake and consumption of sugar sweetened beverages in adults aged 18-39 years living in Langa study*", referred to as the HPL study and "*Researching the obesogenic food environment, its drivers and potential policy levers in SA and Ghana study*", or ROFE study. Although the data collection of these studies is not considered primary data for my PhD thesis methodology, I was actively involved in the primary data collection for both of these projects as a researcher. I served as a co-investigator on the HPL project, were I was involved in data collection, training, supervising fieldwork and quality control of the project. I was also involved in training, supervising fieldwork and quality control for the portion of the ROFE study that collected data from supermarkets (which I analysed as secondary data for this study).

Figure 2 below briefly outlines how the datasets (discussed in detail later in the chapter) were used to answer the objectives of this thesis.

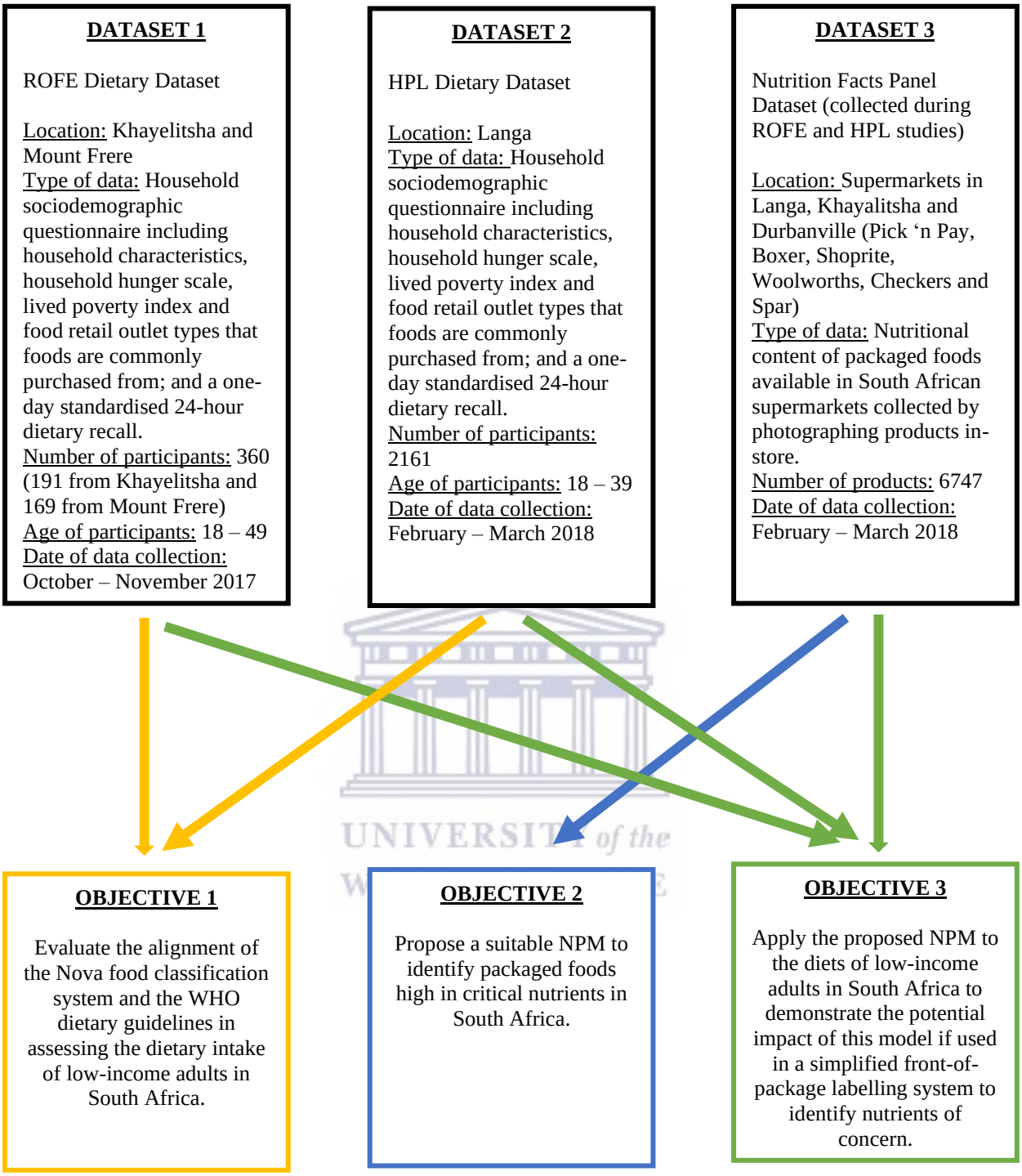

Figure 1: Overview of datasets used to answer study objectives

3.1 Theoretical framework and conceptual design

3.1.1 Theoretical framework

Health behaviour change, including changing the food environment and food choices, is part of a complex adaptive system that is multi-faceted, interconnected and relies on feedback loops between the individual and the surrounding environment (Holden, 2005; King, 2015). Both the external food environment (through availability, prices, marketing and regulation, and vendor and product properties) as well as the personal domain (through accessibility, affordability, conveniences and desirability) have an important effect on influencing food acquisition and consumption patterns; and as a result health outcomes (Turner et al. 2017).

A complex problem like changing the UPP food environment to reduce obesity and NCD incidence can be understood through applying change theories. These theories examine the mechanisms through which interventions are expected to bring about specific changes and also how these changes may interact with one another (Hawkes et al., 2015; Stein & Valters, 2012). A strong theory of change can enable all the various stakeholders to work together towards achieving the same goal (Seidman, 2017). Recently, the Ministry of Health in Chile has used change theory to effectively address inequalities in their health system by introducing a law on food labelling and advertising to try and reduce its high obesity levels (Solar & Frenz, 2017). Packaged foods high in critical nutrients (sugars, sodium, saturated fats and energy) carry a large black warning octagon on the front-of-package, and these foods cannot be sold on school premises or advertised to children. A year after the law was implemented 68 % of the population had changed their purchasing habits and 20 % of the food industry had reformulated products (Food and Agriculture Organization & World Health Organization, 2018).

The Lancet's 2015 "*Smart policies for obesity prevention*" formulated a theory of change where people's environments are central and act as the mediator between learned food preferences and eating behaviours (Figure 2). Four key areas were highlighted as essential during the development of this theory. Firstly, that food preferences play an important role in determining what people eat and that the social, food and information environments play a role in developing these food preferences. Secondly that there are barriers to accessing, preparing and consuming healthy foods, particularly for those of a low socio-economic status. Thirdly, food price and presentation affect purchase and

consumption choices made and lastly that food system activities (e.g. production, processing, distribution and marketing) are influenced by food policies (Hawkes et al., 2015).

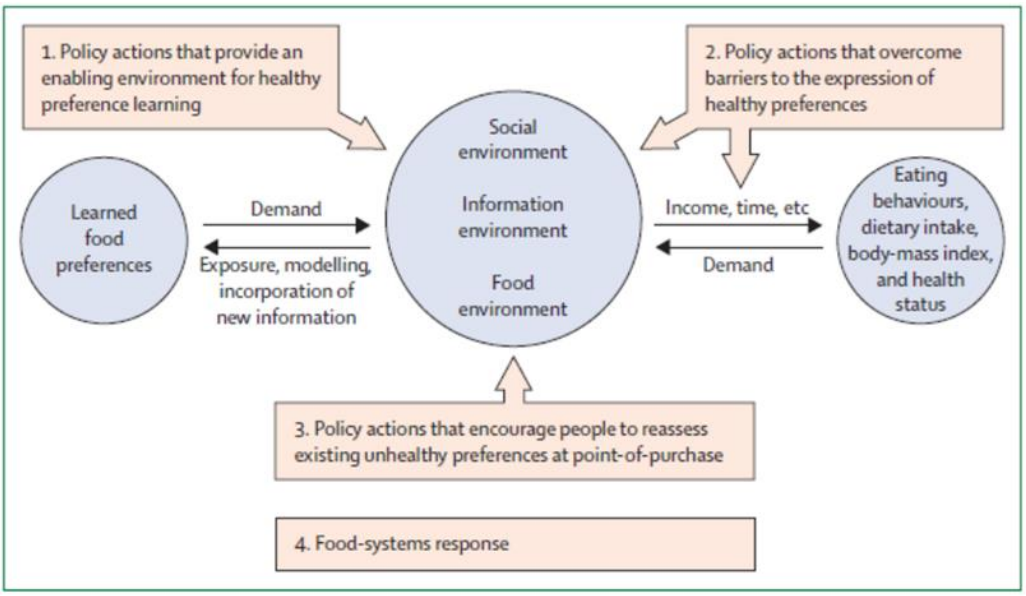

Figure 2: Theory of change framework and the four mechanisms through which food policy actions work (Hawkes et al., 2015)

3.1.2 Conceptual framework for this study

The theory of change framework described above can be applied to this study. Envisioned areas of change have been superimposed onto the framework in dark blue in Figure 3 below. Although this study will not involve the development of policies, developing a NPM has the potential to be used in a wide range of polices.

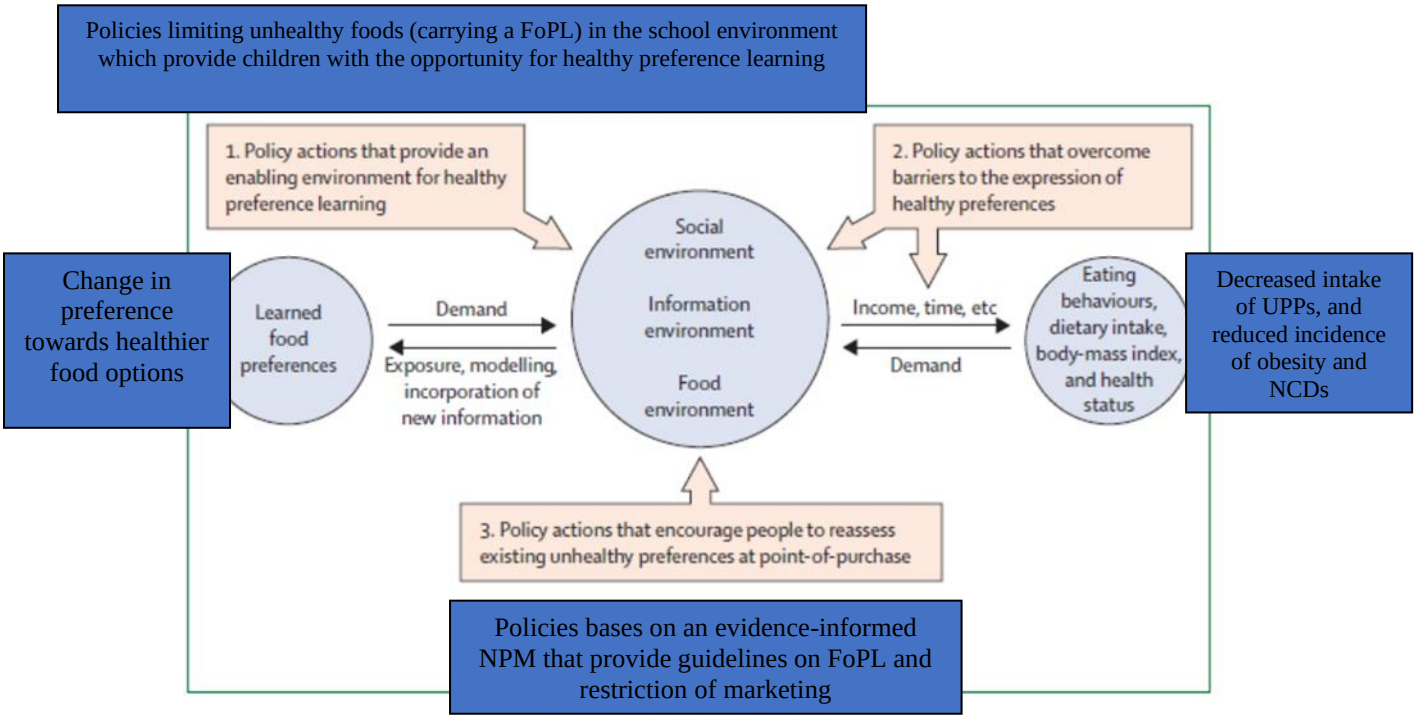

Figure 3: Conceptual framework for this study (as applied to the food policy theory of change framework)

An evidence-informed NPM can be used in numerous restrictive food policies to inform the classification of unhealthy foods. These policies, such as a front-of-package labelling policy that warns against foods high in unhealthy nutrients of concern, or a policy that restricts foods with a warning label from being sold on school premises or marketed to children can in turn potentially result in a decreased intake of UPPs, and thus potentially result in a reduced incidence of obesity and related NCDs.

3.2 Methodology: Objective one

Objective one of this study evaluated the alignment of the Nova food classification system and the WHO dietary guidelines in assessing the dietary intake of low-income adults in South Africa. It also served to inform objective three of the study.

The harmful effects of UPPs are frequently overlooked and underestimated. Including an assessment of food processing in health and nutrition evaluations will allow for better prevention and control of obesity and related NCDs (Moubarac et al., 2014). The Nova classification system (note Nova is not an acronym) is a recognised tool that can be used in public health policy for the development of

guidelines that describe dietary patterns by the level of processed food consumption (Kelly & Jacoby, 2018; O'Halloran et al., 2017). It is a food classification system with four food categories that takes the extent, nature and reason for processing into account when categorising foods and beverages. The four groups are 1) unprocessed or minimally processed foods; 2) processed culinary ingredients; 3) processed foods; and 4) UPPs (Monteiro et al., 2016, 2017).

A number of countries around the world have made use of the Nova classification system to assess dietary intake (Juul & Hemmingsson, 2015; Louzada et al., 2015; Monteiro, da Costa Louzada, et al., 2018; Moubarac et al., 2013; O'Halloran et al., 2017; Solberg, Terragni, & Granheim, 2016), and this classification system is used as the basis for the Brazilian food and nutrition guide (Monteiro et al., 2016). In 2015, the FAO included the Nova system in their guidelines on collecting food processing information from food surveys, (Food and Agriculture Organization, 2015). Applying the Nova food classification system to food composition databases has been identified as way to quantify the contribution of UPP to the food supply. This can assist in evaluating the quality of dietary intake in various population groups (O'Halloran et al., 2017).

In order to identify appropriate healthy levels of nutrients in dietary intake data, WHO-set guidelines for the prevention of chronic diseases can be used. These include guidelines for critical nutrients identified to play an important role in NCDs, namely total fat, saturated fat, trans fat, sodium and sugar (World Health Organization, 2003). There are also individual WHO guidelines available for sugar (World Health Organization, 2015a) and sodium (World Health Organization, 2012).

3.2.1 Research design

Secondary analysis of two purposefully selected cross-sectional datasets was undertaken. These two studies used different sampling strategies, but used the same methodology to collect dietary intake data by means of a one-day 24-hour dietary recall.

3.2.2 Population

Three low-income South African communities were studied (Table 1Table *1*: Summary of population statistics for study communities (Statistics South Africa, 2012)), Langa, Khayelitsha and Mount Frere (also known as KwaBhaca). Langa and Khayelitsha are urban townships in Cape Town, Western

Cape. Mount Frere is a rural town in the Eastern Cape. These sites where purposefully selected geographical sites, as the researchers were familiar with them.

Table 1: Summary of population statistics for study communities (Statistics South Africa, 2012)

	Khayelitsha		Langa		Mount Frere	
Total population	391 749		52 401		5 252	
Total number of households	188 810		17 402		1 751	
Geographical size	38.71		3.09		3.53	
Population/ km^2	101 20		16 958		1 486	
Households/ km^2	4877.55		5631.52		495.99	
% Female	51.1	**% Male** 48.9	50.4	49.6	54.8	45.2
Predominant race	Black African (98.6 %)		Black African (99.1 %)		Black African (96.08 %)	
Predominant 1st language	isiXhosa (90.5 %)		isiXhosa (92.0 %)		isiXhosa (86.58 %)	

3.2.3 Sampling procedures

Different sampling procedures were used for the ROFE and HPL studies, to meet their primary objectives. Individuals were only included in studies if they met the inclusion criteria, and informed consent was given.

For ROFE study sites (Khayelitsha and Mount Frere) 300 households were randomly sampled in October and November 2017, with a 20 % oversampling margin to compensate for non-responders. A semi-purposive stratified sampling strategy was used to select research clusters. Four clusters per site were selected based on proximity to key features (transport hubs, supermarkets, main roads and living areas) as well as by housing type. Households in each quadrant were counted to determine an appropriate sampling interval for each cluster and a purposively selected starting point was chosen. In each household one randomly selected individual was chosen as a respondent between the age of 18 to 49 years (respondents were stratified to ensure representation of gender).

In Langa (HPL study), systematic door-to-door sampling was conducted in February and March 2018. A total of sample size of 2250 participants was needed. A household survey was conducted and one randomly selected consenting adult between the ages of 18 to 39 years per household was included in the study (this age was selected for the HPL study because they are the highest per capita consumers of sugary beverages). The community of Langa was chosen for the HPL study due to the previous ROFE work in this study area (the ROFE study serves as a baseline for the HPL project).

3.2.4 Data collection methods

All fieldworkers were extensively trained in relevant aspects before data collection took place. Pilot studies were undertaken to standardise the method in which fieldworkers asked questions, to ensure consistency and reliability of interviewing techniques.

All fieldworkers had a tertiary level bachelor qualification. Most general fieldworkers had a social work qualification and all diet fieldworker had a nutrition related qualification (dietetics, nutrition or consumer science). Fieldworkers were fluent in languages spoken at the study sites (isiXhosa and English) and worked in pairs of a general- and diet fieldworker during data collection for safety reasons.

Using cell phones to digitally record answers (in Open Data Kit or ODK) (Hartung et al., 2010) the general fieldworker completed the household sociodemographic questionnaire and the food acquisition questionnaire. The diet fieldworkers completed paper-based questionnaires to record the 24-hour dietary recalls. In the field, four to five pairs of fieldworkers with a team leader functioned as a team.

3.2.5 Data collection instruments

Both the ROFE and HPL studies used the same validated questionnaires to collect dietary and general household information.

3.2.5.1 Household sociodemographic questionnaire

This questionnaire included previously validated socio-demographic questions suitable for use in South Africa, such as a household roster, a short birth history, household characteristics, the household hunger scale (Ballard, Deitchler, & Ballard, 2011), the dietary diversity score (FAO, 2021) and the lived poverty index (Mattes, Dulani, & Gyimah-Boadi, 2016).

3.2.5.2 24-hour recall

A one-day 24-hour recall was conducted by trained diet fieldworkers with a tertiary level nutrition related bachelor qualification. They received extensive training on the methods used to conduct a 24-hour recall and made use of standardised 24-hour recall kits during data collection. Standardised food photobooks were included in the kits.

3.2.5.3 Household food consumption and acquisition questionnaire

Aspects of this questionnaire, such as the dietary diversity score were used in analysis. Information on food purchasing practices was included. Please note that although food purchasing is discussed under objective one, it was presented together with the results of objective three (as manuscript four in chapter four).

This questionnaire also included an abbreviated unquantified food frequency questionnaire. In the proposal stage of this research project, the food frequency questionnaire was considered for inclusion during analysis, however, as it was unquantified the decision was made to only use the 24-hour recall data for dietary intake analysis for a more accurate analysis.

3.2.6 Data analysis

Twenty-four hour dietary recalls were coded by trained data capturers. The South African Medical Research Council (SA MRC) Food Quantities Tables (Langenhoven, Conradie, Wolmarans, & Faber, 1991) and Food Composition Tables (FCT) (Medical Research Council, 2017) were used for coding. Stata version 15 (StataCorp, College Station, TX, USA, 2017) and Stata version 17 (StataCorp, College Station, TX, USA, 2021) were used to review, clean and analyse the data. Nutrient content was verified by identifying outliers, checking the original 24-hour recalls and then making corrects when appropriate. Participants with excessive consumption (>20 000 kJ/day) as well as those who consumed less than 400 kJ per day were excluded from analysis.

The SA MRC FCT (Medical Research Council, 2017) was used to identify foods and beverages to which the Nova food classification system could be applied. Foods were assigned to one of the four Nova groups (Monteiro et al., 2016, 2017). These four groups are based on the purpose, nature and extent of industrial processing (Monteiro et al., 2017; Moubarac et al., 2014). As the share of energy intake coming from UPPs was the outcome of interest, products were classified into two groups, ultra-processed (Nova group 4) or not (Nova groups 1-3). Two registered dietitians independently applied the Nova classification to the foods and beverages found in the SA MRC FCT. A stepwise approach was followed and discrepancies between classifications were resolved by discussing these with a third dietitian and reaching consensus. Using the share of energy intake that UPP intake accounted for, quartiles of UPP consumption were created. Participants were classified as high UPP consumers if

they were in the highest quartile of UPP consumption, and defined as low UPP consumers if they were within the lowest quartile of UPP consumption.

The Healthy Diet Indicator 2020 (HDI-2020) (Herforth, Wiesmann, Martínez-Steele, Andrade, & Monteiro, 2020) was used to assess dietary quality. The HDI-2020 criteria is based on WHO recommendations (World Health Organization, 2012, 2015a) and other international dietary recommendations. It includes five healthy food components that should be encouraged to promote health and six unhealthy components for which dietary intake should be restricted. The global diet quality questionnaire (DQ-Q) guidelines of the global diet quality score (Bromage et al., 2021) were used to identify products to include in the HDI-2020 criteria on occasions when the data from the 24-hour dietary recall alone was insufficient to assess whether or not the HDI-2020 criteria were met. The probability of meeting international dietary recommendations was compared between the lowest and highest quartiles of UPP consumers. The variety of shop types, and the types of food outlets that are most frequently visited to purchase certain categories of foods were explored.

Descriptive dietary intake statistics were performed and scores were calculated for the household hunger scale (Ballard et al., 2011), lived poverty index (Mattes et al., 2016), and dietary diversity score (FAO, 2021). Differences in nutritional intake by sex were examined using the Mann-Whitney U test. Quantile regression analysis assessed differences in median nutrient intake by quartile of UPP consumption. Logistic regression analysis was performed to calculate the probability of low and high UPP consumers meeting WHO- and other international dietary guidelines (using the HDI-2020 criteria). All models were adjusted for sex, age, area of residence and household income. For all statistical tests, the level of significance was set at $p < 0.05$.

3.2.7 Validity and reliability

To improve content validity in phase one of the study data collection instruments were compiled by South African experts in the field, who collaborated with international experts for further advice and recommendations. As mentioned in section 3.2.5 instruments were based on existing validated instruments and only adjusted to ensure suitability for the study objectives. Internal consistency was ensured by using the same instruments for both the ROFE and HPL studies.

3.2.8 Limitations and assumptions

This study has a number of limitations that need to be kept in mind when interpreting the findings. Results of two different studies are included. The same methodologies, standardised training and questionnaires were used. However, some of the fieldworkers differed between the two studies and study participants were not exactly the same. Only two of the nine provinces of South Africa are included, which limits the generalisability of findings. To try and account for this, regression analysis results were adjusted for area of residence, age, sex and household income. Three seasons were included during data collection (spring in Mount Frere and Khayalitsha, and summer and autumn in Langa). As dietary intake can differ by season (Willett, 2012), it is possible that the inclusion of all four seasons may have resulted in different dietary intake results.

Due to the available secondary data, dietary assessment was based on a single-day 24-hour recall. This does not capture intra-person variation from day to day. One day of recall date has likely resulted in a wider measurement error distribution that if more days were used, however, assuming measurement error is random, rank-ordering of quartiles is appropriate as the observations in the top 25th percentile would likely remain the same, even with additional days of recall data. Additionally, the large sample size included in the study allows for sufficiently accurate means with the single-day dietary recall data (Willett, 2012).

The SAMRC FCT contains some missing values, especially for sugar (both total and added). Due to this, study findings likely underestimated the true dietary share of nutrients of concern to discourage. As the secondary dietary data included in this study was not detailed down to the brand level and product name assumptions had to be made when classifying products according to the Nova food classification system. For instance, assumptions needed to be made regarding whether products were store bought or homemade. To limit the effect of assumptions, independent classification was undertaken by two trained dietitians familiar with this type of analysis, and discrepancies were resolved through discussion with a third dietitian.

3.3 Methodology: Objective two

The purpose of objective two was to propose a suitable NPM for packaged foods and beverages in South Africa that identifies products high in nutrients of concern that should be limited.

3.3.1 Research design

For objective two secondary data analysis of an existing packaged food dataset was conducted. A a combination of Rayner's internationally accepted approach for NPM development (Scarborough et al., 2007), as well as the more recent six steps recommended for NPM development by the WHO (World Health Organization, 2019a) was used to develop a suitable, context-specific NPM that identifies foods high in nutrients of concern to limit, in order to be able to identify unhealthy packaged foods in South Africa. In order to evaluate the performance of the proposed NPM, its algorithm, together with the algorithms of three other purposefully selected NPMs, was applied to the South African packaged foods dataset.

In order to select a suitable, context-specific NPM to be used in food policy a stepwise approach needs to be followed (M. Rayner et al., 2004; Reeve et al., 2018; Scarborough et al., 2007). Following Rayner's internationally accepted approach in NPM development, there are seven steps that need to be followed, these are (Scarborough et al., 2007):

1) Analysis of data to determine the purpose of the NPM in South Africa;
2) Analysis of data to determine the target population of the NPM;
3) Analysis of data to determine whether to use across-the-board or category-specific criteria in the model;
4) Analysis of data to determine which nutrients and other food components to include;
5) Analysis of data to determine which base or combination of bases to use;
6) Analysis of data to determine which model type to use;
7) Analysis of data to select appropriate numbers and thresholds to use.

More recently, the WHO published guidelines on NPM development in the WHO draft guidelines on front-of-package labelling. It recommends six steps in the development or adaptation of an NPM. These are (World Health Organization, 2019a):

1) Analysis of data to determine whether or not to develop a new model or adapt an existing one;
2) Analysis of data to determine which nutrients to incorporate into the NPM;
3) Analysis of data to determine which food groups to include;
4) Analysis of data to determine the applicability of the NPM;
5) Validation of the NPM through testing;
6) Consideration of options for implementing NPMs.

For the development of the NPM in this study, the two approaches recommended above have been merged into the following five steps, which guided the analysis and the decisions made:

1) Determining the purpose, and target population of the NPM;
2) Selecting appropriate nutrients and other food components to include;
3) Selecting a suitable NPM type, criteria and base;
4) Selecting appropriate numbers and thresholds;
5) Deciding on the process for validating the proposed NPM

These five steps guided the final recommended NPM. It is important to note that although presented as a stepwise process, the steps are in a practical sense interrelated and interdependent, with decisions made in one step affecting the decisions made in other steps (Verhagen & van den Berg, 2008).

3.3.2 Population

Although theoretical, the South African population as a whole has been considered when examining the implications of different NPMs on the South African packaged food supply. This is because all packaged food products available in supermarkets provide the basis for the application of the various NPMs.

3.3.3 Sampling procedures

To obtain a database of packaged and processed food products available in the South African market place, data on the nutritional content of packaged foods available on the South African market was collected through observation at food retail stores in February and March 2018. This was as part of the ROFE and HPL studies. Data was collected from purposefully selected retail stores in the same areas where dietary intake data was collected, in Khayelitsha (Pick ‘n Pay and Boxer) and Langa (Shoprite). To ensure the diversity of products carried for retail stores not represented in Khaylitsha and Langa, data was captured in the middle-class suburb of Durbanville (Woolworths, Checkers, Pick ‘n Pay and Spar). At each store nutritional information on the product packaging was captured for all packaged and processed food and beverages that contained a bar code. A total of 6747 products was included in the final dataset for analysis.

3.3.4 Fieldwork

Trained fieldworkers used a standardised protocol to identify important information on food labels, and to capture and submit photographs for the database. All packaged foods products with food labels available in the stores at the time of data collection (February and March 2018) were captured on the application, "Data Collector" developed by The George Institute.

Before analysis took place foods were classified according to different NPMs. Foods were grouped into food groups according to each NPMs specifications. Foods requiring reconstitution (e.g. adding water to concentrate) to convert from an "as sold" form to an "as consumed" form were calculated by using information retrieved from product photographs.

3.3.5 Testing against various nutrient profiling models

Three NPMs were identified as suitable for comparison against the proposed NPM. The SA Health and nutrition claims (HNC) NPM adopted from Food Standards Australia/New Zealand's (FSANZ) NPM that is currently used as the basis for assessment of health and nutrition claims in the Draft R429 (National Department of Health, 2014), the Chilean Warning Octagons (CWO) NPM (Food and Agriculture Organization & Pan American Health Organization, 2017; Reyes et al., 2019), that has gained attention for its success in Chile (Correa et al., 2019) and has been adopted for use in Peru (Ministerio de Salud del Perú, 2018) and Israel (Ministry of Agriculture, 2017), and the Pan America Health Organisation (PAHO) model that is based on robust scientific evidence, and has been previously validated (Pan American Health Organization & WHO, 2016). The PAHO model was developed as a result of rigorous work by an Expert Consultation Group composed of recognised authorities from Latin America in the field of nutrition (Pan American Health Organization & WHO, 2016), and is used as the basis for food policy in Mexico (Secretaria de Economia, 2020). Both the CWO and PAHO models have been developed to be used for front-of-package warning labels, but it is unclear if either of them are appropriate for the South African context. These three models were tested alongside the model proposed in this thesis, that was developed specifically for the South African population, after extensive literature review, and together with consultation with experts at the Directorate of Food Control at the National Department of Health.

Once the dataset was cleaned, products were excluded if they could not be ranked (e.g. raw products are not considered by PAHO) or because of missing information on critical nutrients. Nutrient profile classification of packaged foods was calculated according to each NPM using algorithms generated in Stata. Foods and beverages were classified as either compliant, or non-compliant, depending on the nutritional criteria of the NPM being evaluated. For the SA HNC model a product was considered compliant when it met the criteria for carrying a health or nutrition claim; for the CWO a product was considered compliant it was excluded from carrying any warning label according to the 2019 criteria (in other words it did not exceed any of the model's limits for energy, sugar, sodium or saturated fat) and for PAHO it was considered compliant it complied with all the stipulated criteria for total fat, saturated fat, trans-fat, sodium, free sugar and non-sugar sweetener.

3.3.6 Data analysis

A stepwise approach was followed when developing a suitable, context-specific NPM to be used for food policy (Naseri et al., 2018; Scarborough et al., 2007).

If there was missing information that prevented evaluation by any of the four NPMs products were excluded from analyses. The SA HNC requires calculations of a fruit, vegetable, nuts and legumes (FVNL) score based on the percentage of fruits and vegetables contained in a product. To calculate this, a similar methodology was followed as described by Bernstein et al (Bernstein, Franco-Arellano, Schermel, Labonté, & L'Abbé, 2017). Likewise, if free sugar values were not available the method proposed by PAHO was used to calculate values (Pan American Health Organization & WHO, 2016). A registered dietitian assigned all classifications.

Product compliance with the NPM was determined based on the nutritional criteria of each NPM. Differences in proportion and mean number of foods identified as non-compliant across models were investigated using tests of proportions and *t*-tests respectively. The mean contents of nutrients of concern were calculated and compared across NPMs based on level of compliance. The level of agreement between each NPM was evaluated using pairwise correlation coefficients. The level of significance was set at $p < 0.05$.

3.3.7 Validity and reliability

The database was reviewed and cleaned in Stata (version 15, StataCorp, College Station, TX, USA). The nutrient content of products in the database were verified as correct by identifying outliers and correcting the information when appropriate by using the photographs of each product. Missing information for specific nutrients were verified, and when critical nutrients information was not reported in the nutrient information panel it was calculated when possible. For cases where added sugar was present, but the amount was not specified the added sugars were estimated using the method proposed by PAHO (Pan American Health Organization & WHO, 2016).

3.3.8 Limitations and assumptions

Data was collected biggest retailers in the Western Cape. It is possible that certain products only occur in certain retail outlets or certain geographical areas and were thus excluded. As it is not a legal requirement to have nutritional content on packaged foods in South Africa a large number of products were excluded from analysis due to missing data. Despite this, the dataset used in this study is the most comprehensive dataset of nutritional information on packaged foods available in South Africa currently.

In South Africa, nationally representative dietary intake data is sparse, and the data that is available is not representative of the population (Mchiza et al., 2015). This makes assessing dietary intake in the country challenging. Additionally, there are some inherent limitations to nutrient profiling. It considers the nutrient content of a food, but does not take into account how often the food is eaten, or the context that the food is being eaten in (Scarborough & Rayner, 2013).

After an NPM has been proposed, it is important that it be tested for appropriateness by applying it to the local food supply chain (Cooper, Pelly, & Lowe, 2016; Townsend, 2010). However, it is difficult to validate a NPM as there is no gold standard for classifying the healthfulness of foods. Criterion-related validity is too time consuming and expensive to use practically, and thus one must rely on construct validity to validate a NPM by testing its performance alongside other NPMs on the local food supply (Cooper et al., 2016; Townsend, 2010). To improve validity, decisions regarding the design of the NPM were made in consultations with experts at the National Department of Health.

To compare the performance of different NPMs certain assumptions were made. Products were included in assessment if they met the inclusion criteria for all four NPMs. In reality, items excluded by one NPM may be included in another NPM. Although standardised methods were followed to calculate missing nutrient values, assumptions made may have not always been correct.

3.4 Methodology: Objective three

In order to meet objective three of the study, the proposed NPM (proposed in objective two) was applied to the diets of low-income adults in South Africa to demonstrate the feasibility of this model to be used in a simplified front-of-package labelling system to identify nutrients of concern.

3.4.1 Research design

For objective three of the study dietary intake data was sourced from the HPL and ROFE studies discussed under objective one (refer to section 3.2). The proposed NPM identified in objective two was applied to foods consumed by the sample population.

3.4.2 Data analysis

Similar data analysis methods to those described in sections 3.2.6 and 3.3.6 were used. The NPM identified in objective two (Frank et al., 2021) was applied to the relevant foods eaten by study participants in objective one. Using the nutrient profiling model, the number of products which could potentially carry warning labels was assessed overall, as well as by each nutrient of concern (sodium, saturated fat, total sugar and non-sugar sweetener). The difference in the share of energy accounted for by products that would be subject to a warning label between high and low UPP consumers was compared using a two-sample Wilcoxon rank-sum test, with statistical significance considered at $p < 0.05$. Data analysis was conducted in Stata version 17 (StataCorp, College Station, TX, USA, 2021).

3.4.3 Limitations and assumptions

A number of the limitations of this study are the same as those discussed in section 3.2.8 (as the same dataset is used) and will thus not be repeated here.

This study made use of existing nutritional composition data to assess the number of products that would be subject to a warning label. Any product reformulation that may occur should mandatory front-of-package warning label regulations be implemented has not been accounted for. As a result, it is necessary to note that the results likely over-estimate of the share of the diet that would be subject to a warning label. However, the study does still provide useful information about the total share of the diet that could be impacted by a combination of both reformulation and/or warning labels. The SAMRC FCT food groups did not align directly with the food groups in the questionnaire that assessed retail food outlet types, and this prevented direct comparison. Despite this, the available information did allow for an investigation into the types of retail food outlets that products subject to warning labels would typically be purchased from.

3.5 Ethical considerations

The study protocol for this study received ethics approval from the UWC Humanities and Social Science Research Ethics Committee (HSREC), ethics approval number: HS19/6/3 (Appendix 1.1: Ethics approval for this project). Additionally, for the primary studies used in data analysis ethical approval was granted from the UWC Biomedical Research Ethics Committee (BMREC) (ROFE study: BM 17/8/20; and HPL study: BM 18/6/2). The ethical approval letters for the ROFE and HPL projects are attached as Appendix 1.2: Ethics approval for ROFE project and Appendix 1.3: Ethics approval for HPL project.

As this project makes use of secondary data please refer to Appendix 2: Ethical Considerations for ROFE and HPL project for more information on ethical considerations regarding the ROFE and HPL projects. Community considerations, informed consent, confidentiality and privacy and data storage and disposal are discussed in Appendix 2: Ethical Considerations for ROFE and HPL project. Consent forms and information sheets are also attached as appendices (Appendix 3.1: HPL Consent Form Englishto Appendix 3.6: Information sheet for HPL English), as well as the questionnaires used in the primary research (Appendix 4.1: HPL & ROFE Diet Questionnaire to Appendix 4.4: HPL & ROFE Household Questionnaire). The primary studies were conducted according to the ethical principles of the International Declaration of Helsinki, and the SA MRC Ethical Guidelines for research (principles of respect for autonomy, justice, beneficence and non-maleficence were adhered to).

3.5.1 Reporting of research

There is an ethical obligation to share and disseminate research findings. To ensure this, this thesis is in the format of a thesis by publication. All articles have, or currently are, undergoing peer review. Open access journals have been selected for publication of all articles to ensure equitable access to the publications.

I have presented the findings of this research on several platforms and will continue to do so in the future. The development of the NPM discussed in objective two was undertaken for the benefit of the South African National Department of Health. As such, results were shared with the Directorate of Food Control during meetings throughout 2019, 2020 and 2021. I was also a co-author on a comprehensive research report submitted to the National Department of Health in 2021 titled "*Developing a front-of-pack label for foodstuffs in South Africa: Technical report*", where the NPM development process is discussed in detail. Additionally, I presented results at a webinar in April 2021 organised by the National Department of Health for researchers and various stakeholders in South Africa. I have also shared the process, and findings of the NPM development process with the Kenyan Ministry of Health and Kenya Bureau of Standards (in June 2021), the Ghana Ministry of Health (in September 2021), the Chinese Nutrition Society (throughout 2022 as an international expert on nutrient profiling), and served on the nutrient profiling sub-committee of the Healthier Diets 4 Healthy Lives project in Ghana (throughout 2022). I have been invited to be involved in similar processes in Ethiopia and Cameroon in 2023.

I have presented findings regarding UPPs and dietary intake at the UWC Research Day (2022), and at the 2022 International Society of Behavioral Nutrition and Physical Activity (ISBNPA) conference in Phoenix, USA. To provide an overview of the project, I participated in the Three Minute Thesis (3MT) competition at the UWC, which I won, as well as the South African national 3MT competition, where I was placed third in the country. I have also accepted to present further findings at the 2023 South African Nutrition Congress and will continue to look for further opportunities to disseminate the findings.

CHAPTER 4: Results

The results chapter comprises of four journal articles (two published and two under review) that answer the research question and study objectives posed by this project. A summary of each manuscript is followed by the full text of the manuscript. Supplementary information to the manuscripts, as well as reviewer comments and author feedback for the published manuscripts are available in Appendix 5.1: Reviewer comments and responses to manuscript and Appendix 6.1: Manuscript one supplementary material. Table 2 below provides a brief summary of the research objectives that each of the manuscripts address.

Table 2: Research objectives and manuscripts that represent the results of this research

Research objective	Research sub-objective	Manuscript
1. Evaluate the alignment of the Nova food classification system and the WHO dietary guidelines in assessing the dietary intake of low-income adults in South Africa	1.1 Critically evaluate the adequacy of the diet of low-income adults in South Africa based on the WHO recommended dietary intake guidelines and the Nova food classification system	Manuscript 1 (under review)
	1.2 Identify the types of food outlets that various food categories are commonly purchased from	Manuscript 4 (under review)
2. Propose a suitable NPM to identify packaged foods high in critical nutrients in South Africa	2.1 Use an evidence-informed approach to develop a suitable NPM	Manuscript 2 (published)
	2.2 Compare this model to three other models used in LMICs, to strengthen the proposal	Manuscript 3 (published)
3. Apply the proposed NPM to the diets of low-income adults in South Africa to demonstrate the potential impact of this model if used in a simplified front-of-package labelling system to identify nutrients of concern	3.1 Using information from the dietary intake of individuals of low-income adults in South Africa, assess the proportion of the diet that could be included in a simplified nutrient information labelling system	Manuscript 4 (under review)
	3.2 Using the NPM identified in objective two, analyse whether diets identified as highly processed (in objective one) are more likely to contain more nutrients of concern in comparison to minimally processed diets	Manuscript 4 (under review)

4.1 Manuscript one

Title: Frank T., Ng S.W., Lowery C.M., Thow A.M., Swart E.C. 2022. Dietary intake of low-income adults in South Africa: Ultra-processed food consumption a cause for concern. Submitted to Public Health Nutrition on 26.08.22 (currently under review).

What is already known?

- Fifty-five percent of South Africans live in poverty, and healthy food is unaffordable and unavailable for those residing in low socio-economic areas.
- South Africa has high, and increasing, levels of obesity and nutrition-related NCDs diseases, placing an enormous burden on the health care system in the country.
- South Africa is undergoing the nutrition transition, and UPPs are becoming more prolific and available in all parts of the country.

What are the new contributions from this study?

- Most (92.4 %) low-income adults living in South Africa consumed UPPs on the day prior to data collection. Amongst high UPP consumers, UPPs accounted for 60.3 % of their daily energy intake, whilst for low UPP consumers UPPs only contributed 7.8 % of their daily energy. High UPP consumers also consumed almost double the daily energy of low UPP consumers.
- Amongst low-income adults living in South Africa, high UPP consumers are more likely to consumer significantly higher amounts of nutrients linked to increased chronic disease risk (saturated fat, sodium, free sugar and processed meat); whilst low UPP consumers are less likely to consume excessive quantities of these nutrients of concern.
- Regardless of level of UPP food consumption, protective dietary component (fruits and vegetables, beans and legumes, nuts and seeds, whole grains and dietary fibre) intake remains low, with less than 20 % of all participants meeting any of these guidelines.

How might this study affect research, practice or policy?

- This study reinforces previous studies in South Africa on nutrient intake and confirms that healthy food is not consumed in adequate amounts. This information can be used to inform policies promoting a healthier food environment, such as policies that address the cost of healthy foods through subsidisation and agricultural sector policies that promote sustainable practices to produce healthy and affordable produce.
- Little research using 24-hour recalls and the Nova food classification system has been conducted in South Africa to evaluate the amount of UPP consumed. This is (to my knowledge) the first study of this type that has been conducted in South Africa using 24-hour

recall dietary data, and certainly the largest dietary intake study in South Africa to make use of this methodology. This provides new insight into UPP consumption rates amongst low-income adults in South Africa and identifies the extent of UPP consumption. This information should be used to inform food policies that are designed to restrict the intake of UPPs. One such policy is the proposed front-of-package warning label policy that the National Department of Health has indicated they are intending to implement. To this effect, the results will be shared with the National Department of Health once published.

Contribution of the candidate: Together with input from my supervisors (S.W.N, A.M.T, and E.C.S) I conceptualized the study, and methodology for this study. I conducted all data management, data cleaning and data analysis. Supervisors and co-authors reviewed and provided feedback on the data analysis (S.W.N and C.M.L). I wrote the draft manuscript, and supervisors and co-authors contributed to reviewing the manuscript (S.W.N, C.M.L, A.M.T and E.C.S). Supervisors provided overall guidance to the project (S.W.N, A.M.T and E.C.S). Additionally, primary data collection used as data sources in this manuscript was conducted by E.C.S., with myself as the project coordinator in the larger one of the two studies.

Please refer to Appendix 6.1: Manuscript one supplementary material for supplementary material that will be published alongside the manuscript.

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Dietary intake of low-income adults in South Africa: Ultra-processed food consumption a cause for concern

Journal:	*Public Health Nutrition*
Manuscript ID	Draft
Manuscript Type:	Research Paper
Subject Category:	3. Nutritional status and body composition
Keywords:	ultra-processed, South Africa, dietary quality, low-income, nutrition policy

Abstract:	Objective: Given the rapidly changing food environment, and proliferation of ultra-processed foods (UPF) in South Africa (SA) this study aimed to critically evaluate dietary quality and adequacy of low-income adults using the Nova classification system and the World Health Organization's (WHO) dietary guidelines. Design: Secondary household data and 1-day 24-hour recalls were analysed from two cross-sectional studies. Foods consumed were classified according to the Nova classification system. Compliance with WHO dietary guidelines and UPF consumption trends were evaluated. Setting: Three low-income areas (Langa, Khayalitsha and Mount Frere) in SA were included Participants: 2521 participants (18-50 years) were included in the study Results: Participants had a mean energy intake of 7762kJ/day. Most participants were within the acceptable WHO guideline range for saturated fat (80.4%), total fat (68.1%), sodium (72.7%) and free sugar (57.3%). UPF comprised 39.4% of diets among the average adult participant. Only 7.0% of all participants met the WHO guideline for fruit and vegetables, and 18.8% met the guideline for fibre. Those within the highest quartile of share of energy from UPF consumed statistically higher amounts of dietary components to limit and were the highest energy consumers overall.

	Conclusions: Low-income adults living in SA are consuming insufficient protective dietary components while UPF consumption is prevalent. Higher UPF consumers consume larger amounts of nutrients linked to increased chronic disease risk. Policy measures are urgently needed in SA to protect against the proliferation of harmful UPF, and to promote and enable consumption of whole and less processed foods.

Dietary intake of low-income adults in South Africa: Ultra-processed food consumption a cause for concern

Abstract

Objective: Given the rapidly changing food environment, and proliferation of ultra-processed foods (UPF) in South Africa (SA) this study aimed to critically evaluate dietary quality and adequacy of low-income adults using the Nova classification system and the World Health Organization's (WHO) dietary guidelines.

Design: Secondary household data and 1-day 24-hour recalls were analysed from two cross-sectional studies. Foods consumed were classified according to the Nova classification system. Compliance with WHO dietary guidelines and UPF consumption trends were evaluated.

Setting: Three low-income areas (Langa, Khayalitsha and Mount Frere) in SA were included

Participants: 2521 participants (18-50 years) were included in the study

Results: Participants had a mean energy intake of 7762kJ/day. Most participants were within the acceptable WHO guideline range for saturated fat (80.4%), total fat (68.1%), sodium (72.7%) and free sugar (57.3%). UPF comprised 39.4% of diets among the average adult participant. Only 7.0% of all participants met the WHO guideline for fruit and vegetables, and 18.8% met the guideline for fibre. Those within the highest quartile of share of energy from UPF consumed statistically higher amounts of dietary components to limit and were the highest energy consumers overall.

Conclusions: Low-income adults living in SA are consuming insufficient protective dietary components while UPF consumption is prevalent. Higher UPF consumers consume larger amounts of nutrients linked to increased chronic disease risk. Policy measures are urgently needed in SA to protect against the proliferation of harmful UPF, and to promote and enable consumption of whole and less processed foods.

Introduction

The manner in which food is produced, distributed and marketed has changed drastically in recent history. Although food security has improved (prior to the onset of the COVID-19 pandemic), economic development has displaced traditional dietary patterns and driven a shift in food preferences, resulting in the nutrition transition[1]. This changing food environment, synonymous with a proliferation of packaged foods high in sugar, salt, and saturated fat, otherwise known as ultra-processed foods (UPF), undermines dietary patterns based on minimally- and unprocessed food and ingredients[2]. The entry of large transnational food corporations in the Global South over the last few decades has resulted in rapidly increasing consumption rates of UPF in low- and middle-income countries (LMIC)[3]. Consumption habits and choices are continually shifting towards unhealthy UPF due to the price, taste, convenience, availability and marketing strategies employed by large corporations[2].

Although South Africa is classified as an upper-middle income country, it has one of the highest levels of inequality in the world, with 55% of the population living in poverty[4], and a continually rising unemployment rate, at 34% in 2022[5]. Given the country's historical discriminatory past of apartheid, with black people segregated to reside in under-resourced townships with poor access to education and employment, those living in low-income townships remain particularly vulnerable to the effects of rising food prices. Like much of the rest of the Global South, the food environment within South Africa is rapidly changing, with multinational food companies accounting for the majority of the market share[6]. Foods are increasingly being eaten away from home, with fast-food options increasing. The higher cost and limited availability of healthy foods makes convenient healthy options unattainable for the majority of the population[4,7,8]. Additionally, the build environment in townships makes it difficult for low-income shoppers to select healthy foods, with less availability and poorer quality options available in low socioeconomic neighbourhoods[9]. As a result,

cheap, energy-dense, ultra-processed and unhealthy food options are becoming the food of choice for many[7].

UPF refer to "*formulations mostly of cheap industrial sources of dietary energy and nutrients plus additives, using a series of processes*"[10]. These are typically industrially processed foods, high in nutrients known to negatively affect health (sodium, saturated and trans fats, and added sugars) and are energy dense[11]. These high-energy, low nutritional quality foodstuffs are usually made from cheap ingredients and additives, but are very palatable, require little preparation and are convenient for consumers[12]. Numerous studies associate the increased consumption of UPF with obesity and diet-related non-communicable diseases (NCD) like hypertension, diabetes, dyslipidemia and certain cancers[13–16]. These diet-related NCDs result in increased mortality levels, particularly in LMICs, were the majority of these deaths occur[17]. Studies in South Africa have shown that foods are selected because they are cheap, filling and tasty, but not necessarily nutritious[7,8]. Consequently, NCD, such as diabetes and hypertension are fast becoming the most burdensome diseases in the South African health system[18,19]. One in five women in South Africa is severely obese. Sixty-eight percent of women are overweight or obese, as are 31% of men. Hypertension, overweight and obesity prevalence have been increasing since 1998[20], and those living with obesity are more likely to suffer from disease multimorbidity[21]. On a macronutrient level, obese individuals may appear to be food secure, but on a micronutrient level, food and nutritional insecurities are prevalent[22].

As UPF have been shown to be harmful to health, it is important to examine their intake when assessing dietary patterns and health of individuals and populations[23]. The Nova classification system, as a tool to identify UPF, has been used to assess dietary intake in a growing number of countries[24–29]. In 2015, the FAO included the Nova system in their guidelines on collecting food processing information from food surveys[30], and a recent World Health Organisation (WHO) report has used the Nova classification system to describe the increase in UPF intake in Latin America over the past decade[31]. Applying the Nova food classification system to food composition databases has been identified as a way to quantify the contribution of processed foods to the food supply. This can assist in evaluating the quality of dietary intake in various population groups[25]. To our knowledge, this has not yet been done in South Africa.

Therefore, the aims of this study are two-fold. First, we seek to describe what share of the diet of low-income adults living in South Africa is comprised of UPF. Second, we seek to assess the adequacy of the diet of low-income adults in South Africa using international WHO dietary recommendations and evaluate potential associations with level of UPF consumption. Using international criteria to assess dietary intake creates the potential for comparison to other contexts, and analysing the intake of UPF in South Africa allows for better monitoring of the nutrition transition.

Methods

Secondary analysis of dietary data from two purposefully selected datasets collected in three low-income areas in South Africa (Langa and Khayelitsha in Cape Town, and Mount Frere in the Eastern Cape) was undertaken. These two studies used different sampling strategies, but the same methodology and data collection instruments.

Sampling procedures and data collection

Sampling procedures used in Khayelitsha and Mount Frere differed to those used in Langa, to meet their primary study objectives. Individuals were only included in the studies if they met the inclusion criteria, and if informed consent was obtained.

In the study conducted in Khayelitsha and Mount Frere, 300 households were randomly sampled at each site in October and November 2017, with a 20% oversampling margin to compensate for non-responders. A semi-purposive stratified sampling strategy was used to select research clusters. Four clusters per site were selected based on proximity to key features (transport hubs, supermarkets, main roads and living areas) as well as by housing type. Households in each quadrant were counted to determine an appropriate sampling

interval for each cluster and a purposively selected starting point was chosen. In each household one randomly selected individual was chosen as a respondent between the age of 18-50 years (respondents were stratified to ensure representation of gender). For the Langa sample, systematic door-to-door sampling was conducted in February and March 2018 throughout the entire area of Langa, with a target sample size of 2250 participants. One randomly selected consenting adult between the ages of 18 to 39 years old per household was included in the study.

All three study sites used the same questionnaires to collect dietary and general household information. The only exception was body mass index (BMI) derived from measured height and weight, which was only collected in Langa. The household sociodemographic questionnaire included previously validated socio-demographic questions, such as household characteristics, the household hunger scale[32] and the lived poverty index[33]. A one-day standardized 24-hour dietary recall was collected for each participant. Fieldworkers were extensively trained and fluent in languages spoken at the study sites. They used cellphones to digitally record sociodemographic data and paper-based questionnaires to complete the 24-hour dietary recalls.

Participants from these primary studies were only included for secondary analysis if they had completed all the questionnaires and did not have any missing dietary intake data. In total, 2161 participants were included from Langa (85.3% of respondents), 191 from Khayalitsha (61.2% of respondents) and 169 from Mount Frere (51.2% of respondents), for a total sample of 2521 adults.

Data coding and analysis

Twenty-four-hour dietary recalls were coded by trained data capturers with a tertiary level nutrition qualification. The South Africa Medical Research Council (SAMRC) food quantities[34] and food composition tables[35] (FCT) were used for coding. An extensive assumptions manual was developed to ensure assumptions were made in a standardised manner when necessary.

Food and beverages were classified as ultra-processed according to the Nova food classification system, a system that groups foods, for the purpose of public health policy, into four categories based on the purpose, nature and extent of industrial processing[10,23]. The four groups are: 1) unprocessed or minimally processed foods, 2) processed culinary ingredients, 3) processed foods, and 4) ultra-processed foods[10,36]. As the share of energy intake coming from UPF was the outcome of interest we classified products into two groups, ultra-processed (Nova group 4) or not (Nova groups 1-3). Two registered dietitians independently applied the Nova classification to the foods and beverages consumed by study participants. Discrepancies between classifications were resolved by consulting with a third dietitian and reaching consensus. Quartiles of UPF consumption were created, based on the share of energy intake that UPF accounted for. Participants were considered to be low UPF consumers if they were within the lowest quartile of UPF consumption, and high UPF consumers if they were in the highest quartile.

We used the Healthy Diet Indicator 2020 (HDI-2020)[37] to assess the quality of the participants' diet. The HDI-2020 criteria is based on WHO-[38,39] and other international dietary recommendations. There are six components for which dietary intake should be restricted, and five components that should be encouraged, following the criteria shown in Table 1. More detail on the HDI-2020 can be read elsewhere[37]. When the data from the 24-hour dietary recall alone was insufficient to assess whether or not the HDI-2020 criteria were met, the global diet quality questionnaire (DQ-Q) guidelines of the global diet quality score[40] were used to identify products to include in the HDI-2020 criteria. Unfortunately, for nutrient-specific evaluations, missing values in the SAMRC FCT resulted in underreporting of intake for some nutrients in the analyses. This was particularly pronounced for total and added sugar. Please see the limitations section and Appendix A and B for more details. Additionally, there are no free sugar values in the food composition table, so added sugar was used as a proxy. The probability of meeting international dietary recommendations was compared between the lowest and highest quartiles of UPF consumers. For WHO guidelines that use the share of energy as the criteria, the contribution to share of total energy was calculated by quartile of UPF. For components

where the guidelines were in grams, rather than share of total energy, the contribution per 1000kJ was calculated.

We used STATA version 15 (StataCorp, College Station, TX, USA, 2017) to review, clean and analyse the data. Nutrient content was verified by identifying outliers, checking the original 24-hour recalls and correcting the information when appropriate. Participants who consumed more than 20 000kJ per day, or less than 400kJ per day were excluded. Descriptive dietary intake statistics were performed and scores calculated for the household hunger scale[32], lived poverty index[33], and dietary diversity score[41]. The Mann-Whitney U test was used to compare differences in nutritional intake by gender. Due to the non-parametric nature of the data, quantile regression analysis was performed to assess differences in median nutrient intake by quartile of UPF consumption. Logistic regression analysis was performed to calculate the probability of low and high UPF consumers meeting WHO- and other international dietary guidelines (using the HDI-2020 criteria). All models were adjusted for age, sex, household income and area of residence. For all analyses, a level of significance was assumed at $p<0.05$.

Results

Demographics and dietary intake of low-income adults

Of the 2521 study participants, 68.1% were female. Whilst 40.0% of participants with anthropometric measurements (n=2024) had a normal weight, obesity prevalence levels were much higher in women, with 43.7% (n=587) of women, and 7.9% of men (n=54), living with obesity. The majority (86.2%) of participants had not completed secondary education, and more than half of the participants had a monthly household income of R3000 (226 USD based on 2018 exchange rates) or less. Dietary diversity, which was assessed by evaluating the minimum dietary diversity for women (MDD_W), was only achieved for 24.3% of female participants. Despite this, 86.4% of participants reported little to no household hunger, and 60.5% reported a low lived poverty index (see Table 2 Panel A).

The mean energy intake was significantly higher amongst men than women (8551kJ/d vs 7393kJ/d; $p<0.001$). This trend was also observed for most other nutrients. Men consumed significantly more total fat (59.7g/d, $p=0.001$), and saturated fat (16.8g/d, $p=0.005$) than women who consumed a mean 51.9g/d and 14.9g/d respectively. The mean daily protein consumption was 10g higher in men than women (67.5g vs 57.7g, $p<0.001$), whilst total sugar only differed by 2g/day (64.3g vs 62.5g; $p=0.699$). Interestingly, despite their energy intake being lower, women consumed significantly more added sugar than men (23.8g/d vs 20.5g/d; $p<0.001$). They also consumed more whole grains and fruits and vegetables than men, although this was not statistically significant. The average fibre intake amongst participants was 17.4g/day (see Table 3).

Ultra-processed food intake

The percentage of total energy intake from UPF was similar amongst men and women (39.0% and 37.1% respectively, $p=0.062$). UPF intake accounted for a significantly larger share of dietary intake amongst younger consumers, contributing 40.2% of daily energy intake amongst 18- to 29-year-olds, and 22.3% of intake amongst 40- to 50-year-olds ($p<0.001$). Household income was not associated with the proportion of UPF consumed ($p=0.087$), as those with the lowest household income (<R3001/d) consumed a similar proportion of UPF to the highest income households (>R10 000/d), at 36.7% and 37.9% of total daily intake respectively. Those without any formal education consumed significantly lower amounts of UPF (30.2%) than those who had completed primary (37.8%) and secondary (39.4%) education ($p=0.002$) (see Table 2 Panel B).

Figure 1 shows the distribution of the share of ultra-processed food to total energy intake amongst study participants. Very few participants (7.6%, n=192) reported that they did not consume any UPF in the previous day. There were clear gradients with respect to nutrient intake, when analysed by quartile of share of energy from UPF. The highest quartile of UPF consumers consumed a median 10264kJ/d of total energy (60.3% of which was accounted for by UPF intake) whilst the lowest quartile consumed a median 5605kJ/d (of which

7.8% was attributed to UPF). The same significant trend by quartile for median intake was observed for total fat, saturated fat, total sugar, and sodium; with the highest UPF consumers consuming the largest quantities of these nutrients of concern linked with NCDs and obesity. Added sugar intake also increased by UPF quartile, but the difference between quartiles was not significant. Interestingly, median total fibre and fruit and vegetable intake also increased by quartile of UPF consumers, although the increase was not significant for fruits and vegetables. In both of these groups, despite the increase in absolute terms, the opposite trend, which was significant, was observed for g/1000kJ, with the contribution decreasing with each ascending quartile (whilst sodium had the opposite trend) (Table 4).

Adequacy of the diet based on international recommendations

Table 5 Panel A shows that overall, very few participants met international recommendations for dietary components that are beneficial to health. Only 7.0% of participants met the WHO recommended intake of 400g of fruit and vegetables per day in the previous day. The mean intake amongst the 1963 participants who did not meet the guideline was 93.0g/day. Similarly, low numbers of participants met the protective recommendations for frequent consumption of beans and other legumes, nuts and seeds, and whole grains (with 4.6%, 7.3% and 15.6% meeting each respective guideline). Slightly more (18.8%) participants met the recommended intake of 25g or more of fibre per day, although the mean intake amongst those who didn't meet it remained low, at 13.9g/day.

At least 50% of participants met the recommendations for all nutrients to limit. Sixty-eight percent of participants met the recommendation of consuming less than 30% of their total energy intake from fat, 80.4% consumed less than 10% of their total energy intake from saturated fat per day and 72.7% consumed less than 2000mg sodium per day. No processed meat was consumed by 79.6% of participants on the previous day, and 86.9% of participants did not consume excessive amounts of red meat. Although free and added sugar intake were difficult to assess (see the methods and limitation section for more details), depending on whether intake was assessed using the free sugar criteria from the DQ-Q or the 24-hour recall data for added sugar, between 57.3% and 82.1% met the recommendation of less than 10% of total energy respectively (Table 5 Panel A).

Alignment of international dietary recommendations and the Nova system in assessing dietary inadequacy

Table 5 Panel B shows the predicted probabilities of meeting international guidelines by level of UPF consumption (high v. low). For dietary recommendations that consider the share of total energy (total fat, saturated fat and free sugar), high UPF consumers were significantly less likely to meet the recommendation than low UPF consumers. The only exception was free sugar intake when using added sugar from the 24-hour recall, which did not have a significant difference. High UPF consumers were also significantly more likely to have excessive sodium and processed meat intake, and insufficient bean and legume consumption. However, high UPF consumers were significantly more likely to meet the recommendations for nuts and seeds, wholegrain and fibre intake. No significant differences were observed between high and low UPF consumers for fruit and vegetable intake, or unprocessed red meat consumption.

Discussion

Despite the participants being low-income adults living in South Africa, most participants reported either low or low-medium levels of lived poverty, and only 13.6% reported moderate to severe hunger. These findings are somewhat aligned with other findings from other studies[42,43], although since undertaking this study (data collected in 2017 and 2018), levels of lived poverty and food insecurity have worsened in South Africa[42,43]. Only 24.3% of women met the criteria for minimum dietary diversity, indicating that although they might not report high levels of hunger, the diet is not nutritionally diverse, and is lacking in micronutrients. This is

supported in that, for all components identified in the HDI-2020 to be protective for health, less than 20% of participants consumed adequate amounts. These protective foods are often costly, resulting in cheaper, more filling, and unhealthier alternatives being selected instead[7].

While most participants met the recommendations for total fat, saturated fat, and sodium intake, examining nutrient intake based on energy consumed from UPF reveals that disparities exist in the healthfulness of participants diets. Those who consumed the most UPF also consumed the most energy and dietary components that are recommended to be restricted, except for red meat where no significant difference was observed in the two groups. Numerous studies have linked high UPF consumption to poor health outcomes[44]. While we did not look at specific health outcomes, we found a clear positive gradient of association between share of energy from UPF and nutrients of concern and an inverse association between share of energy from UPF and dietary components to encourage. Consequently, the probability of meeting international dietary guidance is higher among those who are in the lowest UPF consumption quantile compared to those who are on the highest quantile of UPF consumption. Given the findings of this study, and others around the world that have found ultra-processed food intake is high, and increasing[15], it is perhaps time for the WHO to consider introducing a recommendation for UPF contribution to total energy similar to the guidelines it has developed for saturated fat or free sugar that should not exceed 10% of total dietary intake.

This study highlights the need for the South African Government to implement better strategies to protect South Africans against the proliferation of UPF, and more importantly to protect low-income South Africans who are most vulnerable to the economic shocks of poor health outcomes from undue influence towards UPF consumption. Recent studies in South Africa have found that 76% of packaged foods sold in South African supermarkets are ultra-processed[45], and that more shelf space in stores is allocated to unhealthy products than healthy products[46] leaving little room for consumers to make healthy food choices. There is a need to ensure that healthy and nutritious foods are readily available, affordable, and desirable to consumers, including low-income people, and that unhealthy UPF are less predominantly the food of choice.

A policy that the South African National Department of Health is currently considering, and could contribute to an improved food environment is mandatory front-of-package warning labels[47]. These labels inform consumers about products containing excessive amounts of nutrients of concern and can in turn be used to inform further regulations, such as marketing restrictions (e.g. barring two-for-the-price-of-one specials, promotions to win prizes, advertisements to children, etc.), restricting these products in schools, or at point-of-sale in supermarkets where consumers are more likely to make rash decisions. Such policies have already been or are soon to be implemented in Chile, Mexico, Peru, Israel, Singapore and the United Kingdom. Additionally, measures similar to the Health Promotion Levy (a tax on sugary beverages which has been found to be effective in South Africa)[48,49] could be considered for products that carry a front-of-package warning label. Revenue raised could be used to subsidise the price of healthier food choices. In the same way that unhealthy UPF should be restricted, the consumption of healthy fresh foods should be encouraged.

Limitations and assumptions

This study has a number of limitations that need to be kept in mind when interpreting the data. First, only two of the nine provinces of South Africa were included, which limits the generalisability of findings. Data from two different studies were included. Although the same methodologies, standardised training and questionnaires were used for both studies, some of the fieldworkers differed between the studies and study participants were not exactly the same. The sample size also differed significantly by area. To try and account for this, regression analysis results were adjusted for area of residence, age, sex and household income.

Second, seasonality has been found to influence dietary intake[50]. Although three seasons were included during data collection (summer and autumn in Langa and spring in Khayalitsha and Mount Frere) it is possible that results may have differed had all four seasons been included.

Third, when collecting dietary data one needs to take self-reported bias as well as social desirability bias into account. Dietary assessment was based on a single-day 24-hour recall due to the available secondary data, and did not capture intra-person day-to-day variation in intake. The distribution of intake would have been better accounted for with two or more 24-hour recalls per participant or the inclusion of a quantified food frequency questionnaire for a subset of the sample; however the large sample size of this study allows for sufficiently accurate means with a single-day recall[50]. Despite the one day of recall data likely resulting in a wider distribution of intake due to more measurement error, the rank-ordering of quartiles is still appropriate, assuming measurement error is random. The observations in the top 25th percentile would very likely be the same, even with multiple days of recall.

Fourth, there were missing values in the SAMRC FCT, particularly for total and added sugar. Thus when the SAMRC FCT was applied to the intake data, we found that 19.4% and 30.6% of food items reported consumed were missing total and added sugar values respectively. More than 50% of these missing values were UPF products and missingness was greater among UPF products than among all products. There were no missing values for energy, and five or less percent of missing values for total fat, saturated fat, sodium and fibre, and thus the degree of underestimation of intake is higher for total- and added sugar. Food groups where more than 40% of consumed products were UPF included soups, sauces, and seasonings; beverages; sugars, syrups, and sweets; and other products. These food groups tended to have higher numbers of missing values originating from UPF products than products that weren't UPF (although this varied by nutrient and food group). As such, the findings presented in this paper regarding the share of nutrients of concern to discourage are likely conservative in terms of the association between the percentage of UPF consumed and nutrient outcomes (see Appendix A and B for more details). Additionally, the SAMRC FCT does not have brand level nutritional information (nor was this captured in the 24-hour recalls). The nutritional composition of packaged UPF can differ significantly from one brand to another. However, the SAMRC FCT is the only South African specific FCT available, and thus remains the most appropriate FCT to use currently.

Fifth, assumptions needed to be made when classifying products according to the Nova food classification categories. As the secondary dietary data used for this study was not detailed, certain assumptions such as whether products were home-made or shop bought needed to be made. Although steps were put in place to limit classification errors, it is possible that some products were incorrectly classified. Little to no analysis of UPF using 24-hour recall data has been conducted in South Africa previously, so despite the limitations with the dietary data, this study provides a baseline assessment of UPF consumption amongst low-income people living in South Africa.

Conclusion

The nutrition transition is advanced and UPF consumption is prevalent amongst low-income consumers in SA. UPF contribute disproportionately to energy intake, especially amongst those with the highest UPF consumption, and these high UPF consumers consume larger amounts of nutrients associated with increased NCD risk. Compared to low UPF consumers, high UPF consumers have higher overall energy consumption, higher sodium, sugar and fat intake; and are less likely to meet WHO recommendations for nutrients to limit. Most low-income adults living in South African assessed in this study consumed insufficient protective dietary components such as fibre, legumes, fruits and vegetables, and had insufficient dietary diversity. Policy measures are urgently needed in SA to protect against the proliferation of harmful UPF, and to promote and enable the consumption of whole and less processed foods. There is an urgent need to realign the food system in South Africa and make healthy options achievable for all.

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Tables

Table 1. Global dietary recommendations assessed using the Healthy Diet Indicator 2020 (HDI-2020)

		Dietary element Elements based on HDI-2020	**Global recommendation**	**Reference source for guideline**	**Criteria for scoring** (quantitative intake in one day)	**Approach to coding and analysing data**
Dietary components to limit	1	Total fat	<30% total energy	World Health Organisation	<30% total energy	Total fat identified and calculated from 24-hr diet recall data
	2	Saturated fat	<10% total energy	World Health Organisation	<10% total energy	Saturated fat identified and calculated from 24-hr diet recall data
	3	Salt (dietary sodium)	<5g/d (<2000mg sodium/d)	World Health Organisation	<2000mg sodium	Dietary sodium identified and calculated from 24-hr diet recall data
	4a	Free (added) sugars (24-hr recall)	<10% total energy	World Health Organisation	<10% total energy	Added sugars identified and calculated from 24-hr diet recall data
	4b	Free sugars (DQ-Q)	<10% total energy	World Health Organisation	<10% total energy	Free sugars identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	5	Processed meat	"Consume very little, if any, processed meat"	World Cancer Research Fund	0g	Processed meat identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	6	Unprocessed red meat	≤350-500g/week	World Cancer Research Fund	≤71g	Unprocessed red meat identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
Dietary components to encourage	7	Fruits and vegetables	≥400g/d	World Health Organisation	≥400g	Fruits and vegetables identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	8	Beans and other legumes	"A healthy diet contains…legumes"	World Health Organisation	>0g	Beans and legumes identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	9	Nuts and seeds	"A healthy diet contains…nuts"	World Health Organisation	>0g	Nuts and seeds identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	10	Whole grains	"A healthy diet contains…whole grains"	World Health Organisation	>0g	Whole grains identified using DQ-Q criteria Amount consumed calculated from 24-hr diet recall data
	11	Dietary fibre	>25g/d	World Health Organisation	>25g	Dietary fibre identified and calculated from 24-hr diet recall data

DQ-Q: Diet quality questionnaire

Table 2. Share of total energy intake from ultra-processed foods (UPF) and prevalence of obesity according to demographic characteristics

		Panel A	Panel B	
		Distribution n (%)	Mean share of total energy intake from UPF % (SE)	P value *
Sex	Male	804 (31.89)	38.97 (0.85)	0.062
	Female	1717 (68.11)	37.09 (0.56)	
Age	18-29	1453 (57.64)	40.24 (0.62)	<0.001*
	30-39	974 (38.64)	35.36 (0.75)	
	40-50	94 (3.73)	22.28 (1.95)	
Area	Khayelitsha	191 (7.58)	29.81 (1.57)	<0.001*
	Langa	2161 (85.72)	39.52 (0.50)	
	Mount Frere	169 (6.70)	23.13 (1.68)	
Household income (per month)	<R3001	1116 (52.87)	36.64 (0.70)	0.087
	R3001-R4000	312 (14.78)	36.72 (1.31)	
	R4001-R5000	211 (10.00)	38.22 (1.74)	
	R5001-R7500	207 (9.81)	38.86 (1.58)	
	R7501-R10000	137 (6.49)	39.87 (2.11)	
	>R10000	128 (6.06)	37.93 (2.13)	
Nutritional status**	Underweight	108 (5.34)	40.90 (2.24)	0.933
	Normal weight	809 (39.97)	39.85 (0.83)	
	Overweight	466 (23.02)	38.00 (1.06)	
	Obese	325 (16.06)	37.67 (1.30)	
	Severely obese	184 (9.09)	40.12 (1.75)	
	Morbidly obese	132 (6.52)	42.10 (2.02)	
Education level	No/min formal completed	123 (4.90)	30.17 (2.13)	0.002*
	Completed primary	2042 (81.32)	37.82 (0.52)	
	Completed secondary	346 (13.78)	39.42 (1.33)	
	Completed tertiary	0 (0.00)	-	
Lived poverty	Low (<0.51)	1491 (60.51)	37.89 (0.62)	0.023
	Low-med (0.51-1.0)	598 (24.27)	39.26 (0.92)	
	High-moderate (1.1-1.5)	214 (8.69)	38.08 (1.67)	
	High (>1.5)	161 (6.53)	30.75 (1.73)	
Household hunger	Little/no hunger	2169 (86.41)	37.83 (0.51)	0.469
	Moderate hunger	324 (12.91)	36.55 (1.34)	
	Severe hunger	17 (0.68)	39.05 (6.24)	
Minimum dietary diversity for women (MDD-W)#	Achieved MDD-W	417 (24.33)	37.35 (0.91)	0.784
	Did not achieve MDD-W	1297 (75.67)	37.00 (0.69)	

*Regression analysis used to calculate P value. Level of significance assumed at P<0.05.

**Missing values are due to anthropometry measurements only being taken in Langa (sample age 18-39yrs; 2024 measurements taken)

#Minimum dietary diversity for women (MDD-W) includes only women, up to age of 49 years

Table 3. Dietary intake of males and females aged 18-50 in Langa, Khayelitsha and Mount Frere

	Female				Male				Total				P value
	Mean	SD	Median	IQR	Mean	SD	Median	IQR	Mean	SD	Median	IQR	
Energy (kJ)	7392.83	3123.21	6918.08	3894.77	8550.79	3549.63	8046.90	4332.76	7762.13	3308.87	7328.42	4074.97	<0.001*
Energy from ultra-processed food (kJ)	2873.91	2384.44	2415.70	2794.00	3464.03	2787.10	2984.65	3281.54	3062.11	2534.27	2595.88	3025.00	<0.001*
Protein (g)	57.65	29.69	52.43	35.52	67.47	34.05	62.12	40.67	60.78	31.48	55.27	36.35	<0.001*
Total Fat (g)	51.91	34.53	45.12	41.54	59.71	42.85	49.76	45.19	54.40	37.55	46.30	43.18	0.001*
Saturated fat (g)	14.90	11.54	12.34	12.01	16.79	14.24	13.28	12.60	15.50	12.49	12.54	11.97	0.005*
Monounsaturated fatty acids (g)	17.35	13.10	14.28	14.29	19.97	17.12	15.24	15.66	18.18	14.55	14.60	14.63	0.003*
Polyunsaturated fatty acids (g)	14.09	11.48	11.01	12.77	16.22	13.98	12.07	15.18	14.77	12.37	11.29	13.59	0.004*
Carbohydrate (g)	246.96	107.65	233.11	131.74	276.35	117.43	265.30	149.31	256.33	111.68	243.99	140.09	<0.001*
Total Sugar (g)[#]	62.47	46.03	53.40	58.23	64.34	49.97	56.56	63.15	64.07	47.32	54.40	58.23	0.699
Added sugar (g)[#]	23.81	31.33	16.63	35.59	20.52	31.31	4.61	31.52	22.76	31.36	14.63	34.28	<0.001*
Dietary Sodium	1534.28	1301.44	1252.68	1215.13	1825.11	1515.98	1558.64	1565.59	1627.03	1379.88	1318.66	1336.48	<0.001*
Processed meat (g)	20.57	57.04	0.00	0.00	24.91	74.47	0.00	0.00	21.95	63.15	0.00	0.00	0.905
Unprocessed red meat (g)	22.31	68.54	0.00	0.00	35.53	100.73	0.00	0.00	26.53	80.44	0.00	0.00	0.008*
Dietary Fibre (g)	16.82	10.48	14.79	11.27	18.62	11.35	16.66	12.74	17.40	10.80	15.30	11.78	<0.001*
Fruits and vegetables (g)	129.52	171.08	75.00	170.00	127.29	167.86	68.50	187.00	128.81	170.03	75.00	175.00	0.186
Beans and other legumes (g)	4.09	23.92	0.00	0.00	5.43	30.23	0.00	0.00	4.52	26.10	0.00	0.00	0.447
Nuts and seeds (g)	1.71	7.94	0.00	0.00	2.79	11.36	0.00	0.00	2.06	9.18	0.00	0.00	0.080
Whole grains (g)	29.47	99.37	0.00	0.00	23.67	88.09	0.00	0.00	27.62	95.94	0.00	0.00	0.133

*Level of significance assumed at P<0.05. Mann-Whitney U test used to analyze level of significant difference between males and females

[#]For nutrient-specific evaluations, missing values in the South African food composition table resulted in an underestimate of values, which was particularly pronounced for total and added sugar (see Appendix Tables A and B for details).

[##]Trans fats excluded from all analysis due to insufficient data in the South African food composition table

Figure 1. Distribution of the share of ultra-processed food to total energy intake

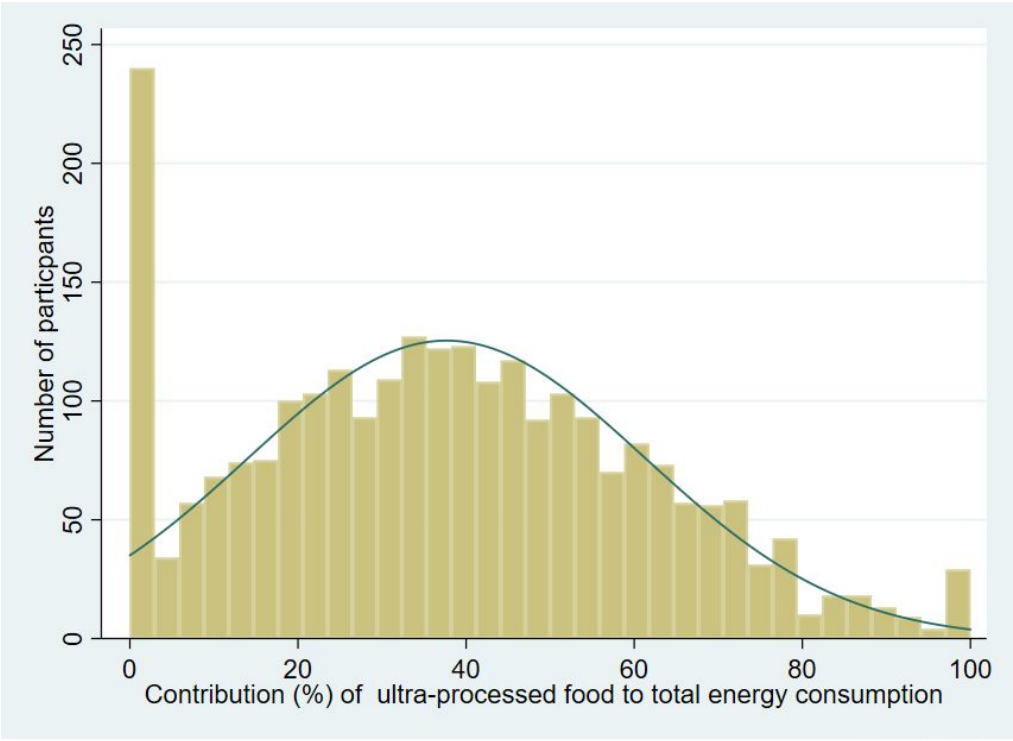

Table 4: Dietary intake by quartile of share of energy from ultra-processed food (UPF) for adults aged 18-50 years in Langa, Khayalitsha and Mount Frere

			Median (SE)				P value	Share of total energy % (SE)				P value
		N#	Q1 UPF	Q2 UPF	Q3 UPF	Q4 UPF		Q1 UPF	Q2 UPF	Q3 UPF	Q4 UPF	
Dietary components to limit	**Total Energy (kJ/day)**	2111	5605.07 (144.28)	6485.22 (127.44)	7604.26 (137.92)	10264.25 (155.25)	<0.001*	-	-	-	-	-
	Energy from UPF (kJ/day)	2111	529.87 (40.53)	1931.93 (26.70)	3281.72 (38.36)	5803.44 (105.89)	<0.001*	7.75 (0.67)	30.58 (0.69)	44.47 (0.77)	60.29 (0.88)	<0.001*
	Total fat (g/day)	2111	28.24 (1.06)	38.06 (0.98)	50.23 (0.96)	79.64 (2.09)	<0.001*	20.44 (0.46)	23.07 (0.56)	25.53 (0.39)	29.44 (0.58)	<0.001*
	Saturated fat (g/day)	2111	7.57 (0.35)	10.59 (0.31)	13.67 (0.37)	21.74 (0.65)	<0.001*	5.27 (0.15)	6.03 (0.14)	6.84 (0.16)	8.28 (0.22)	<0.001*
	Total Sugar (g/day)**	2111	31.24 (1.57)	48.16 (1.78)	63.63 (1.88)	85.94 (2.73)	<0.001*	9.15 (0.42)	13.18 (0.50)	14.66 (0.40)	14.53 (0.42)	<0.001*
	Added sugar (g/day)**	2111	6.48 (0.95)	12.82 (1.62)	12.88 (1.71)	21.34 (1.80)	0.331	1.93 (0.28)	3.23 (0.39)	2.90 (0.39)	3.36 (0.35)	0.016*
								Contribution (mg or g) per 1000kJ energy				
	Dietary Sodium (mg/day)	2111	466.87 (28.61)	1073.50 (21.27)	1584.16 (34.82)	2624.83 (57.66)	<0.001*	83.38 (5.71)	172.32 (3.27)	215.07 (4.69)	262.35 (5.89)	<0.001*
Dietary components to encourage	**Dietary Fibre (g/day)**	2111	12.00 (0.43)	14.45 (0.46)	15.74 (0.30)	19.50 (0.42)	<0.001*	2.26 (0.06)	2.20 (0.05)	2.11 (0.04)	1.89 (0.04)	<0.001*
	Fruits & Vegetables (g/day)	2111	70.85 (5.77)	75.85 (6.73)	72.85 (5.96)	70.85 (5.20)	0.098	13.47 (1.21)	12.29 (1.22)	9.74 (0.76)	7.13 (0.51)	0.004*

Quantile regression analysis performed due to non-parametric data to assess differences in intake by quartile of UPF consumption. Quartiles of UPF consumption were created based on the share of absolute energy intake that UPF accounted for. Participants were considered to be low UPF consumers if they were within the lowest quartile of UPF consumption, and high UPF consumers if they were in the highest quartile of UPF consumption.

*Adjusted for age, sex, household income and area of residence. Level of significance assumed at p<0.05.

410 participants excluded from all analysis due to missing data on household income.

**For nutrient-specific evaluations, missing values in the South African food composition table resulted in an underestimate of values, which was particularly pronounced for total and added sugar (see Appendix Tables A and B for details).

Analysis of processed meats, unprocessed red meat, beans and other legumes, nuts and seeds, and whole grains excluded from analysis due to low number of participants consuming these dietary components, and small cell counts not permitted for quantile regression.

Table 5: Using the Healthy Diet Indicator 2020 to assess the probability of low and high ultra-processed food (UPF) consumers meeting WHO- and other international dietary guidelines

					Panel A				Panel B		
		Dietary element	Criteria for scoring (quantitative intake in one day)	N#	Meets guideline		Does not meet guideline		Predicted probability of meeting guideline if low UPF consumer## % (SE)	Predicted probability of meeting guideline if high UPF consumer## % (SE)	p-value*
					n (%)	Mean (SE)	n (%)	Mean (SE)			
Dietary components to limit	1	Total fat	<30% total energy	2111	1437 (68.07)	39.44 (0.59)	674 (31.93)	85.49 (1.63)	78.59 (1.80)	52.40 (2.22)	<0.001*
	2	Saturated fat	<10% total energy	2111	1698 (80.44)	11.63 (0.17)	413 (19.56)	31.06 (0.82)	88.89 (1.38)	66.34 (2.11)	<0.001*
	3	Dietary sodium	<2000mg sodium	2111	1535 (72.71)	1001.80 (14.24)	576 (27.29)	3290.02 (66.29)	97.88 (0.61)	25.00 (1.94)	<0.001*
	4a	Free (added) sugars (24-hr recall)	<10% total energy	2111	1732 (82.05)	12.86 (0.40)	379 (17.95)	67.00 (2.05)	79.77 (1.73)	83.71 (1.67)	0.109
	4b	Free sugars (DQ-Q)	<10% total energy	2111	1209 (57.27)	22.09 (0.83)	902 (42.73)	23.24 (1.13)	79.76 (1.80)	40.35 (2.13)	<0.001*
	5	Processed meat	0g	2111	1680 (79.58)	0.00 (0.00)	431 (20.42)	103.63 (5.01)	94.21 (0.98)	60.86 (2.19)	<0.001*
	6	Unprocessed red meat	≤71g	2111	1834 (86.88)	1.96 (0.26)	277 (13.12)	189.25 (8.09)	87.72 (1.46)	84.66 (1.56)	0.156
Dietary components to encourage	7	Fruits and vegetables	≥400g	2111	148 (7.01)	589.65 (18.84)	1963 (92.99)	93.86 (2.26)	7.49 (1.19)	6.82 (1.07)	0.678
	8	Beans and other legumes	>0g	2111	98 (4.64)	99.62 (7.96)	2013 (95.36)	0.00 (0.00)	7.34 (1.16)	2.95 (0.73)	0.002*
	9	Nuts and seeds	>0g	2111	153 (7.25)	29.27 (1.65)	1958 (92.75)	0.00 (0.00)	1.46 (0.52)	12.26 (1.48)	<0.001*
	10	Whole grains	>0g	2111	329 (15.59)	167.25 (9.58)	1782 (84.41)	0.00 (0.00)	10.15 (1.31)	17.32 (1.70)	0.001*
	11	Dietary fibre	>25g	2111	396 (18.76)	34.72 (0.54)	1715 (81.24)	13.91 (0.14)	15.06 (1.56)	26.56 (1.96)	<0.001*

* Logistic regression analysis performed to calculate the probability of meeting dietary guidelines by quartile of ultra-processed food (UPF) intake. Adjusted for age, sex, household income and area of residence. Level of significance assumed at p<0.05.

410 participants excluded from all analysis due to missing data on household income. For nutrient-specific evaluations, missing values in the South African food composition table resulted in an underestimate of compliance with guidelines. This was particularly pronounced for total and added sugar (see Appendix A and B for more details).

Low UPF consumers are those with the lowest quartile of UPF consumption, and high UPF consumers are those with the highest quartile of UPF consumption

4.2 Manuscript two

Title: Frank T., Thow A.M., Ng S.W., Ostrowski J., Bopape M, Swart E.C. 2021. A fit-for-purpose nutrient profiling model to underpin food and nutrition policies in South Africa. Nutrients, 13, 2584. doi: 10.3390/nu13082584

What is already known?

- There are numerous NPMs in existence, which are used to identify various types of foods (such as unhealthy or healthy foods), and they are used to underpin different food policies around the world.
- There has been an NPM tested in South Africa and proposed through draft regulation R429/2014 for use in South Africa, specifically for the purpose of identifying foods that may carry health and nutrition claims.
- South Africa is facing an obesity and NCD crisis, and levels of consumption of unhealthy UPPs are increasing.

What are the new contributions from this study?

- This study provides the first comprehensive evaluation of the nutritional composition of packaged foods in South Africa, finding that 75.6 % of all packaged foods included in this study are ultra-processed, suggesting an oversupply of UPPs in the South African marketplace.
- This study follows an evidence-informed approach to develop a new NPM that identifies products high in nutrients of concern to limit (saturated fat, sugar, sodium and non-sugar sweetener); that is context-specific and suitable for use to underpin restrictive food policies in South Africa.

How might this study affect research, practice or policy?

- This research (together with manuscript three) was presented to the South African National Department of Health, and at their request, it was also presented at a webinar the Department held for the South African public (predominately researchers, food and beverage industry and health advocacy partners) in 2021. At this webinar the National Department of Health

indicated that they have been reviewing existing draft regulations in order to update and finalise regulations that will include front-of-pack labelling regulations.

- Besides being used for front-of-package warning label regulations, this NPM, that is easy-to-implement and suitable for the resource limited context of South Africa has the potential to underpin further restrictive food policies in South Africa, such as marketing restrictions, restrictions in the school food environment, and taxation of unhealthy snack foods. To this end, I (together with fellow researchers) have made a public oral submission to the South African Department of Communications and Digital Technologies on the *white paper on audio and audio-visual content services policy framework* (Department of Communications and Digital Technologies, 2020) proposing that this NPM be used to identify unhealthy products that should be restricted from child-directed marketing.
- This NPM can be used by other researchers in South Africa as a practical manner to identify unhealthy packaged foods, which they may want to evaluate for various purposes. It is currently being used in three ongoing research projects to identify unhealthy snack foods, identify unhealthy products that are being marketing through social media, and unhealthy breakfast cereal that have on-package marketing in South Africa.

Contribution of the candidate: Together with input from my supervisors (A.M.T., S.W.N., and E.C.S.) I conceptualized the study, and methodology for the study. I carried out data management and data cleaning, together with the assistance of one co-author (J.O.). I conducted data analysis, which was reviewed by my supervisors (A.M.T. and S.W.N., and E.C.S.). I wrote the draft manuscript, and supervisors and co-authors contributed to reviewing the manuscript (A.M.T., S.W.N., J.O., M.P., and E.C.S.). I addressed reviewer comments, and supervisors and co-authors reviewed answers (A.M.T., S.W.N., J.O., and E.C.S.). Supervisors provided overall guidance to the project (A.M.T., S.W.N., and E.C.S.). Additionally, primary data collection used as the data source in this manuscript was conducted by E.C.S., with myself as the project coordinator.

Please refer to Appendix 5.1: Reviewer comments and responses to manuscript for reviewer comments and author feedback; and to Appendix 6.2: Manuscript two supplementary material for supplementary material published alongside the manuscript.

nutrients

MDPI

Article

A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa

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Abstract: South Africa (SA) is facing a rising prevalence of obesity and diet-related chronic diseases. The government is seeking to develop effective, evidence-based policy measures to address this. A well-designed, fit-for-purpose nutrient profiling model (NPM) can aid policy development. The aim of this study was to develop a fit-for-purpose NPM in SA. Steps included: (1) determining the purpose and target population; (2) selecting appropriate nutrients and other food components to include; (3) selecting a suitable NPM type, criteria and base; and (4) selecting appropriate numbers and thresholds. As part of the evaluation, the nutritional composition of packaged foods containing nutritional information (n = 6747) in the SA food supply chain was analyzed, a literature review was undertaken and various NPMs were evaluated. Our findings indicated that it is most appropriate to adapt an NPM and underpin regulation with a restrictive NPM that limits unhealthy food components. The Chile 2019 NPM was identified as suitable to adapt, and total sugar, saturated fat, sodium and non-sugar sweetener were identified as appropriate to restrict. This NPM has the potential to underpin restrictive policies, such as front-of-package labelling and child-directed marketing regulations in SA. These policies will support the fight against obesity and NCDs in the country.

Keywords: nutrient profiling; South Africa; LMIC; food policy

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1. Introduction

There is global consensus that better policies are needed to address the obesity pandemic [1,2]. Comprehensive, operationalizable and solidly designed food policies have the capacity to substantially improve diets at a local, national and international level. These benefits are not only for a select few, but also reach disadvantaged, lower socioeconomic groups [3]. Underpinning various country-level food policies with one well-designed nutrient profiling model (NPM) can support good regulatory practice and a consistent regulatory approach through providing a transparent basis on which to distinguish healthier and less healthy foods for policy application [4]. NPMs developed together with industry are more lenient and permit more foods than those grounded with scientific evidence [5], resulting in little progress, if any, in addressing rising rates of malnutrition in all its forms and NCDs. As such, the development of an NPM should be independent of industry involvement.

There are a range of policy measures that can benefit from an NPM as their foundation. These include policies and regulations on front-of-package labelling, marketing to children, school food guidelines, health and nutrition claims on foodstuff, food taxation, food fortification, food procurement in hospitals, prisons and old age homes and the informing of welfare support schemes [6]. Several countries have introduced mandatory food policies that make use of NPMs. For instance, Chile has used the same NPM to effectively restrict foods that have front-of-pack (FOP) warning labels from being sold or eaten on or near school grounds, and to prohibit marketing of foods carrying an FOP label [7].

1.1. The Need for Evidence-Based Restrictive Food Policies in South Africa

SA has undergone a transition from infective to non-communicable diseases [8] and South Africans are consuming more and more harmful, ultra-processed foods high in fats, sugar and salt [9]. Given this, the SA government has identified the need to implement policies and practices to prevent and control obesity [10]. Indeed, the current COVID-19 pandemic, with poorer prognosis and higher mortality rates linked to obesity and NCDs [11] has highlighted the strain that obesity places on the healthcare system [12].

The active SA food labelling regulation, R146, was implemented in 2010 [13]. Following this, in 2014, a draft regulation, R429, was published [14] that makes recommendations for an NPM for health and nutrition claims (hereafter referred to as the SA HNC NPM). In June 2016, SA implemented mandatory upper sodium limits in various processed food categories [15]. Regulation 127 of 2011, for trans-fats, prohibits foods that contain more than 2 g of trans-fat per 100 g of oil or fat [16]. These actions suggest that there is recognition of the potential harms associated with certain ingredients or amounts of nutrients in SA and a need to restrict them.

There is a need for strong policies to promote health and prevent non-communicable diseases (NCDs) in low- and middle-income countries (LMICs) [17]. A transparent, evidence-based approach without industry interference should be followed in their development [17,18]. In SA, powerful commercial actors have been shown to influence health policy formulation processes to favor their interests over those of the public's health and pockets [19–22]. As such, an independently developed NPM may support the government to develop a strong policy.

1.2. Considerations for a Fit-for-Purpose NPM to Underpin Restrictive Food Policy in SA

Different NPMs vary significantly in purpose and complexity, so it is of utmost importance that policymakers consider the purpose and operationalizability of the model they intend to implement, in order to select a model that will achieve the intended purpose [6,23]. Implementation of policy related to NPMs has been slow in LMICs, possibly due to limited resources and a lack of population level nutritional data that are required to inform the development of NPMs within these countries [17,24,25]. Additionally, the LMIC setting faces a number of challenges in the food policy arena, including struggles with multi-sectoral collaboration, implementation of proposed policies and the ability to follow through with long-term commitment to policy goals [26].

According to a 2018 systematic review of all NPMs used in government regulation globally (78 models worldwide), only one NPM has been developed for Africa [6]. This is the SA HNC NPM, included in the draft R429 of 2014 for the purpose of regulating health and nutrition claims. It has also been validated for use in child-directed marketing restrictions [27,28]. This model is based on the Food Standards Australia/New Zealand's (FSANZ) NPM, which in turn was adapted from the UK Ofcom NPM [29], and thus originally designed for high-income countries. Since then, the World Health Organization (WHO) African Region has proposed an NPM [30], although it has yet to be implemented by any country.

A single fit-for-purpose NPM that can be used to ground various restrictive food policies in SA is an ideal starting point for regulating the processed food environment and will ensure a consistent message for the public and the food industry. Using one NPM in

various policies can also reduce administrative burden [4]. If regulations are to be put in place, they need to be easy to implement, require limited resources to enforce and they must not be costly. The objective of this paper is to identify a suitable, context-specific NPM for food policy in SA, using an established step-wise approach.

The LMIC setting of SA offers a diverse and challenging context. It is important that an independent, robust approach following accepted scientific process is used to develop a feasible, context-specific NPM [17,31–33]. This paper contributes to existing scientific research on NPMs by investigating the various aspects to consider when developing a fit-for-purpose NPM for restrictive food policies in SA, which has the potential to influence food policy in South Africa, and more broadly, other LMICs in Africa.

2. Materials and Methods

For this paper, the NPM development process was informed by the internationally accepted seven-step approach developed by Scarborough, Rayner and Stockley [32] and the six steps recommended for NPM development or adaptation in the WHO draft guidelines on front-of-pack labelling (FOPL) [33]. Although this is presented as a step-wise process, these steps are practically interrelated and interdependent and decisions made in one step affect the decisions in other steps [34]. Steps will be discussed in combination under these broad headings:

1. Determining the purpose, and target population of the NPM;
2. Selecting appropriate nutrients and other food components to include;
3. Selecting a suitable NPM type, criteria and base;
4. Selecting appropriate numbers and thresholds.

The decisions are informed by a combination of location-specific primary research, as well as lessons learnt through existing literature. Where literature was reviewed, the authors used narrative literature review methodology to identify appropriate, targeted literature. Taking the resource limitations of the country into account, provisions for straightforward classification, implementation and evaluation were considered at each step.

2.1. Data

Primary data collection was necessary to evaluate the composition of packaged foods in SA. Nutritional information on packaged foods and beverages (n = 6747) with nutrition information panels (NIP) was collected photographically by trained fieldworkers from large supermarkets in SA (Pick 'n Pay, Woolworths, Checkers, Spar and Shoprite) in 2018. Products that did not contain an NIP were excluded from analysis (Supplementary Tables S1 and S2 and Supplementary Figure S1 contain detailed methodological information). These data were used to calculate the mean nutritional content of various nutrients of concern. For non-sugar sweetener (NSS) specifically, where the mean content could not be calculated (as data are not provided), the number of different NSS's was assessed by identifying NSS in the ingredient list using a standardized list of search terms (Supplementary Table S3).

2.2. Steps in NPM Development

2.2.1. Step 1: Determining the Purpose and Target Population of the NPM

To determine the purpose and target population, we reviewed relevant population level data [35–41] and the policy context to identify the key nutritional problems faced by the SA population. We researched existing literature to identify the target population, their disease burden and dietary intake patterns to select the most appropriate NPM. We also reviewed strategic plans and dietary guidelines developed by the SA Department of Health to gain insights into the nutrition problems identified by the government for the population as a whole.

To assess the level of processing in South African packaged foods, collected data were evaluated by making use of the NOVA classification system as described elsewhere [42,43].

2.2.2. Step 2: Deciding Which Nutrients and Other Food Components to Include

Making use of literature review, whilst considering the purpose of the NPM and risk profile of the target population, international dietary guidelines and nutrients and food components considered for inclusion in the NPM were reviewed to identify those most appropriate to include.

As current draft regulations [14] in SA make use of an NPM that includes nutrients of concern to both encourage and limit, in this study we compared differences between an NPM that only considers unhealthy nutrients of concern to restrict, and one that includes both healthy and unhealthy components by applying their criteria to the SA packaged food supply (n = 6747). The Chile Warning Octagon (CWO) 2019 was selected as it assesses nutrients of concern linked only to poor health outcomes (sugar, sodium, saturated fat and energy) that need to be restricted through food policy. A number of studies indicate its success in Chile [44–48], and other countries have used Chile's NPM [49,50]. The SA HNC NPM assessed health and nutrition claims in draft SA regulation [14] and was adopted from Food Standards Australia and New Zealand's (FSANZ) NPM (which relied on the UK Ofcom NPM in its development [29]). To determine the difference between the SA HNC NPM baseline score (which is the score solely for 'nutrients to limit'—sugar, sodium, saturated fat and energy) and the final SA HNC NPM score (which includes points for fiber, protein, fruits, vegetables, nuts and legumes as 'nutrients to encourage'), we evaluated the baseline and final SA HNC NPM separately, alongside the CWO 2019 NPM.

Algorithms were generated in STATA (version 15, StataCorp, College Station, TX, USA) to evaluate the packaged food supply against these NPMs. We classified foods and beverages as either compliant or non-compliant, depending on the nutritional criteria of the NPM. For the SA HNC NPM, a product was considered compliant when it met the criterion of being allowed to carry a health claim (for beverages a score of less than 1, for processed cheese and fats a score of less than 28 and for other foods a score of less than 4). Similarly, for the SA baseline HNC NPM, a product was considered compliant when it met the criterion of being allowed to carry a health claim—but for this model, points were not awarded for 'nutrients to encourage'. For the CWO 2019 NPM, a product was considered compliant when it was excluded from carrying a warning label according to the 2019 criteria (it did not exceed any of the model's limits for energy, sugar, sodium or saturated fat).

A fruits, vegetables, nuts and legumes (FVNL) score needed to be calculated for the SA HNC NPM. As the percentage of fruits and vegetables is not routinely included on the NIP in SA, we manually estimated scores. A similar methodology, as described by Bernstein et al. [51], was followed for the calculations. An FVNL score of 0 was assigned to sub-categories without FVNLs (e.g., fats and oils). For groups which may contain FVNLs, products were individually reviewed within the context of its group. We considered the order of ingredients, the form of the FVNL ingredients (concentrated or non-concentrated), number of FVNL ingredients compared to the number of non-FVNL ingredients and type of product in order to determine the score. A dietitian performed all classifications.

To consider nutrients of concern within packaged foods in SA, we divided the packaged food supply into sub-categories and the mean content of nutrients of concern was calculated. Most of this information was available from the NIP, however, free sugar content of products was estimated according to the method proposed by the Pan American Health Organization (PAHO) [52] when not available on the NIP. To evaluate the suitability of the inclusion of energy in the NPM products excessive in energy only (and not sugar, saturated fat or sodium), the CWO 2019 NPM was utilized.

2.2.3. Step 3: Selection of a Suitable NPM Type, Criteria and Base

To inform the selection of the NPM type, we used the approach described by Rayner, Scarborough and Stockley [31,32] to decide on the base unit of measure, whether to make use of a categorical or continuous model, as well as whether to select across-the-board thresholds or category-specific criteria.

The criteria underpinning an NPM can be applied across all foods, ('across-the-board') or alternatively, it can differentiate between food categories, allowing either comparison across different food categories or comparison within food categories ('category-specific') [53]. Models can be either threshold-based or continuous [32]. Threshold-based NPMs identify predetermined cut-points that will place food into different categories in a binary manner. Different cut-points can be used for different nutrients in one food (e.g., a different cut-point each for sugar, sodium and saturated fat). With a continuous model, foods are classified on a continuous scale, ranking nutritionally better, or worse, than another product. Points are awarded based on different criteria for various nutrients and a summative healthfulness score is calculated from this, depending on the NPM's criteria [31].

To inform the decision, we conducted a review of the literature, examining the pros and cons of various approaches, whilst taking the LMIC context of SA into consideration.

2.2.4. Step 4: Choosing the Thresholds to Use

In order to decide whether to use the same cut-points as an existing NPM, or to adapt them for SA, we followed the same methodological approach as that described in the Chilean paper [54] for the development of cut-points. For the SA list of foods, two dietitians analyzed the SA Medical Research Council Food Composition Table (FCT) [55] independently of each other. Any discrepancies in classification were resolved in a group discussion with a third dietitian. All three dietitians were in agreement about the final list of foods included. As the SA FCT is not as comprehensive as the USDA FCT, the final list of foods was shorter, at 183 foods.

3. Results

3.1. The Purpose and Target Population of the NPM

South Africans are consuming more and more harmful, ultra-processed foods [9,56] that are linked to NCDs [57]. This is clear from the analysis of the packaged food supply in SA (Figure 1 and Supplementary Table S4). In 2018, 83% of packaged products evaluated in SA supermarkets (89% of foods and 61% of beverages) were either processed or ultra-processed, according to the NOVA classification [42,43].

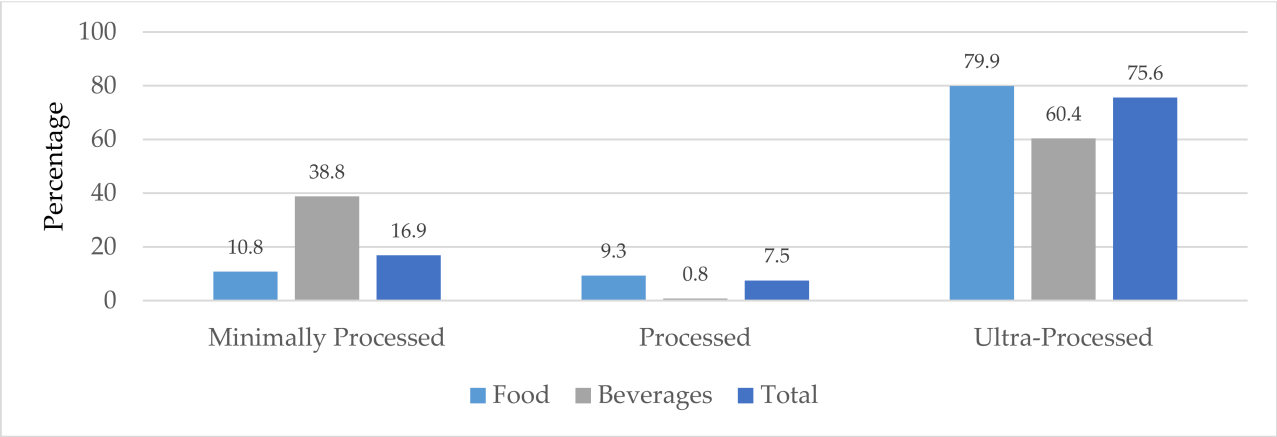

Figure 1. Packaged foods and beverages in the SA marketplace (2018) classified as minimally processed, processed and ultra-processed, according to the NOVA classification system. Note: the NOVA category, 'culinary ingredients' has been omitted from analysis.

The NCD mortality rate has steadily increased and NCDs are the main cause of death in SA [58]. The 2016 SA Demographic and Health Survey (SADHS) reported that overweight, obesity and hypertension prevalence have been on the rise since 1998, with 31% of men and 68% of women overweight or obese [35]. A recent report by the World Obesity Federation anticipates that SA is likely to have the 10th highest level of childhood

obesity in the world by 2030, with approximately 28% of children aged 5 to 19 obese in 2030 [36].

Additionally, a review of all adult dietary studies done in SA between 2000 and 2015 found that there is still a high prevalence of micronutrient deficiencies. High food prices and limited availability of nutrient-dense foods in townships and poorer urban centers are thought to be contributing factors [37]. A predominantly carbohydrate-based diet with low nutrient density is common in SA [38–41].

The nutrition policy priorities in SA are clearly articulated in the National Department of Health's Strategy for the Prevention and Control of Obesity in SA 2015–2020: 'create an enabling environment that supports the availability and accessibility of healthy food choices in various settings'. It highlights the need for the development of norms and standards on sugar and fat content of ultra-processed foods and also notes the importance of FOPL and consideration of ethical marketing of food to children [10]. Currently, draft regulation [14] in SA includes an NPM to assess health and nutrition claims, but no NPM has been developed for SA to use in restrictive food policies, such as FOPL and marketing to children.

Although those at risk for developing NCDs and children (with rapidly increasing obesity prevalence) will benefit most from the potential restrictive food policies that the NPM can underpin, these food policies are broadly applicable across different population groups and age groups. Due to heterogeneity in nutritional requirements across different life stages, it is recommended that adult dietary guidelines be used to guide NPM criteria [33]. The only age group excluded from NPMs is children below the age of six months, where exclusive breastfeeding is recommended and protected by existing regulation in SA [59].

Recommendation

The purpose of the NPM should be to identify unhealthy, processed packaged foods that result in poor health outcomes. The appropriate target population for the NPM is all adults and children above the age of six months.

3.2. Nutrients and Other Food Components to Include

Literature review indicated that countries implementing regulations (with mandatory NPM applications) have predominately focused on negative nutrients of concern linked to poor health outcomes, which they restrict through policies such as FOPL, marketing restrictions and regulations in the school environment [18]. This is because generally, using an NPM that includes both 'nutrients to limit' (such as salt, sugar and saturated fat which are harmful to health) and 'nutrients to encourage' (such as fiber, fruit and vegetables, nuts and legumes which are beneficial to health), in a restrictive regulatory environment is limited and becomes complicated to implement. To date, only Israel has added another, positive FOPL in the form of a green logo for healthy, minimally processed foods [60] that do not contradict their warning labels.

From the results in Figure 2 and Table 1, it is apparent that the additional points awarded for 'nutrients to encourage' in the final SA HNC NPM give rise to a more lenient score than the initial SA HNC NPM baseline score, which only includes 'nutrients to limit', resulting in more compliant products in all categories, except for sodas, where it does not change. These results highlight the leniency that 'nutrients to encourage' introduces into the final score of an NPM. Of the models included in this study, the most lenient model was the SA HNC NPM, with 47% of foodstuffs compliant, and the SA HCN Baseline model was the strictest, with 19% compliance.

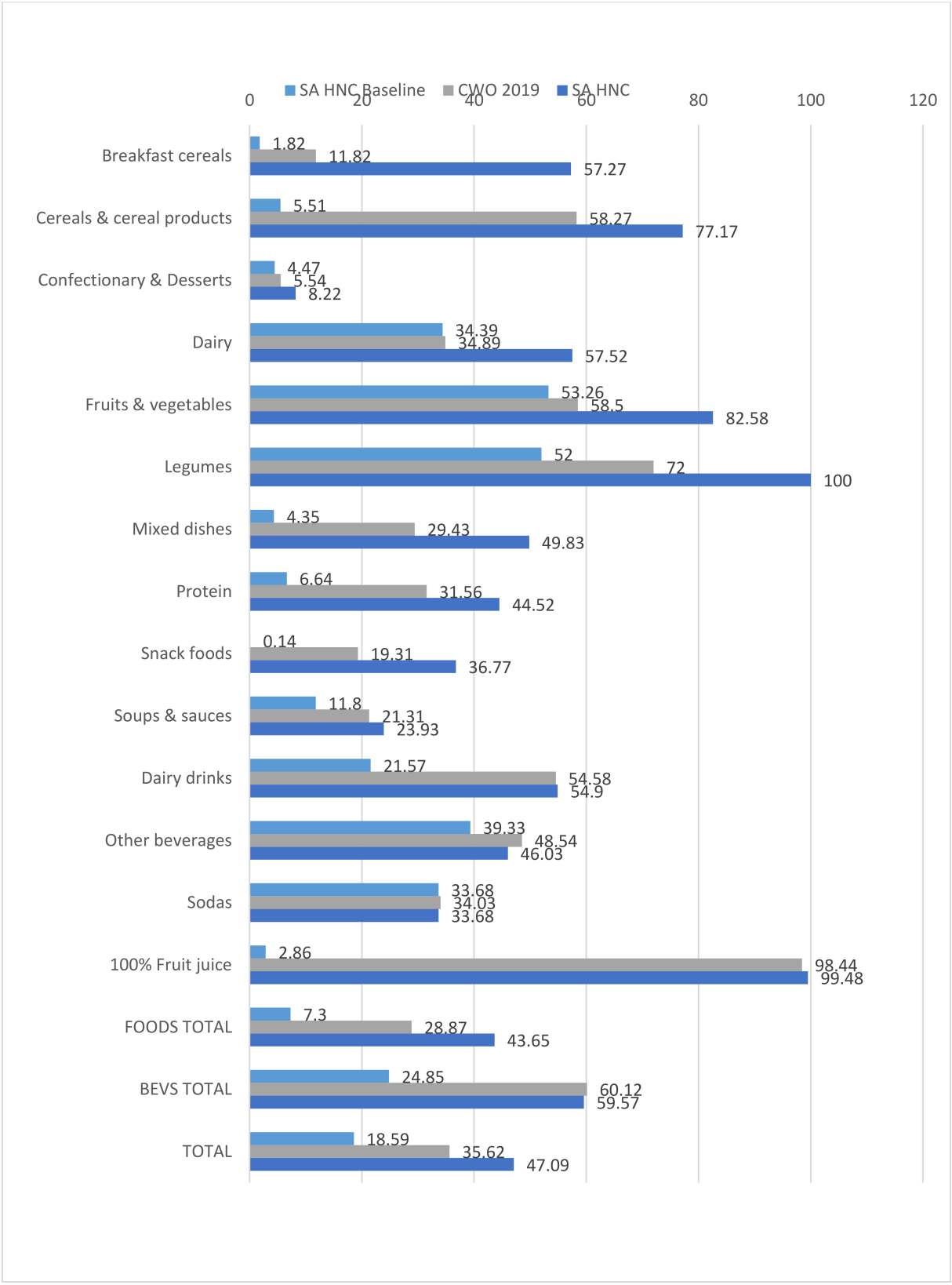

Figure 2. Proportion of SA packaged food and beverage products compliant with the SA HNC, SA HNC baseline and CWO 2019 NPM criteria by groups.

Table 1. Qualitative table reflecting how the addition of 'nutrients to encourage' affects NPM leniency, in terms of the proportion of products compliant (i.e., that fall beneath the thresholds and are not deemed 'unhealthy').

	Highlighted Food Categories	SA HNC Baseline (Only 'Nutrients to Limit'	CWO 2019 (Only 'Nutrients to Limit')	SA HNC (Nutrients to Limit and Encourage)
Categories where the addition of 'nutrients to encourage' may potentially be beneficial	Dairy Drinks	21.57% compliant with criteria	54.6% compliant with criteria	54.9% compliant with criteria
	In this category one would want to mitigate the effects of lactose, a carbohydrate naturally present in milk, which contributes to the total sugar score. Here the addition of 'nutrients to encourage' potentially assists; although given the differences in algorithms, the CWO criteria (which only includes 'nutrients to limit') has a similar compliance level.			
Categories where the addition of 'nutrients to encourage' allows for a more lenient score	Breakfast cereals	1.8% compliant with criteria	11.8% compliant with criteria	57.3% compliant with criteria
	Dairy (food)	34.39%	34.89%	57.52%
	Fruits and vegetables	53.26	58.5%	82.58%
	Legumes	52%	72%	100%
	These categories highlight where the more lenient score of the SA HNC NPM causes contestation due to the addition of protein, fiber, FVNL (fruit, vegetables, nuts and legumes) points. In all of these categories the SA HNC NPM scored at least 23% higher than for the CWO 2019. Although these foods may include healthy components, the impact of undesirable ingredients cannot be negated by 'nutrients to encourage'. Most of the fruits, vegetables and legumes that are restricted by the CWO 2019 contain high levels of sugar or sodium. The significant change in compliance due to the addition of 'nutrients to encourage' is seen in the difference in scores between the baseline and final SA HNC NPM.			
Categories that are strict regardless of nutrients to encourage or limit	Confectionery & Dessert	4.47%	5.54%	8.22%
	Soda	33.68%	34.03%	33.68%
	These categories contain a large number of unhealthy products that are linked to poor health outcomes. Even when 'nutrients to encourage' are added, they score poorly across different NPMs. The addition of 'nutrients to encourage' does not result in a more lenient score.			

A review of the literature indicates that trans-fat, saturated fat, added or free sugar and sodium are harmful to health, and contribute to the obesity and NCD epidemic [61–66]. According to a review of NPMs used in government-led nutrition policies, all NPMs ($n = 78$) included 'nutrients to limit'. The most common nutrients of concern identified in these NPMs were sodium, saturated fat and total sugar [6]. Table 2 provides the mean nutrient content of unhealthy nutrients of concern in packaged foods in SA.

3.2.1. Sugar

International guidelines recommend the restriction of free or added sugar (rather than total sugar) as this is the sugar that is harmful to health [67]. Please refer to Supplementary Table S5 for the definitions of sugar used in this paper. Intrinsic sugar is not believed to be as harmful as free sugar [67]. These differences can be seen in Table 2 for the dairy and fruit categories, where the total and free sugar content differ significantly due to the high intrinsic sugar levels.

WHO dietary guidelines recommend that a maximum of 10% of daily energy should be derived from total sugar and 5% from free sugar [67]. Based on a reference energy intake of 8400 kJ (or 2000 kCal) per day, this equates to 1 g of total sugar per 168 kJ and 1 g of free sugar per 336 kJ consumed in a day. As the average energy content per 100 g of foods in this sample is 1072.8 kJ (see Table 2 above), in order to align with WHO dietary guidelines, total sugar should ideally be below 6.4 g/100 g and free sugar should be below 3.2 g/100 g. Similarly, for beverages (with an average energy content of 160.7 kJ/100 mL), total sugar should be below 1 g/100 mL and free sugar below 0.5 g/100 mL. However, the sugar content of foods in this sample far exceeds the sugar recommendations in the WHO dietary guidelines, as 21.2% of energy (13.4 g/100 g) is attributed to total sugar and 18.4% (11.6 g/100 g) to free sugar. Although beverages contain less sugar per 100 mL than foods, sugar contributes most of the energy in beverages, at 76.2% (7.2 g/100 mL) and 54.0% (5.1 g/100 mL), respectively, for total and free sugar.

Table 2. Mean content of nutrients of concern in packaged foods in SA per 100 g (2018).

	Energy (kJ)	Total Sugar (g)	Free Sugar (g)	Total Fat (g)	Saturated Fat (g)	Trans Fat (g)	Sodium (mg)	Contains NSS *n* (%)
Breakfast cereals *n* = 110	1588.2	17.2	16.3	8.9	2.9	0.03	210.6	0 (0)
Cereals & cereal products *n* = 254	989.9	3.1	3.2	6.1	2.4	0.11	338.5	8 (3.2)
Confectionary & dessert *n* = 1119	1559.8	38.4	35.1	14.0	7.7	0.12	142.5	143 (12.8)
Dairy *n* = 791	766.5	6.4	3.5	12.6	8.8	0.33	322.1	70 (8.9)
Fruits & vegetables *n* = 196	677.4	29.8	15.2	2.1	1.2	0.02	41.9	0 (0)
Vegetables *n* = 510	315.9	3.3	3.3	3.6	0.7	0.03	392.6	5 (1.0)
Legumes *n* = 100	342.7	2.1	2.1	0.8	0.2	0.03	290.3	0 (0)
Mixed dishes *n* = 299	813.0	3.3	3.2	9.3	4.0	0.17	429.2	10 (3.3)
Protein *n* = 602	787.4	1.4	1.4	9.9	3.5	0.13	826.0	18 (3.0)
Snack foods *n* = 699	2059.4	6.8	6.1	27.9	7.7	0.06	476.8	58 (8.3)
Soups & sauces *n* = 610	676.1	9.7	9.6	11.2	2.2	0.07	746.3	35 (5.9)
Food total *n* = 5290	1072.8	13.4	11.6	12.4	5.1	0.12	411.2	347 (6.6)
Dairy drinks *n* = 306	255.1	6.0	4.9	1.8	1.1	0.07	43.3	58 (19.0)
Other beverages *n* = 478	116.7	5.8	4.0	0.1	0.08	0.004	13.4	213 (44.6)
Sodas *n* = 288	125.1	6.9	6.9	0.04	0.02	0.01	18.6	160 (55.6)
100% fruit juice *n* = 385	190.0	10.4	6.0	0.05	0.02	0.0	9.5	1 (0.3)
Beverage total *n* = 1457	160.7	7.2	5.1	0.45	0.3	0.01	19.7	432 (29.6)
Food & beverage total *n* = 6747	875.7	12.1	10.7	9.8	4.1	0.09	326.6	779 (11.5)

As the chemical structure of free (or added) sugar is the same as total sugar they cannot be differentiated objectively through laboratory tests [68]. One could require manufacturers to report the added sugar on the NIP (as in the USA), although this is reliant on the manufacturer being trustworthy about the recipe composition. Alternatively, the approximate amount of free or added sugars in foods can be calculated [52,69]. However, this approach requires assumptions to be made, is time-consuming and open to misinterpretation. In the resource-limited LMIC setting, this is not a suitable method to use. The total and added sugar challenge is not new. When the UK Office of Communications (Ofcom) NPM was being developed, added sugar was proposed, but due to the technical difficulties involved in analyzing added sugars, total sugar was selected instead [70]. Numerous other countries, including Chile [7], Israel [50] and Peru [49], have opted to use total sugar in their regulations.

In order to work around this, Chile recommends applying the total sugar cut-point of the NPM only to those foods that have added sugar, salt or saturated fat [54]. This is to prevent foods such as fresh fruit from receiving a classification of 'high in sugar' (as one would not want to accidentally restrict a healthy product, such as fresh fruit, through the application of an NPM). However, this allows 100% fruit juice to 'pass' the CWO 2019 NPM criteria as it is considered free, but not added, sugar (see Table 3 below in which 99 percent of 100% fruit juices are compliant with the CWO 2019 sugar criteria).

Table 3. Number of packaged SA products that would be regulated by the CWO 2019 NPM criteria (overall, for sugar, sodium, saturated fat and energy).

	Number Regulated (Overall)	Number Regulated for Sugar	Number Regulated for Sodium	Number Regulated for Saturated Fat	Number Regulated for Energy	Number Regulated for Only Energy
Breakfast cereals *n* = 110	97	74	16	31	94	11
Cereals & cereal products *n* = 254	106	1	71	34	47	10
Confectionary & dessert *n* = 1119	1057	997	83	600	912	12
Dairy *n* = 791	515	262	246	56	74	3
Fruits & vegetables *n* = 706	293	129	163	13	29	8
Legumes *n* = 100	28	0	28	0	3	0
Mixed dishes *n* = 299	211	14	177	113	36	3
Protein *n* = 602	412	6	390	88	88	3
Snack foods *n* = 699	564	95	388	394	552	35
Soups & sauces *n* = 610	480	206	416	106	244	12
Food total *n* = 5290	3763	1784	1978	1435	2079	97
Dairy drinks *n* = 306	139	135	4	0	39	1
Other beverages *n* = 478	246	243	1	0	3	2
Sodas *n* = 288	190	190	0	0	2	0
100% juice *n* = 385	6	3	3	0	0	0
Beverage total *n* = 1457	581	571	8	0	44	3
Food & beverage total *n* = 6747	4344	2355	1986	1435	2123	100

This is of some concern, as long-term overconsumption of fructose (the sugar found in fruit juice) may result in cardiovascular and metabolic diseases [71] as well as increased all-cause mortality risk [72]. It has been argued that efforts to reduce sugar consumption need to be extended to 100% fruit juice [72]. In 2019, the Indian Academy of Pediatrics recommended fruit juice should not be given to infants and young children below the age of two years, and that very limited amounts should be given to older children [73].

Given the difficulties of measuring added or free sugar, it is recommended that SA make use of total sugar in the NPM. However, unlike Chile, where added sugar is used as a qualifying criterion, it is recommended that the SA NPM use free sugar—including any form of fruit juice concentrate (e.g., pulp)—rather than added sugar in the qualifying criteria.

3.2.2. Fat

Consideration should be given to total fat, saturated fat and trans-fat.

Total Fat: The WHO recommends an intake of between 15 and 30% of total energy from fat [74]. Recently, the US dietary guidelines removed total fat as a nutrient of concern to focus instead on unhealthy saturated fats [75].

Total fat has not been identified as appropriate to include in this NPM because fat is not harmful to health per se. Indeed, certain components, such as mono- and polyunsaturated fatty acids are beneficial to health and provide protection against certain NCDs, such as cardiovascular disease [76–79].

Saturated fat: The WHO recommends that less than 10% of the total daily energy intake should be from saturated fats [80]. The Codex Alimentarius non-communicable disease guidelines for saturated fat (NRV-NCD) recommend that saturated fatty acid intake should not exceed 20 g/day, based on a reference energy intake of 8400 kJ (or 2000 kCal) [81].

The Heart and Stroke Foundation SA, as well as international organizations such as the American Heart Association and Heart UK, recommend limiting saturated fat intake due to the risk of elevated cholesterol levels and the increased risk of heart disease. As saturated fat is known to be harmful to health [76–78], it is recommended that it should be included in the NPM.

Trans-fat: In line with WHO recommendations, SA implemented a regulation on trans-fat, R127, in 2011 [16]. The WHO guideline recommends that less than 1% of the total energy intake be derived from trans-fat [80]. The R127 effectively deals with trans-fats and prohibits foods sold in SA to have more than 2 g of trans-fat per 100 g of fats and oils. The analysis of the mean trans-fat content of packaged foods in SA (Table 2) indicates that the mean trans-fat level is 0.09 g, which is below 1 g per 100 g. Thus, it is unnecessary for the NPM in SA to include trans-fat as the country has already effectively dealt with this harmful nutrient through regulation R127 of 2011.

3.2.3. Sodium

Salt should be restricted to less than 5 g per day, and sodium to less than 2 g per day according to WHO Guidelines [82]. Codex Alimentarius recommends that sodium intake should not exceed 2000 mg per day, based on a reference energy intake of 8400 kJ (or 2000 kCal) to prevent NCDs. This translates to 1 mg per 4.18 kJ [81]. SA introduced sodium regulations (R214/2013 [15]) in two phases, from 2016 to 2019. The intended purpose of this regulation is to reduce sodium levels in foods with the aim to reduce hypertension, and is category specific and does not target all foods [83].

As the mean energy content in SA packaged foods (Table 2) is 1072.8 kJ/100 g, one would expect the sodium content to be below 258 mg/100 g to align with recommended dietary intake [81,82]. However, the mean sodium content is high, at 411 mg/100 g. There are four food categories: mixed dishes; protein; snack foods; and soups and sauces, which remain particularly high in sodium. Unlike the trans-fat regulations, which adequately address trans-fat by virtually removing it from the SA market, sodium needs to be included in the NPM as certain products have excessive quantities of sodium.

3.2.4. Energy

Although Chile [7] and the WHO African Region [30] have opted to include energy as a criterion in their NPMs, it is postulated that packaged and processed foods high in energy are also high in sugar, saturated fat and/or sodium. Further, there is an expectation that by including criteria for sugar, saturated fat and sodium, most foods high in energy will be addressed.

This was found to be true when applying the thresholds for the CWO 2019 NPM to the SA packaged food supply (Table 3). Very few products were excessive only in energy. Of the 4344 products regulated, only 100 products (or 2.3%) were above the cut-off for energy, but no other nutrient. The other 97.7% of products were regulated for sugar, sodium and/or saturated fat. This is in line with Camacho and Ruppel [84] who argue that by focusing on the calorie balance (total energy) in policies, one gives the food industry a convenient exit strategy so that they can avoid engaging with the obesity crisis. Diet composition, particularly in the case of processed foods, is potentially more harmful to health than the overall calorie balance. In countries facing high levels of stunting, wasting and micronutrient deficiencies, NPMs that focus on energy may be problematic [85].

3.2.5. Non-Sugar Sweetener

For this paper, following the NPM for the WHO Africa Region [30], the term non-sugar sweeteners (NSS) will be used (definition in Supplementary Table S5). The use of NSS, such as artificial sweeteners and polyols, in the food supply is becoming more commonplace and has become central to sugar substitution [86]. They are consumed not only through foods, but also in medicines, food supplements and other products such as toothpaste [87]. NSSs are among the most widely used food additives globally [88]. This is partly because consumers are interested in reducing sugar intake [89] and also because the introduction of food policies such as a sugary beverage tax or front-of-pack labelling has incentivized the food industry to reformulate and replace sugar with NSS [90,91] instead of reformulating into products that are less sweet. Table 2 indicates that 55.6% of sodas (and 29.6% of all packaged beverages) and 12.8% of confectionery (and 6.6% of all packaged foods) in SA already contained NSS in 2018 (before the implementation of South Africa's sugar-sweetened beverage tax known as the Health Promotion Levy).

Because of the increased use of NSS, it is important that a thorough evaluation be conducted of its risks and benefits before advocating for, or discouraging, its use [92]. Although numerous studies and systematic reviews of these studies have been conducted on the topic of safety in the use of NSS, there is no consensus among researchers. One of the challenges is that many different NSSs exist and new NSSs are constantly becoming available [89].

The sweetness level of different NSSs also differs [93,94]. They do not all have the same physiological effect [95], and quantities of NSS intake are largely unknown. Worldwide, only two countries (Chile [7] and very recently Saudi Arabia [96]) include quantities of each type of NSS on the NIP. This makes it nearly impossible to accurately investigate consumption volumes across the world as the data are simply not available.

In Chile, food companies are reformulating products to replace sugar (which is regulated) [91] with NSS (which is not regulated). More than half (55.5%) of all packaged products in Chile now contain at least one NSS, making it difficult to select NSS-free options [97]. In SA, since the introduction of the HPL, there has been growing evidence of product reformulation [98], and although NSSs have yet to be investigated, many brands have reformulated sugar down from above 10 g/100 mL to less than 5 g/100 mL [99]. It is likely that much of this sugar has been replaced with NSS.

It is impossible to set a cut-point for NSS, unlike for other nutrients of concern such as sodium, saturated fat or sugar which have evidence-based cut-points, as there is currently inadequate evidence to identify an NSS cut-point. However, there is growing concern around children's exposure to NSS and its effects on their sweetness preferences later in life [100,101] and gut health [102]. The impact of prolonged use remains unclear [102], and recently, NPMs targeting children have recommended that children's exposure to sweeteners be restricted [30,103].

As food policies should be proactive in protecting the health of the population, the evidence currently available suggests that it is wise to regulate the use of NSS or at the very least, require clear information about its presence and amounts in food products to monitor its presence better. After all, the purpose of food policies is to encourage a shift towards the consumption of more whole, unprocessed foods rather than alternative, ultra-processed foods.

3.2.6. Recommendation

An easy to operationalize NPM aimed at reducing the demand for processed foods linked with NCDs and obesity should include 'nutrients to limit', and exclude 'nutrients to encourage'. Saturated fat, sodium, non-sugar sweetener and total sugar (with free sugar, not added sugar, used as the qualifying criteria when assessing the inclusion criteria of the NPM) have been identified as appropriate to include in the NPM.

3.3. Selecting the NPM Type, Criteria and Base

Base unit of measure: WHO and Codex Alimentarius dietary guidelines provide guidance with regard to nutrients of concern in reference to their contribution to the percentage of total energy [67,80] or as a nutrient reference value that should not be exceeded per day [81,82]. However, these refer to the total daily intake per person, and it is not easy to practically implement because different people have different energy requirements, and packaged foods represent only a portion of overall daily intake. The draft WHO FOPL guidelines recommend NPMs be developed using a per 100 g approach [53]. The portion size or per serving approach results in several challenges as different age groups should have different portion sizes, and consumption patterns differ among individuals [70]. Portions are easier for the food industry to manipulate, and often represent portion sizes that are 'healthier' but not realistic in relation to the package size or the amount that people eat. Consistent with Codex Alimentarius guidelines [81], nutritional information in SA is displayed in a per 100 g/100 mL format for foods and liquids. Considering the pros and cons of various options available (Table 4), and given the current 100 g/100 mL format used in SA, continuing in the same manner would be practical.

Table 4. Pros and cons of different base approaches.

	Pros	Cons
Per 100 g/100 mL	Simple to conceptualize and easy to compare foods Used on nutrition information panels on SA packaged foods	Certain foods are eaten in very small quantities (e.g., oil) while others are consumed in large quantities (e.g., beverages)
Per 100 kJ/% total energy	Allows for food consumed in smaller quantities to be put into context	Difficult to make sense of individual food items that do not represent total energy intake for the day
Per serving	Recognizes that portion sizes of different food types vary significantly, and if eaten in large quantities, will contribute more to nutritional intake than smaller amounts	Serving sizes are determined by the food producer and as a result vary significantly, even within a food category Easy to manipulate serving sizes to appear 'healthier', but these are not representative of the amount usually consumed

Across the board vs. food category specific: An across-the-board approach establishes consistent criteria which limit the risk of misinterpretation or incorrect classification [6]. It is not resource-intensive and is straightforward to implement. However, as all foodstuffs are treated in the same manner, regardless of their inherent nutrient composition, it could suppress reformulation within a category if changes are needed for most of the foods in that category. A category-specific approach, such as is used for marketing restrictions by the WHO Africa Region NPM [30], allows for criteria that are specific to the nutritional composition of different types (or categories) of food; and the criteria can be informed by the nutritional content of existing foods in the category [6]. However, the numerous categories with different thresholds make it difficult for regulators to implement and it potentially allows leeway for the food industry to manipulate within category thresholds.

It is important to consider the context, and to weigh up robustness with the ability to apply it appropriately when selecting the most appropriate NPM [6]. To date, all countries that have adopted a mandatory warning label model have focused on only two categories (food and non-alcoholic beverages). This includes Chile [104], Israel [50], Peru [49] Uruguay [105], Mexico [106] and most recently, Brazil [107]. To ensure a simple, easy-to-implement approach, a category-specific approach is not appropriate for the SA

setting as it is more resource-intensive (both for implementation and evaluation). An across-the-board approach is recommended for the NPM.

Threshold vs. continuous: A threshold-based approach has been successfully implemented in the mandatory, restrictive food policies of a number of countries, including Israel [50], Chile [104] and Peru [49]. It is administratively simple, as no calculation or comparisons need to be made before classifying a food (it either meets the cut-point or it does not). Previously, when the generally encouraged model was one that included both nutrients to encourage and limit, a continuous or scoring system was well justified. The rationale was that foods were composed of many nutrients and a single cut-off would result in the loss of valuable information [70]. However, this argument only holds true when both nutrients to encourage and restrict are considered or when the NPM is being used to underpin a positive logo that focuses only on whole, minimally processed foods, as in Israel [60].

Continuous models require a number of different calculations to be performed and can be human resource-heavy. Ultimately, when used together with an FOPL or health claim system, a threshold is still used to determine whether a product can carry a claim or not, or whether it is red, yellow or green. In this sense, a scoring approach is always used in conjunction with a threshold.

Recommendation

The SA NPM should use a straightforward approach and an across-the-board, threshold-based approach, that is applied to all packaged foodstuffs and uses a 'per 100 g' base for solids and the 'per 100 mL' base for liquids.

3.4. Thresholds to Use

The most appropriate and relevant nutrient cut-points are selected based on the recommendations made in steps one through three.

Where possible, it is recommended to adapt existing NPMs to make them context-specific, rather than inventing them from scratch due to the immense time and resources required to develop an NPM [33]. Based on the above considerations, the CWO 2019 NPM [7] appears to be the most suitable NPM to adapt. For the purpose of this paper, other NPMs considered include Mexico [106], Peru [49], Israel [50], PAHO [52], WHO Africa Region [30] and the FSANZ (SA HNC) [14] models (Supplementary Table S6). The PAHO NPM considers the percentage-of-energy approach, rather than a per 100 mL or per 100 g approach, and it is therefore not appropriate. The SA HNC NPM considers both nutrients to encourage and limit, which is difficult to implement and does not meet the purpose as discussed earlier. The WHO African Region NPM uses a category-specific approach rather than an across-the-board approach, which is why it has not been selected. Compared to other NPMs considered, the CWO 2019 NPM most appropriately meets requirements based on recommended components for the SA FOPL NPM. It is a mandatory, threshold-based, across-the-board model using a 'per 100 g' or 'per 100 mL; approach and it focuses on negative 'nutrients to limit'. A number of other countries have already adopted this NPM into their regulation, including Peru [49] and Israel [50]. Furthermore, the Chilean NPM has shown some promising results in the food policies it is underpinning in Chile [44–48].

The cut-points developed for the CWO 2019 NPM were based on nutrient composition analysis of 358 whole, unprocessed foods, using the USDA nutrient database [54]. No similarly comprehensive database is available for SA. The SA FCT includes 183 whole, unprocessed foods (110 foods with nutrients analyzed in SA, 65 based on the USDA FCT and eight on FCTs from other countries), resulting in an SA-specific sample size 69.3% smaller than that used for Chile. Given this, it was deemed appropriate to adopt the Chilean cut-points as-is for sodium, saturated fat and total sugar. This approach was also used by Israel and Peru [49,50].

Recommendation

This analysis indicates that the following cut-points (Table 5) be used for the proposed NPM, that have been adapted from the Chilean approach.

Table 5. Final proposed cut-points for an NPM suitable to be used in restrictive food policies in SA.

Solid Food (g) Cut-Points		Liquids (mL) Cut-Points	
Sodium mg/100 g	400 mg	Sodium mg/100 mL	100 mg
Total sugar g/100 g	10 g	Total sugar g/100 mL	5 g
Saturated fat g/100 g	4 g	Saturated fat g/100 mL	3 g
Non-sugar sweetener	Contains any	Non-sugar sweetener	Contains any

It is recommended that this NPM, if used, should be applied to all packaged foods and non-alcoholic beverages in SA containing any of the following:

1. Free sugar;
2. Added sodium;
3. Added saturated fat;
4. Non-sugar sweetener.

4. Discussion

Given the proposed NPM's ability to identify unhealthy products, it is appropriate for use to underpin restrictive food policy in South Africa. This could include FOPL regulations (which indicate packaged products high in unhealthy nutrients of concern), marketing restrictions, taxation policies and policies that restrict unhealthy foods in schools, hospitals and other government institutions. Elsewhere in the world these restrictive policies have been successful initiatives towards promoting a healthier food environment by supporting a move away from unhealthier food choices. [108].

The use of an evidence-based NPM built on a scientific basis that supports non-discriminatory policy measures is necessary in the international trade context [109,110], where limitations imposed by international trade and investment agreements have been found to impede public health policies [111]. A scientific basis of measure in policy development ensures trade and investment agreements are respected and do not place undue limitations on public health priorities [109,112]. Without adequately researched, evidence-based regulations, governments run the risk of being forced to retract regulations due to trade and investment agreements, as was seen with the turkey tail ban in Samoa [113].

Taking the resource limitations of SA into account, an important consideration in the development of this NPM was straightforward classification, implementation and evaluation for any NPM that is used in national regulations. For example, in our evaluation of the SA HNC NPM, the FVNL score had to be calculated manually for each product as it is not routinely reported on NIPs in South Africa. This was a time-consuming task, performed by nutrition experts. From a monitoring and evaluation standpoint, it is not a feasible assessment approach (due to the time and skills required) and it is not advisable to include an FVNL score in an NPM used in regulation in South Africa without mandating an FVNL nutritional declaration on the product packaging. This principle applies to all food components included in an NPM. It would be prudent, if including NSS in the NPM, to follow Chile [7] and Saudi Arabia [96], and strengthen current sweetener regulations in South Africa [114] by requiring mandatory reporting of NSS quantities on nutritional packaging. One of the newer approaches to NSS policy can be found in Mexico [106]. Their new law on front-of-package profiling includes an information box that states: 'Contains non-sugar sweeteners, not recommended for children'. This is placed in a large black box with white characters. They originally intended having a warning label for NSSs but, based on industry objections and World Trade Organization concerns, they shifted to an information box which has passed legal scrutiny.

As with most NPMs, the proposed NPM cut-points are applicable to foods and beverages in an as-consumed form. Should an NPM be used in regulations in SA, food labels should include the nutritional composition per 100 g 'as-consumed' alongside the 'as-packaged' composition if reconstitution through home preparation is required (e.g., concentrated fruit drinks). Manual calculations are time-intensive and may result in errors. Future regulations should stipulate that, should the 'as-consumed' information be missing, the NPM criteria will be applied to the 'as-packaged' information to encourage the 'as-consumed' information to be included. In addition, should nutritional information be unavailable on the product packaging (or missing for certain nutrients of concern), then by default the product should be assessed as 'excessive' in the nutrient of concern for which there is no information.

Distinguishing between healthy and unhealthy foods to regulate through policy is challenging for policy makers as the food industry contests definitions and argues that they are vilifying foods by differentiating them. Because of this, it is important that the purpose of the NPM is clearly understood. Recently, the argument has been made that NPMs in countries with high levels of malnutrition and stunting should include 'nutrients to encourage' [85]; however, this was not identified as suitable for the purpose of our proposed NPM. Positive components do not neutralize the negative health consequences of consuming the unhealthy components in the same product. The SA HNC NPM included in this analysis was developed to allow health and nutrition claims, which focus on 'nutrients to encourage'. However, research by authors involved in the development of the SA HNC NPM concluded that the NPM was more lenient than other NPMs when marketing restrictions were applied to foods high in fat, sugar and salt [27]. This supports concerns that the addition of (healthy) 'nutrients to encourage' can confuse the matter when trying to identify unhealthy foods [23]. The approach of classifying foods as 'healthy' or 'healthier' has allowed the industry to add nutrients or additives (e.g., isolated or synthetic non-digestible carbohydrates that count towards fiber) to otherwise unhealthy products [115]. 'Healthier does not necessarily mean healthy per se, and the notions of 'better than' may mislead consumers away from what is best' [70]. An NPM with the purpose of identifying unhealthy products to restrict should thus only include 'nutrients to limit'.

However, there is still space to consider 'nutrients to encourage'. Work has already been done in SA in the development of a positive FOP logo [116] and an approach similar to Israel could be considered, where additional criteria are used to identify healthy, minimally processed foods that may carry a positive FOP logo [60]. Although we have not identified the current SA HNC NPM proposed in draft R429/2014 as appropriate for restrictive food policy, it could still be useful for its intended purpose—to regulate health and nutrition claims on packaged foods. It is possible that the two NPMs could work in tandem; permitting foods that are not identified as unhealthy via the SA FOPL NPM to be assessed for eligibility of health and/or nutrition claims via the SA HNC NPM. If this approach is considered, we recommend that it be designed carefully to complement the restrictive NPM, only permitting positive messaging on products not carrying an FOP warning label. Having both a warning label and positive message could provide a mixed message and confuse consumers.

Limitations and Strengths of the Study

No NPM is without limitations. Consumption frequency, as part of normal daily dietary intake was not considered, and instead we focused on the nutrient profile of the foods themselves, rather than their role in the diet. Nationally representative dietary intake data in SA are sparse, as nutrition surveys are not regularly done, nor are they representative of the population [37]. This makes assessing dietary intake in the country challenging.

Similarly, certain assumptions, which may not have always been accurate, had to be made as free sugar and FVNL values were not available. Data were collected in the Western Cape Province of SA, at big retail outlets, so it is possible that products that only appear in certain locations or shops were excluded.

A large number of products were excluded from analysis as the nutritional content of packaged foods could not be assessed for compliance if they did not have an NIP, which is not a legal requirement in SA. To overcome this, the SA government could regulate NIPs on all packaged foods as mandatory. The information this panel provides can be used to assess compliance with various food regulations. In accordance with Codex guidelines [81], the panel should be clear and easy to understand and presented in a standardized manner.

After an NPM has been proposed, it is important that it be validated and tested for appropriateness by applying it to the local food supply chain [117,118]. This was outside the scope of this paper, although it is an essential step before an NPM can be accepted as appropriate for a certain setting. This has been mitigated to some extent by consulting with dietitians on the nutrient thresholds in South Africa, following the approach used in Chile. The validation study has been submitted elsewhere (currently under consideration for publication).

This study makes use of a recently collected dataset, which, to our knowledge, is the most comprehensive dataset of nutritional information on packaged foods in South Africa. A systematic process was followed to assess various NPM options using available data and literature, as well as existing regulations. Cultural dimensions are often overlooked in policy making processes. Adapting an NPM for a specific context, as has been done for South Africa throughout this NPM development process, is critical to ensure context-specific solutions.

5. Conclusions

This article proposes a fit-for-purpose NPM that is suitable to use in restrictive food policies in SA. It is adapted from the Chilean NPM and includes criteria for sodium, total sugar, saturated fat and non-sugar sweetener. It has the potential to be the foundation for FOPL and child-directed marketing regulations, broader taxation policies and to act as a guide for products to prohibit them from being sold or served in schools, hospitals or other government facilities. Although implementing these policies will not resolve the obesity and NCD crisis in the country, they will be an additional step in the fight. It has the potential to inspire other LMIC in Africa and can be scaled up for use elsewhere.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13082584/s1, Figure S1: Flow diagram representing initial and final datasets, and reasons for exclusion, Table S1: Primary data collection methodology, Table S2: Number and proportion of products included in analysis (N = 6747), overall and by food category, Table S3: Non-sugar sweetener (NSS) search terms used to identify NSS ingredients in products, Table S4: Number and proportion of food and beverages (N = 6747) in the SA marketplace (2018), overall and by food category classified as ultra-processed according to the NOVA classification system, Table S5: Definitions of sugar and non-sugar sweetener used in this paper, Table S6: Characteristics of nutrient profiling models considered for inclusion.

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4.3 Manuscript three

Title: Frank T, Ng S.W., Miles D.R., and Swart E.C. 2022. Applying and comparing various nutrient profiling models against the packaged food supply in South Africa. Public Health Nutrition 25(8), 2296-2307. doi: 10.1017/S1368980022000374

What is already known?

- The South Africa National Department of Health is interested in implementing an NPM, that has been tested and is context-specific and appropriate for use in South Africa, into food policy that discourages the supply and demand of products containing high amounts of nutrients linked to poor health outcomes.
- One of the methods to test the performance of an NPM is to test its performance alongside existing NPMs that have been developed for similar purposes.

What are the new contributions from this study?

- This is the first study to test the proposed NPM (developed in manuscript two) against other NPMs, using the South African packaged food supply. It is also the first study to test any NPMs using such a large dataset of packaged foods collected in South Africa.
- This study provides confirmation that the proposed NPM (developed in manuscript two) is fit-for-purpose, and appropriate for use to underpin restrictive food policies in South Africa. It shows that the proposed NPM is implementable and able to identify products that are high in saturated fat, sugar, sodium or containing non-sugar sweetener.

How might this study affect research, practice or policy?

- Besides the points raised in section 4.2 regarding manuscript two, which are also relevant to this paper, this study provides supportive evidence that the proposed NPM (developed in manuscript two) performs well when tested using the South African packaged food supply and is fit-for-purpose. This provides evidence to the South African National Department of Health that this NPM can be effectively used to underpin restrictive food policy in South Africa.

Contribution of the candidate: Together with input from my supervisors (S.W.N and E.C.S) I conceptualized the study, and methodology for the study. I carried out data management and data cleaning together with one of the co-authors (D.R.M). Data analysis was conducted by me, and supervisors and co-authors reviewed and provided feedback on the data analysis (D.R.M., S.W.N. and E.C.S). I wrote the draft manuscript, and supervisors and co-authors contributed to reviewing the manuscript (S.W.N., D.R.M. and E.C.S). I addressed reviewer comments, and supervisors and co-authors reviewed answers (S.W.N., D.R.M. and E.C.S). Supervisors provided overall guidance to the project (S.W.N and E.C.S). Additionally, primary data collection used as the data source in this manuscript was conducted by E.C.S., with myself as the project coordinator.

Please refer to Appendix 5.2: Reviewer comments and responses to manuscript for reviewer comments and author feedback; and to Appendix 6.3: Manuscript three supplementary material for supplementary material published alongside the manuscript.

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Applying and comparing various nutrient profiling models against the packaged food supply in South Africa

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Abstract

Objective: This study aimed to apply the newly developed Chile Adjusted Model (CAM) nutrient profiling model (NPM) to the food supply in South Africa (SA) and compare its performance against existing NPM as an indication of suitability for use to underpin food policies targeted at discouraging consumption of products high in nutrients associated with poor health.

Design: Cross-sectional analysis of the SA-packaged food supply comparing the CAM to three other NPM: SA Health and Nutrition Claims (SA HNC), Chilean Warning Octagon (CWO) 2019, and Pan-American Health Organisation (PAHO) NPM.

Setting: The SA-packaged food supply based on products stocked by supermarkets in Cape Town, SA.

Participants: Packaged foods and beverages (*n* 6474) available in 2018 were analysed.

Results: Forty-nine per cent of products contained excessive amounts of nutrients of concern (considered non-compliant) according to the criteria of all four models. Only 10·9 % of products were not excessive in any nutrients of concern (considered compliant) according to all NPM evaluated. The CAM had an overall non-compliance level of 73·2 % and was comparable to the CWO 2019 for foods (71·2 % and 71·1 %, respectively). The CAM was the strictest NPM for beverages (80·4 %) due to the criteria of non-sugar sweeteners and free sugars. The SA HNC was the most lenient with non-compliance at 52·9 %. This was largely due to the inclusion of nutrients to encourage, which is a criterion for this NPM.

Conclusion: For the purpose of discouraging products high in nutrients associated with poor health in SA, the CAM is a suitable NPM.

Keywords
Nutrient profiling
South Africa
Food policy
Nutrients of concern
Obesity

Obesity and non-communicable diseases (e.g. hypertension, diabetes, dyslipidemia and certain cancers) are linked to the consumption of ultra-processed foods high in added sugar, salt, trans- and saturated fats[1]. Non-communicable diseases are associated with increased mortality levels, particularly in low- and middle-income countries[2]. Changing lifestyles and food systems are synonymous with the nutrition transition, with changing diets shifting away from traditional diets to an increased consumption of ultra-processed, refined foods[3]. In sub-Saharan Africa, this nutrition crisis is pronounced, with obesity, and related non-communicable disease prevalence rapidly rising[4]. In South Africa (SA), one-third (31 %) of men and two-thirds (68 %) of women have overweight or obesity, and 20 % of women live with severe obesity[5]. If the current trend for children continues, 28 % of South African children (aged 5 to 19 years) will have obesity by 2030[6]. Similarly, the cost of obesity in SA currently accounts for 1·9 % of the gross domestic product, yet if nothing changes this will increase to 2·6 % by 2060[7].

The double burden of malnutrition (overweight and undernutrition)[8] occurs within an individual over their lifecycle, and across generations within households (stunted/wasted child with an overweight mother). It has long-term consequences for individuals, communities and the economic future of the country[9]. Malnutrition in

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any of its forms leaves one vulnerable to nutritional deficiencies, chronic diseases of lifestyle and infectious diseases including tuberculosis, HIV and coronaviruses[10,11].

Poor nutrition in SA is largely driven by what is available and accessible. Ultra-processed foods high in sugar and fat are cheap sources of energy[12,13]. High levels of unemployment and poverty make healthier options unattainable for most[12]. Both rural and urban poor communities rely heavily on formal supermarkets and/or both formal and informal fast-food outlets and small shops (spazas) to purchase their food[14,15]. Resource constraints drive poor South Africans towards cheap foods resulting in regular consumption of ultra-processed foods[12,13]. Multinational food companies account for the majority of the market share[16] of ultra-processed foods. A recent study found that 76 % of assessed packaged foods in SA supermarkets is ultra-processed[17]. Consumption habits are continually shifting towards ultra-processed products due to economic, environmental and societal factors such as the price, food type, availability and marketing strategies employed by large corporations[18].

Uses of nutrient profiling model in South Africa

One way to address the poor nutritional content of ultra-processed products in SA is to implement policies that both disincentivise manufacturers to produce ultra-processed foods and effectively inform consumers about the health risks. Nutrient profiling models (NPM) can assist to achieve this goal. Nutrient profiling is defined as '*the science of categorising foods based on their nutritional composition, for reasons related to preventing disease and promoting health*'[19]. Well-designed NPM can underpin food and nutrition policies, such as food labelling, child-directed marketing restrictions, taxation and school nutrition standards[20].

In low-to-middle-income countries, the implementation of policies underpinned by NPM has been slow, possibly due to limited resources and a lack of population-level dietary data required to support the development of NPM[21]. However, there is a need for stronger, evidence-based policies to promote health and prevent non-communicable diseases in low-to-middle-income countries[21]. This is especially true as the World Trade Organisation demands transparent, scientific-based motivations for any country wanting to implement food policies that may restrict trade[22], such as policies aimed at discouraging intakes of products high in nutrients or ingredients associated with poor health[23]. Thus, international trade concerns can be minimised by ensuring food policies are based on a transparent and systematic NPM in order to define unhealthy foods[22]. Using one NPM across various country-level policies can reduce confusion by ensuring a consistent approach and message to consumers while reducing administrative burden. In SA, a NPM has recently been proposed to identify unhealthy foods and beverages that can be restricted through relevant policies[17].

The current regulations relating to the labelling and advertising of foods in SA, R146, were implemented in 2010[24]. According to R146, it is mandatory to include an ingredient list on packaged food labels, but a nutrition information panel (NIP) is optional[24]. An updated draft of these regulations, R429 of 2014[25], exists but has not been promulgated. This draft R429 recommended a mandatory NIP to promote transparency of the nutritional content of the foodstuff and to verify compliance to nutrient profiling recommendations for health and nutrition claims. Moreover, trans-fats regulations prohibiting more than 2 g of trans-fat per 100 g of oil or fat were implemented in 2011[26], and SA implemented mandatory Na limits for various processed food categories in June 2016[27]. The SA National Department of Health has been working to finalise R429, with the intention to include a NPM that is suitable for the SA context and discourages the supply and demand of ultra-processed foods and beverages containing high amount of nutrients or ingredients linked to poor health outcomes. Additionally, they have expressed interest in food policies, such as front-of-package warning labels[28].

This study aimed to apply a newly developed NPM to the packaged food supply in SA and compare its performance to other existing NPM as an indication of suitability for use, given the SA Department of Health's interest in it.

Methods

Models selected for comparison

A rigorous process has previously been followed to identify a NPM suitable for use in food policy in SA[17]. This newly developed NPM is referred to as the Chile Adjusted Model (CAM) in this paper. Its performance that needed to be tested alongside existing NPM developed for similar purposes. The models chosen for the comparison included those that have some resonance with the food policies under consideration. These include the Chilean Warning Octagons (CWO) which Chile has successfully used to implement a comprehensive package of food policies[29,30], and the Pan-American Health Organisation (PAHO) model, as the first proponent of restrictive food policies[31]. It was also appropriate to include the existing NPM in SA[32] in the assessment.

NPM details are summarised in Table 1. Briefly, the NPM[32] adopted from Food Standards Australia and New Zealand Food Standards Australia/New Zealand's (FSANZ) NPM (which in turn was adapted from the UK Ofcom NPM)[33] is currently used as the basis for assessment of health and nutrition claims in SA's draft R429[25] and referred to as the SA Health and Nutrition Claims (SA HNC) in this paper. It has also been validated in SA for the purpose of underpinning marketing restrictions to

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Table 1 Characteristics of four nutrient profiling models (NPM)

	South Africa Health and Nutrition Claims (SA HNC)			Chilean Warning Octagons (CWO) 2019		Chile Adjusted Model (CAM)		Pan-American Health Organisation (PAHO)
NPM characteristics	Scoring-based; across-the-board (three categories); per 100 g Category 1: Beverages (including milk) Category 2: Any foods other than those in category 1 or 3 Category 3: Cheese and processed cheese with a Ca content > 320 mg/100 g, edible oil, edible oil spreads, margarine and butter			Threshold-based (threshold per nutrient); across-the-board (two categories); per 100 g for solids and per 100 ml for liquids Solids (any product that indicates their nutritional composition per 100 g is assumed to be a solid) Liquids (any product that presents their nutritional composition per 100 ml is assumed to be a liquid)				Threshold-based; across-the-board. Includes all processed and ultra-processed foods) Applied per % of total energy (per kcal for Na)
Inclusion criteria	All foods and beverages included			Applies to all packaged foods and beverages with added sugar, added Na or added saturated fat		Applies to all packaged foods and beverages with free sugar, added Na, added saturated fat or NSS		All processed and ultra-processed foods (based on NOVA classification[49])
Applied to food products	Category 1	Category 2	Category 3	Solids	Liquids	Solids	Liquids	All
Energy	Score of 0: ≤ 80 kcal (≤335 kJ)/100 g to 10: >800 kcal (>3350 kJ)/100 g		Score of 0: ≤ 80 kcal (≤ 335 kJ)/100 g to 11: >880 kcal (>3685 kJ) /100 g	275 kcal (1150 kJ) /100 g	70 kcal (293 kJ) /100 ml	–	–	–
Total fat	–	–	–	–	–	–	–	≥ 30 % of total energy
Saturated fat	Score of 0 (≤1·0 g /100 g) to 10 (>10·0 g/100 g)		Score of 0 (≤1·0 g /100 g) to 30 (>30·0 g /100 g)	4 g/100 g	3 g /100 ml	4 g /100 g	3 g /100 ml	≥ 10 % of total energy
Trans-fat	–	–	–	–	–	–	–	≥ 1 % of total energy
Total sugar	Score of 0 (≤5·0 g /100 g) to 10 (>45·0 g /100 g)			10 g /100 g	5 g /100 ml	10 g /100 g	5 g /100 ml	–
Free/added Sugar	–	–	–	–	–	–	–	≥ 10 % of total energy
Non-sugar sweetener (NSS)	–	–	–	–	–	Contains NSS		Contains NSS
Na	Score of 0 (≤90 mg/100 g) to 10 (>900 mg/100 g)		Score of 0 (≤90 mg/100 g) to 30 (>2700 mg/100 g)	400 mg /100 g	100 mg /100 ml	400 mg /100 g	100 mg /100 ml	Ratio between Na and energy (kcal) is ≥ 1:1 0r (kJ) is ≥ 4·2:1
Protein	Score of 0 (≤1·6 g/100 g) to 5 (>8·0 g/100 g)			–	–	–	–	–
Fibre	–	Score of 0 (≤0·9 g/100 g) to 5 (>4·7 g/100 g)		–	–	–	–	–
Fruit, vegetable, nuts and legumes (FVNL)	Score of 0 (<25 % concentrated fruit or vegetables or ≤40 % FVNL:) to 8 (100 % FVNL)			–	–	–	–	–

An overall score is calculated for the SA HNC, by first assigning a base score by food category, according to the energy content, saturated fats, total fats, total sugars and Na.
Thereafter, additional points are assigned for content of FVNL, fibre and proteins per 100 g of product.
The CWO, CAM and PAHO have cut points for each nutrient of concern and thus do not calculate an overall score.

children[32]. The Centre of Excellence for Nutrition at North West University proposed the SA HNC[32] which was then incorporated into the draft R429 in 2014 by the SA Department of Health. The NPM referred to as the CWO[29] was developed by the Chile Ministry of Health to underpin policy related to warning front-of-package labelling (FOPL), restriction of marketing to children and regulation in the school environment. Promulgated in 2012, the CWO was implemented in three phases: 2016, 2018, and 2019. The CWO has gained attention for its success in Chile[30] and thus is included in this study applying the most stringent phase, the CWO 2019, as it contains the final cut points that the regulation achieved. The PAHO model was published in 2016 and developed through rigorous work by an expert consultation group composed of recognised authorities from Latin America in the field of nutrition. Its purpose is to identify processed foods excessive in nutrients of concern that can be used to construct food policy[31], as seen in Mexico's mandatory FOPL[34]. The fourth model, the CAM, acknowledges the success of the CWO[30,35,36] but was adjusted by the authors to replace added sugar with free sugar in its qualifying criteria of ingredients, include presence of non-sugar sweetener (NSS) criteria and exclude the energy criteria. The reason for the inclusion of free sugar as opposed to added sugar as a qualifying ingredient in which total sugar values are then assessed is that 100 % fruit juice is excluded from PAHO and CWO 2019. Recent literature suggests that excessive sugar consumption from 100 % fruit juice is harmful and should be limited[37,38]. Likewise, replacement of sugar with NSS should be restricted given the association of the latter with increased morbidity[39,40]. The inclusion of NSS is similar to PAHO[31] and Mexico's[34] recently introduced NPM. Energy was excluded during the NPM development process as only 2·3 % of products evaluated were exclusively high in energy, but not any other nutrient (described elsewhere in detail)[17].

Currently, there is no gold standard for classifying the healthfulness of foods to use for NPM validation. The current study developed algorithms to apply four NPM to a cross-sectional analysis of the SA-packaged food supply collected in 2018. The purpose is to show how similarly or differently the same set of products available in SA would be considered as compliant or not under these four NPM.

Sampling procedures

Nutritional information of packaged food and beverages was collected between February and March 2018, in six supermarket chains that accounted for more than 50 % of the grocery retailer market share in SA in 2018[41]. Selection of these stores ensured a representative sample of packaged foods available on the SA market. Data collection was conducted in Cape Town in the middle-income suburb Durbanville (at Pick 'n Pay, Woolworths, Checkers and Spar), as well as in the low-income suburbs of Langa (at Shoprite) and Khayelitsha (at Boxer and Pick 'n Pay). Fieldworkers took photographs of all packaged food products in the store at the time of data collection. Photographs captured all sides of food containers and include all information from the product packaging (e.g. product name, package size, bar code, ingredients and NIP).

Fieldwork and data entry

Trained university graduate fieldworkers followed a standardised protocol developed by The George Institute (TGI) to capture and submit photographs of food labels to the Foodswitch database using cellphone cameras. TGI supervised a team of data capturers to view the photographs and enter product information into the Foodswitch database using standardised methods and quality control checks.

Products are classified into eleven food categories and four beverage categories. Conversion of foods and beverages requiring reconstitution (e.g. liquid concentrate beverages) from an 'as sold' form to an 'as consumed' form was based on information retrieved from product photographs when available. Data collection comprised of 18 124 products, of which 6747 had sufficient information for NPM analyses. Figure 1 provides a flowchart of sample sizes. Data cleaning and analyses were performed using STATA (version 15, StataCorp.). The nutrient content of products in the database was verified by identifying outliers and cross-checking against the original photographs of each product and corrected when possible.

Table 2 represents the final number of products in various food groups included in the dataset (*n* 6747). Most (78·4 %, *n* 5290) are foods and 21·6 % (*n* 1457) are beverages.

Testing selected nutrient profiling models

Products were excluded from NPM analyses if missing information that hindered scoring for any of the four NPM. The SA HNC requires calculations of a fruit, vegetable, nuts and legumes (FVNL) score based on the percentage of fruits and vegetables contained in a product. FVLN scores were calculated based on the percentage of FVLN in ingredient lists when reported and manually estimated for products without this information (out of 957 products 62 % were manually estimated). A similar methodology for calculation was followed as described by Bernstein *et al.*[42]. First, a FVNL score of 0 was assigned to subcategories without any FVNL (e.g. fats and oils). For groups where products might contain FVNL, each product was individually reviewed and the order of ingredients, number of FVNL ingredients compared to number of non-FVNL ingredients, form of the FVNL ingredients (concentrated or non-concentrated), and type of product were taken into consideration when assigning points. Likewise, if free sugar values were not available but added sugar was listed, then the free sugar content was estimated according to the method proposed by PAHO[31]. A registered dietitian assigned all classifications.

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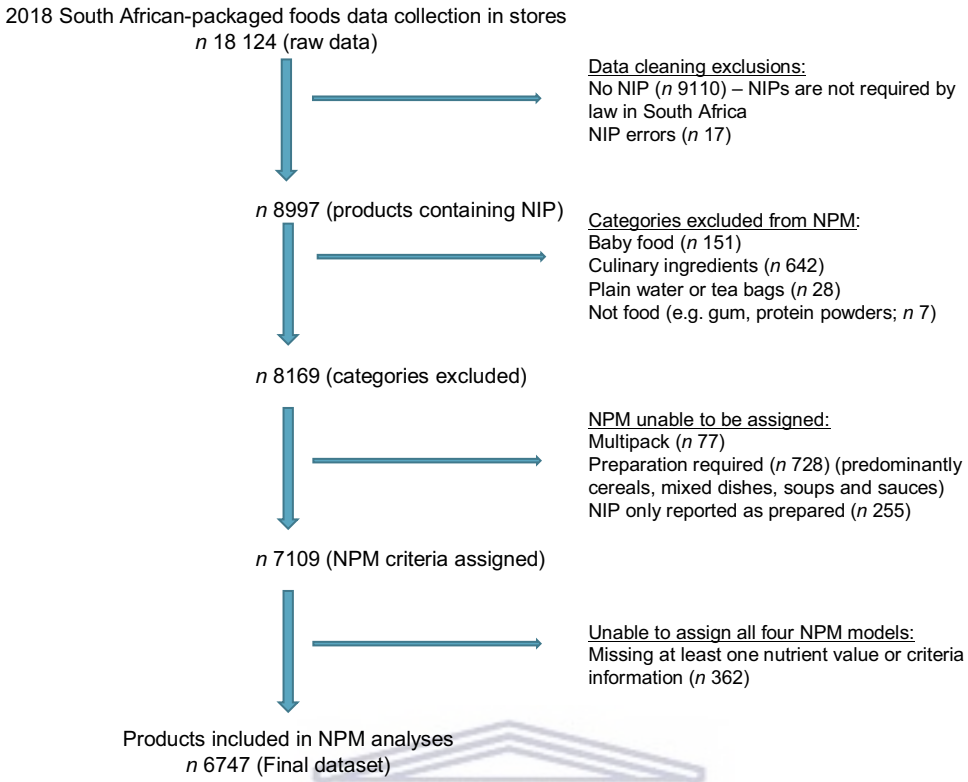

Fig. 1 Flow diagram representing initial, and final dataset, and reasons for exclusion. NIP, nutrition information panel; NPM, nutrient profiling model

Table 2 Proportion of South African-packaged foods and beverages that are non-compliant per NPM overall, for foods and beverages, and by select categories

	Products	South Africa Health and Nutrition Claims (SA HNC)	Chilean Warning Octagons (CWO) 2019	Chile Adjusted Model (CAM)	Pan-American Health Organisation (PAHO)
	n	%	%	%	%
Foods					
Breakfast cereals	110	42·7	88·2	78·2	79·1
Cereals and cereal products	254	22·8	41·7	40·2	84·7
Confectionary and desserts	1119	91·8	94·5	96·5	97·2
Dairy	791	42·5	65·1	70·9	86·1
Fruits	196	8·2	50·0	46·4	51·0
Vegetables	510	21·0	38·2	38·6	69·0
Legumes	100	0·0	28·0	28·0	94·0
Mixed dishes	299	50·2	70·6	70·2	99·7
Protein	602	55·5	68·4	67·9	94·5
Snack foods	699	63·2	80·7	76·3	78·8
Soups and sauces	610	76·1	78·7	76·9	93·4
Total foods	5290	56·4	71·1	71·2	87·1
Beverages					
Dairy drinks	306	45·1	45·4	50·7	57·8
Other beverages	478	54·0	51·5	76·6	85·6
Sodas	288	66·3	66·0	95·5	99·7
100 % fruit juice	385	0·5	1·6	97·4	2·6
Total beverages	1457	40·4	39·9	80·4	60·6
Total food and beverages	6747	52·9	64·4	73·2	81·3

Products were determined to be either compliant or non-compliant based on the nutritional criteria of each NPM. For the SA HNC, compliance includes products meeting criteria for carrying a health claim: for beverages a score of less than 1; processed cheese and fats a score of less than 28; and other foods a score of less than 4. For the CWO 2019, products excluded from carrying a warning FOPL are considered compliant (i.e. nutrients did not exceed

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criteria for energy, sugar, Na or saturated fat). For PAHO, products meeting all the stipulated criteria for total fat, saturated fat, trans-fat, Na, free sugar and NSS are considered compliant. Likewise, products under the CAM are compliant when not exceeding thresholds for sugar, saturated fat, Na or containing any NSS.

Data analysis

The four NPM were compared by the number and proportion of foods classified as either compliant or non-compliant, overall and by food category. Differences across models regarding the proportion and mean number of foods identified as non-compliant were explored by using tests of proportions and *t*-tests, respectively. The mean contents of nutrients of concern among non-compliant products were calculated and compared across NPM. The level of agreement between each NPM was evaluated using pairwise correlation coefficients. A *P*-value of <0·05 was used to determine a level of significance.

Results

Numbers and proportions: results of various nutrient profiling model

Table 2 presents the percentage of products non-compliant for each NPM for foods, beverages and overall, as well as by category. The SA-packaged food supply had the highest non-compliance rate by the PAHO (81·3 %, *n* 5488). For foods, the non-compliance levels were similar for CAM and the CWO 2019 (71·2 %, *n* 3766 and 71·1 %, *n* 3763, respectively). However, the CAM had the highest level of non-compliance for beverages (80·4 %) due to the criteria of free sugars and NSS. The most lenient model was the SA HNC with a non-compliance level of 52·9 % (*n* 3570). This was largely due to a lower share of food products considered non-compliant (56·4 %) than the other NPM, although the beverage share was comparable to CWO 2019. Within seven product categories (legumes, fruits, vegetables, cereal products, diary, breakfast cereals and mixed dishes), the SA HNC was more lenient than any other NPM, by at least 15 percentage points. Conversely, the PAHO was at least 15 percentage points more non-compliant than any other NPM for seven food categories (mixed dishes, protein, legumes, soups and sauces, dairy, cereal products and vegetables). Although the CWO 2019 and CAM had similar results for food categories, one category, breakfast cereals, had noticeably more (10·0 %, *n* 11) non-compliant products for the CWO 2019. Among these products, all eleven were high in energy but did not exceed the CWO 2019 compliance level for Na, sugar or saturated fat. The discrepancy was due to the energy criteria for CWO 2019 omitted in CAM.

For beverages, the CAM had twice as many non-compliant products as both the SA HNC and CWO 2019 (80·4 % non-compliant *v.* 40·4 % and 39·9 %, respectively), and 20 percentage points higher non-compliance than the PAHO (non-compliance level of 60·6 %). The CAM was at least 22 percentage points more non-compliant than the CWO 2019 and the SA HNC for sodas, 100 % fruit juice and other beverages. Although CAM was similar to the PAHO for sodas, the PAHO had more non-compliant products in dairy drinks and other beverages categories (7·12 and 8·99 percentage points more, respectively). Most of these products (*n* 65) were low in energy, but high in Na (*n* 21), free sugar (*n* 17) and/or total fat (*n* 22). The category with the largest difference overall was 100 % fruit juice due to the free sugar qualifying criteria of the CAM. The PAHO, SA HNC and CWO 2019 had a non-compliance rate of 2·6 % or less, whereas the CAM non-compliance rate was 97·4 % (*n* 375).

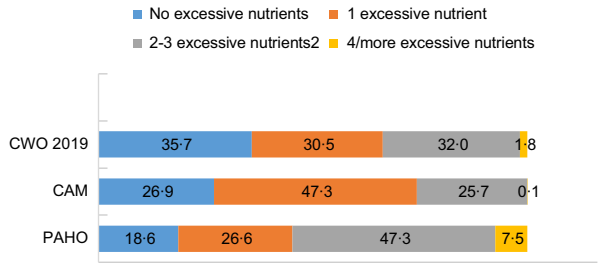

Fig. 2 Total proportion of products with 1, 2–3 or 4 and more 'excess nutrients' – PAHO, CWO 2019 and CAM NPM. NPM, nutrient profiling model; CWO 2019, Chilean Warning Octagon; CAM, Chile Adjusted Model; PAHO, Pan-American Health Organisation

These findings align with the test of proportions where the difference in the percentage of non-compliant products was largest between the SA HNC and the PAHO models, and smallest between the CAM and PAHO models. For foods, specifically there was virtually no difference between the CAM and CWO 2019 (Appendix 1).

As the SA HNC includes both nutrients to encourage and limit, it was excluded from analyses that considered nutrients in excess exclusively. Unlike the three other models that provide threshold-based scores, the SA HNC provides a cumulative score, and thus the SA HNC cannot be directly compared to the other three NPM only regarding excessive nutrients. Figure 2 indicates excessive nutrients by number for the PAHO, CAM and CWO 2019. The PAHO model contains the largest number of products with four or more excessive nutrients (e.g. Na, free sugar, saturated fat, trans-fat, total fat and/or NSS), whilst the CAM is most likely to have only one nutrient in excess. Despite this, overall, the CAM still has more products excessive in at least one nutrient when compared to the CWO 2019. The PAHO model has the largest number of excessive products overall.

Level of agreement in compliance of different nutrient profiling model when assessing the South African-packaged food supply, overall and by category

Table 3 presents details on the level of agreement in compliance of different NPM overall and by category. Appendix

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Table 3 Level of agreement in compliance of different NPM when assessing the SA-packaged food supply, overall and by category

	Products analysed	Excess nutrients; all models		Excess nutrients; SA HNC only		Excess nutrients; CWO 2019 only		Excess nutrients; CAM only		Excess nutrients, PAHO only		No excess nutrients; all models	
	n	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Food													
Breakfast cereals	110	47	42·7	0	0	9	8·2	0	0·0	0	0·0	13	11·8
Cereals and cereal products	254	54	21·3	1	0·4	4	1·6	0	0·0	104	40·9	34	13·4
Confectionary and desserts	1119	1003	89·6	15	1·3	3	0·3	0	0·0	2	0·2	12	1·1
Dairy	791	256	32·4	43	5·4	0	0	0	0·0	84	10·6	67	8·5
Fruits	196	10	5·1	6	0·8	7	1·0	0	0·0	9	4·6	83	42·3
Vegetables	510	106	20·8	0	0	0	0	0	0·0	153	30·0	158	31·0
Legumes	100	0	0·0	0	0	0	0	0	0·0	66	66·0	6	6·0
Mixed dishes	299	141	47·2	0	0	0	0	0	0·0	78	26·1	1	0·3
Protein	602	320	53·2	4	0·7	0	0	0	0·0	150	24·9	29	4·8
Snack foods	699	424	60·7	3	0·4	20	2·9	0	0·0	7	1·0	120	17·2
Soups and sauces	610	427	70·0	6	1·0	0	0	0	0·0	65	10·7	34	5·6
Total foods	5290	2788	52·7	78	1·5	43	0·8	0	0·0	718	13·6	557	10·5
Beverages													
Dairy drinks	306	118	38·6	17	5·6	0	0	0	0·0	19	6·2	112	36·6
Other beverages	478	235	49·2	13	2·7	0	0	0	0·0	36	7·5	56	11·7
Sodas	288	190	66·0	0	0	0	0	0	0·0	12	4·2	1	0·3
100 % fruit juice	385	0	0·0	0	0	0	0	366	95·1	3	0·8	7	19·2
Total beverages	1457	543	37·3	30	2·1	0	0	366	25·1	70	4·8	176	12·1
Total food and beverages	6747	3331	49·4	108	1·6	43	0·6	366	5·4	788	11·7	733	10·9

NPM, nutrient profiling model; SA HNC, South African health and nutrition claims; CWO 2019, Chilean Warning Octagon; CAM, Chile Adjusted Model, PAHO, Pan-American Health Organisation.

2 provides a comparison across NPM of the differences in the mean number of products with excess nutrients by category. Forty-nine per cent of all products (*n* 3331) contained excessive amounts of nutrients of concern and were non-compliant according to all four NPM assessed. Just over half of all foods (52·7 %; *n* 2788) and one-third of all beverages (37·3 %; *n* 5430) were classified as non-compliant. Categories in which more than half the products were non-compliant according to all NPM included confectionary and desserts, soups and sauces, sodas and snack foods. The PAHO model had several categories with higher exclusive non-compliance than the other models. At least 30 % of cereal products, legumes and vegetables were non-compliant only under the PAHO model due to excessive amounts of Na. Of the products non-compliant only to the PAHO, 95·5 % of legumes (*n* 63), 87·6 % of vegetables (*n* 134) and 99·0 % of cereal products (*n* 103) were high in Na. CAM is the only NPM that has a category (100 % fruit juice) with 95 % greater non-compliance. The only products in this category that are CAM compliant are coconut water and lemon juice. All other 100 % fruit juice products exceeded the sugar threshold according to the CAM criteria.

Only 10·9 % (*n* 733) of all products were not excessive in any nutrients of concern according to the four NPM. Compliant products were mainly from dairy drinks (36·6 %, *n* 112), fruits (42·3 %, *n* 83) and vegetables (31·0 %, *n* 158). Snack foods found compliant for all four models (17·2 %) consisted of products such as plain nuts and seeds, plain popcorn, plain rice and corn cakes, crisp bread and some nut butters.

None of the NPM are completely aligned (pairwise correlation coefficients, Table 4; and level of agreement, Appendix 3). The CAM and CWO 2019 were most closely aligned overall, for food, for any excess (0·75 and 0·92) and number (0·84 and 0·91) of excess nutrients. However, there was poor alignment between the CAM and other NPM for beverages, with the highest alignment for beverages between PAHO and CWO 2019 (at 0·66 for any nutrient in excess). As explained previously, the SA HNC was not included in evaluations of nutrients in excess.

Comparison of nutrients of concern between nutrient profiling model

In order to compare how effectively the various NPM cut points achieved the desired outcome for the nutrients of concern, means by compliance and non-compliance were examined (see Table 5).

For all NPM, mean Na content was below 160 mg/100 g among compliant products. The SA HNC had the highest mean Na content in compliant products (157·9 mg/100 g) and the PAHO model the lowest at 42·6 g/100 g. Non-compliant products Na mean ranged from 391·8 mg/100 g

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Table 4 Pairwise correlation coefficients between NPM and any or specific number of nutrients

		Pairwise correlation coefficients between CWO 2019, CAM and PAHO for any nutrient in excess		Pairwise correlation coefficients between CWO 2019, CAM and PAHO for number of nutrients in excess	
		CAM	PAHO	CAM	PAHO
CWO 2019	Food	0·9176	0·5433	0·9089	0·4322
	Beverages	0·3919	0·6566	0·5174	0·4292
	All	0·7505	0·6043	0·8351	0·4813
CAM	Food	–	0·5988	–	0·5291
	Beverages	–	0·3300	–	0·4362
	All	–	0·4699	–	0·5058

NPM, nutrient profiling model; CWO 2019, Chilean Warning Octagon; CAM, Chile Adjusted Model; PAHO, Pan-American Health Organisation.
SA Health and Nutrition Claims NPM not included in this comparison due to the different types of model.

(PAHO) to 476·8 mg/100 g (SA HNC). The highest mean saturated fat content in the compliant group was 2·5 g/100 g, for the CAM NPM. For both total sugar and added sugar, PAHO had the highest compliant content (9·3 g/100 g and 6·5 g/100 g, respectively), while the CWO 2019 had the lowest (5·9 g/100 g and 3·6 g/100 g, respectively).

Mean energy was below 630 kJ/100 g in all four NPM for compliant products. The CAM had a higher mean than the CWO 2019 for energy (663 kJ/100 g and 495 kJ/100 g, respectively). The PAHO has a lower compliant mean (613 kJ/100 g) than the CAM. The CWO 2019, the only model to include energy as a nutrient of concern, had 2123 observations for 'high energy'. Only 91 (1·4 % of the total sample) of these observations were compliant according to the CAM (due to most energy-dense products containing excessive amounts of other nutrients of concern). Interestingly, although protein and fibre are promoted by the SA HNC model, it was the CAM that had the highest averages of these nutrients in the compliant group (6·6 g/100 g and 3·2 g/100 g, respectively).

Note that NSS and FVNL were not included in this nutrient-level analysis. NSS is currently not included on the NIP of packaged foods in SA and although the presence of NNS could be identified via the ingredient list, the amount of NNS could not be compared. The FVNL score was not included in this assessment, as the calculated amount was an estimate and would be inaccurate to compare across different NPM.

Discussion

According to the criteria of the four NPM assessed, between half and 80 % of all products assessed contained excessive amounts of nutrients of concern and are considered non-compliant. This affirms like in many other countries[9] that SA's nutrition transition is advanced[8], and the packaged food supply includes predominately ultra-processed foods in excess of nutrients of concern and may be considered unhealthy[17]. Categories especially high in non-compliant products were confectionary and desserts, soups and sauces, sodas, and snack foods. Only 11 % of products were found to be compliant according to all the NPM analysed and comprised of products beneficial to health, such as fruits and vegetables, and healthier snacks like plain nuts and seeds and low/no sugar dairy drinks.

Similar to other studies, the PAHO model had the highest level of non-compliance[22]. Less than 20 % of the current SA-packaged food supply would be exempt from a warning FOPL (an example of a food policy) should the PAHO be used for this purpose. Conversely, the most lenient model was the SA HNC, which found almost half (47 %) of the products compliant. Its original intended use was to allow health claims, and it is the only NPM assessed to include both nutrients to limit and encourage[25]. This difference was particularly evident in the legumes, fruits, vegetables, cereal and cereal products, dairy, breakfast cereals and mixed dishes categories, where non-compliance levels were at least 15 % lower than the other NPM. In all of these categories, it is easy to score positive points for fibre, protein and/or FVNL as these categories of food often contain these ingredients. There has been some criticism that NPM that contain nutrients to encourage do not achieve the goal of promoting whole-grain and whole foods due to their focus on energy density rather than nutrient density[43]. Unfortunately, the addition of these nutrients to encourage does not automatically cancel out the negative health consequences of consuming large amounts of nutrients of concern. This supports apprehensions that the addition of nutrients to encourage in a NPM can confuse the matter when trying to identify unhealthy foods to restrict in food policy[22]. In fact, the mean fibre and protein content of products compliant with the CAM was higher than the SA HNC; thus, a focus on restricting nutrients of concern does not necessarily negatively bias against healthier products.

The CAM and CWO 2019 had similar levels of non-compliant foods, but the CAM was stricter for beverages. This is due to the additional criteria for NSS, as well as the qualifying inclusion criteria of free sugar instead of added sugar in the CAM. This criterion ensures that high sugar 100 %

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Table 5 Mean content of nutrients of concern per 100 g of product by compliance to NPM criteria

		South Africa Health and Nutrition Claims (SA HNC)								Chilean Warning Octagons (CWO) 2019							
		Compliant				Non-compliant				Compliant				Non-compliant			
		Mean	SE	Median	Min–max	Mean	SE	Median	Min–max	Mean	SE	Median	Min–max	Mean	SE	Median	Min–max
Nutrients to limit	Energy (kJ)	564·4	11·00	310·0	0–3014·2	1152·7	12·05	1135·1	5·9–3083	495·4	11·97	251·0	0–3014·2	1086·2	11·00	1046	25·1–3083
	Total fat (g)	5·5	0·21	1·2	0–77·8	13·7	0·22	10·8	0–78·8	5·3	0·25	0·6	0–76·1	12·3	0·20	8·0	0–78·8
	Saturated fat (g)	1·6	0·06	0·4	0–57·3	6·3	0·12	3·7	0–39·6	1·8	0·10	0·2	0–57·3	5·3	0·10	2·4	0–39·6
	Trans-fat (g)	0·05	0·003	0	0–2·3	0·13	0·010	0	0–14·8	0·06	0·005	0	0–2·4	0·11	0·008	0	0–14·8
	Total sugar (g)	6·4	0·16	4	0–78·3	17·1	0·34	8·3	0–96·1	5·9	0·19	3·5	0–77	15·5	0·29	8·4	0–96·1
	Added sugar (g)	4·1	0·10	2·9	0–45·4	15·6	0·32	6·6	0–96·1	3·6	0·14	2·2	0–77	13·7	0·27	6·1	0–96·1
	Na (mg)	157·9	3·70	48	0–3909	476·8	10·93	317	0–9640	110·4	2·90	38	0–1039	446·2	9·23	323·5	0–9640
Nutrients to encourage	Protein (g)	5·7	0·12	3	0–49	6·6	0·12	4·8	0–67·6	4·9	0·14	2·4	0–49	6·8	0·11	4·9	0–67·6
	Fibre (g)	2·7	0·07	1	0–50·3	2·3	0·05	1	0–34·5	2·3	0·08	0·9	0–50·3	2·5	0·05	1·2	0–34·5

		Chile Adjusted Model (CAM)								Pan-American Health Organisation (PAHO)							
		Compliant				Non-compliant				Compliant				Non-compliant			
		Mean	SE	Median	Min–max	Mean	SE	Median	Min–max	Mean	SE	Median	Min–max	Mean	SE	Median	Min–max
Nutrients to limit	Energy (kJ)	662·7	15·52	389·1	0–3014·2	954·0	10·63	807·5	0–3083·2	613·4	20·50	231·0	0–3273·6	936·0	9·79	761·9	0–3083·2
	Total fat (g)	7·5	0·3	2·1	0–76·1	10·7	0·18	4·5	0–78·8	6·4	0·43	0·3	0–76·1	10·6	0·17	5	0–78·8
	Saturated fat (g)	2·5	0·1	0·8	0–57·3	4·7	0·10	1·7	0–39·6	1·9	0·14	0·1	0–57·3	4·6	0·08	1·8	0–39·6
	Trans-fat (g)	0·09	0·007	0	0–2·4	0·10	0·007	0	0–14·8	0·05	0·007	0	0–2·4	0·11	0·007	0	0–14·8
	Total sugar (g)	5·9	0·27	3·5	0–77	14·4	0·25	8·4	0–96·1	9·3	0·36	5·2	0–78·3	12·7	0·24	5·8	0–96·1
	Added sugar (g)	4·27	0·18	2·5	0–77	12·9	0·26	5·7	0–96·1	6·5	0·36	3·05	0–77	11·2	0·22	4·7	0–96·1
	Na (mg)	149·9	3·57	65·7	0–1039	391·4	8·38	188	0–9640	42·6	2·42	12	0–977	391·8	7·51	268	0–9640
Nutrients to encourage	Protein (g)	6·6	0·16	3·6	0–49·0	6·0	0·10	3·2	0–67·6	4·3	0·17	2·0	0–49	6·6	0·10	4·4	0–67·6
	Fibre (g)	3·2	0·10	1·6	0–45·3	2·2	0·05	1	0–50·3	2·8	0·13	0·6	0–45·3	2·4	0·05	1·1	0–50·3

Compliant indicates product did not meet any criteria; Non-compliant indicates product met one or more criteria.

fruit juices[37,38] that contain fruit concentrate are not inadvertently excluded from being identified as non-compliant in the NPM. As the PAHO assesses free sugar rather than total sugar, one may expect the high free sugar content of 100 % fruit juice to be flagged as non-compliant by the PAHO model. However, the processing level qualifying criterion of the PAHO model exempts 100 % fruit juice as it is not considered processed[44].

The CAM which does not include a criterion for energy had a similar mean energy content to the CWO 2019 which does include a threshold for total energy for compliant products. The mean saturated fat and trans-fat values are slightly higher for the CAM than the other models, which is likely due to the exclusion of an energy criteria for this NPM. However, although the CAM has the highest mean for saturated fat in the compliant group, it is still well below the cut point for foods (4 g) and beverages (3 g). Similarly, the mean trans-fat content in the compliant group is well below the cut point provided in the SA trans-fat regulation[26].

Based on the results of the current study, the CAM is an appropriate NPM for its intended purpose. Out of the four NPM, the CWO 2019 and CAM were most closely aligned to each other. As the CAM was adapted from the CWO 2019, this is to be expected. The difference in alignment for beverages specifically indicates that the CAM's adaptations for ingredient criteria of free sugar and NSS had the intended outcome. Despite CAM having a lower number of products excessive in more than one nutrient of concern in comparison with the CWO 2019 and PAHO, this should not negatively affect its usage in policy as overall it had the second highest level on non-compliant products, and usage in policy is intended to be binary, based on the overall non-compliance of at least one nutrient profiling criterion and not the sum total of the number of excessive nutrients within one product.

The PAHO model may be considered too strict to practically use in policy. There is plenty of evidence suggesting the level of processing as addressed by the PAHO approach is one of its strengths given growing concern and evidence around the role of ultra-processing as an independent factor beyond that of nutrients on poor health outcomes[1]. However, with so few compliant products, particularly in the categories of legumes, vegetables and cereal products where it was much stricter than the other models, the public may become indifferent to its presence should it be used in policy as there will be very few viable compliant options, although this could encourage reformulation by manufacturers. It is the only assessed NPM to evaluate the quantity of free sugar rather than total sugar. From a health standpoint, free sugar is more appropriate to assess than total sugar; however from a regulatory standpoint, there is no way to differentiate between free and total sugar[45] making monitoring and evaluation of free sugar content extremely difficult without access to recipes which are often protected by companies. This is one of the reasons why most NPM used in regulation assess thresholds of total sugar rather than free sugar[46].

Several concerns arise around the SA HNC model. Firstly, calculating the FVNL score is not practical in the SA context. Without regulation requiring reporting of these values, rough estimations have to be made[33,42], making monitoring and evaluation challenging and creating difficulty in identifying dishonest manufacturers who may manipulate values. This is not aligned with recommended good policy objectives[46]. The points awarded for nutrients to encourage inadvertently diminish its effectivity at identifying nutrients to limit, as can be seen in the lower level of non-compliant products in this NPM. This model is currently recommended in SA's draft regulation R429 to identify products permitted to carry a health or nutrition claim rather than to identify harmful nutrients of concern. As such, it may still have a role to play in policy specifically for health claims as a subsequent step to the CAM. It is important that products do not carry both a warning for excessive nutrients of concern and a health claim encouraging consumption of certain healthy components as this has been found to create mixed messages on the healthfulness of foods and confuse consumers[47]. In other words, provided a product is first classified as not excessive in nutrients of concern according to the CAM criteria, a health claim could be allowed for products that also meet the SA HNC criteria.

Limitations and assumptions

Although data were collected in large supermarkets in the Western Cape with the intent of capturing a representative sample of packaged foods available on the SA market, it is possible that certain products only occur in certain shops or geographical areas not included in this data collection. Additionally, products were only included in the study if a NIP was present. As NIP are not currently a legal requirement in SA, many products had to be excluded from NPM analyses. It is recommended that the SA government enforce mandatory regulations for a NIP on all packaged foods. The information this panel provides can be used to assess compliance with various food regulations. The NIP should be transparent, standardised and easy to interpret as aligned with Codex guidelines[48].

Certain assumptions were made to compare across the different NPM. All products were treated equally, and consumption frequency as part of usual dietary intake was not considered. Products were included if they could be assessed according to the inclusion criteria for all four NPM. In real-life settings, some items are included by one NPM and excluded from analysis by another NPM. These items were not included in this analysis. Likewise, as free sugar and FVNL values were not available, assumptions made may have not always been correct. As the score-based SA HNC model includes points for both nutrients to limit and encourage and the threshold-based PAHO, CWO

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and CAM only include thresholds regarding nutrients of concern, it was not possible to compare across all four models specifically for excessive nutrients of concern.

Conclusion

Based on the assessment of four NPM against the SA-packaged food supply, the CAM is a suitable NPM to underpin food policies in SA. It is able to identify unhealthy products high in saturated fat, sugar, Na or containing NSS. Policies it can support include those that require the identification of unhealthy foods to be regulated, such as for the restriction of marketing to children, regulation in the school food environment and for warning FOPL.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980022000374

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4.4 Manuscript four

Title: Frank T., Thow A.M., Swart E.C., and Ng S.W. 2022. The potential effect of a front-of-package warning label for low-income adults in South Africa. Submitted to PLoS ONE on 19.10.22 (currently under review).

What is already known?

- Front-of-package warning label policies have been implemented effectively elsewhere in the world (e.g. Chile, Mexico, Peru and Israel), and are used to inform consumers about products high in unhealthy nutrients of concern, to inform marketing restricts and to inform policies on foods allowed to be sold and distributed in schools.
- A front-of-package warning label has been developed for use in South Africa, tested, and found to be well understood by the South Africa population.
- South Africa has high, and increasing levels of obesity, and nutrition-related NCDs.
- Low-income South Africans purchase foods from a variety of stores, including supermarkets, spaza stores and roadside vendors.

What are the new contributions from this study?

- This study provides evidence that low-income adults living in South Africa do consume the types of foods that would be subject to warning labels and would benefit should a front-of-package warning label regulation be implemented in South Africa. Almost all (92.0 %) participants reporting eating at least one food that would be subject to a warning label on the day prior to investigation, with 38.1 % of mean daily energy originating from products that would be subject to a warning label.
- This study provides evidence that high UPP consumers who are at higher risk for NCDs and obesity consume significantly more energy, saturated fat, sugar and sodium from products that would be subject to warning labels compared to low UPP consumers, and as a result would likely benefit more from a front-of-package warning label policy. These findings validate that the NPM developed and proposed for restrictive food policy in South Africa (in manuscript two and three) is suitable for its intended use, and could be effective if implemented.
- This study found that among low-income South Africans products that are likely to be subject to warning labels are commonly purchased from supermarkets and spaza stores, but very few

are purchased from roadside vendors. Additionally, the products most likely to be subject to warning labels are predominately the types of foods that are commercially produced in large factories. This supports the feasibility of a warning label regulation in terms of practical implementation; as it is easier for large, commercial businesses to implement changes to their package labels than small independent business owners.

How might this study affect research, practice or policy?

- This study provides evidence to the National Department of Health who have proposed implementing front-of-package labeling regulations that the policy has the potential to benefit not only middle- and upper-income South Africans, but also low-income South Africans. Additionally, it provides evidence that those who consume the largest quantities of UPPs (and are at higher risk of NCDs and obesity) are more likely to benefit more from the regulation.
- This study provides a baseline assessment that could provide helpful contextual information to future monitoring and evaluation studies regarding changes in the food environment, should a front-of-package warning label regulation be implemented in South Africa.

Contribution of the candidate: Together with input from my supervisors (A.M.T, E.C.S, and S.W.N) I conceptualized the study, and methodology for the study. I conducted all management, data cleaning and data analysis. Supervisors reviewed and provided feedback on the data analysis (S.W.N). I wrote the draft manuscript, and supervisors contributed to reviewing the manuscript (A.M.T, E.C.S, and S.W.N). Supervisors provided overall guidance to the project (A.M.T, E.C.S, and S.W.N). Additionally, primary data collection used as data sources in this manuscript was conducted by E.C.S., with myself as the project coordinator in the larger one of the two studies.

PLOS ONE

The potential effect of a front-of-package warning label policy for low-income adults in South Africa

--Manuscript Draft--

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Short Title:	The potential effect of a front-of-package warning label policy for low-income adults in South Africa
Corresponding Author:	Tamryn Frank, BSc Dietetics; M Nutrition University of the Western Cape Bellville, Western Cape SOUTH AFRICA
Keywords:	South Africa Low-income Dietary intake Ultra-processed Front-of-package Warning label Ultra-processed
Abstract:	Due to high levels of obesity and non-communicable diseases, mandatory front-of-package warning labels have been proposed in South Africa to promote a healthier food environment. To better understand the potential impact this regulation could have for low-income adults, we assessed the dietary proportion of foods consumed by low-income South Africans that would be subject to warning labels, and the retail food outlet types that these products are commonly purchased from. Secondary data from two cross-sectional studies including 2521 participants (18-50 years) residing in three low-income areas in South Africa (Mt Frere, Khayalitsha and Langa) were collected. We analysed one-day 24-hour dietary recalls and information on retail food outlet types. We assessed which products would be subject to warning labels using the criteria of the nutrient profiling model developed for front-of-package warning labels in South Africa. We classified foods by the Nova classification system to assess alignment between ultra-processed food consumption and products subject to warning labels. Ninety-two percent of this sample reported consuming at least one product on the previous day that would carry a warning label. On average, 38.1% of energy (2960.77kJ/d) from foods reported consumed came from products that would be subject to warning labels. The top 25th percentile of UPP consumers (high UPP consumers) obtained 12 times more energy from warning label products than low UPP consumers (6267.96kJ/d vs 519.18kJ/d, p<0.001). Among high UPP consumers, 79.1% of daily sodium, 60.9% daily sugar and 55.6% of daily saturated fat intake was attributable to warning label products. Low UPP consumers had significantly lower values at 32.4%, 22.1% and 8.1%, respectively. Warning label products were predominately purchased from supermarkets or informal spaza stores. Low-income South Africans are consuming energy dense UPPs, and policies that focus on discouraging unhealthy foods have the potential to promote health amongst low-income South Africans.
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Question	**Response**

The potential effect of a front-of-package warning label policy for low-income adults in South Africa

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The potential effect of a front-of-package warning label policy for low-income adults in South Africa

Abstract

Due to high levels of obesity and non-communicable diseases, mandatory front-of-package warning labels have been proposed in South Africa to promote a healthier food environment. To better understand the potential impact this regulation could have for low-income adults, we assessed the dietary proportion of foods consumed by low-income South Africans that would be subject to warning labels, and the retail food outlet types that these products are commonly purchased from. Secondary data from two cross-sectional studies including 2521 participants (18-50 years) residing in three low-income areas in South Africa (Mt Frere, Khayalitsha and Langa) were collected. We analysed one-day 24-hour dietary recalls and information on retail food outlet types. We assessed which products would be subject to warning labels using the criteria of the nutrient profiling model developed for front-of-package warning labels in South Africa. We classified foods by the Nova classification system to assess alignment between ultra-processed food consumption and products subject to warning labels. Ninety-two percent of this sample reported consuming at least one product on the previous day that would carry a warning label. On average, 38.1% of energy (2960.77kJ/d) from foods reported consumed came from products that would be subject to warning labels. The top 25th percentile of UPP consumers (high UPP consumers) obtained 12 times more energy from warning label products than low UPP consumers (6267.96kJ/d vs 519.18kJ/d, $p<0.001$). Among high UPP consumers, 79.1% of daily sodium, 60.9% daily sugar and 55.6% of daily saturated fat intake was attributable to warning label products. Low UPP consumers had significantly lower values at 32.4%, 22.1% and 8.1%, respectively. Warning label products were predominately purchased from supermarkets or informal spaza stores. Low-income South Africans are consuming energy dense UPPs, and policies that focus on discouraging unhealthy foods have the potential to promote health amongst low-income South Africans.

Introduction

Mandatory front-of-package warning labelling policies have been successfully introduced in a number of countries as part of food policy initiatives promoting a healthier food environment [1]. These front-of-package warning labels can serve to educate the public, to identify products that should not be marketed to children and to restrict in the school food environment, as has occurred in Chile [2] and Mexico [3]. Although these types of policies are fairly new, results from countries that have implemented them are promising [4–7]. However, the adoption and implementation of labelling policies have faced challenges, and clear evidence regarding potential impact can support uptake [8,9].

Recently, in response to the obesity pandemic and rising rates of diet-related non-communicable diseases, there have been extensive efforts to develop and test a front-of-package warning label in South Africa [10,11]. A newly published randomized control trial found the proposed warning label for South Africa outperformed other front-of-package labeling systems under discussion and supported by the food industry, in assisting participants in South Africa to successfully identify unhealthy products [11]. A country specific nutrient profiling model that identifies nutrients of concern to limited (saturated fat, sodium, total sugar and non-sugar sweetener) has been developed and tested to underpin the proposed front-of-package warning label in South Africa [12,13].

Front-of-package warning label systems are generally used on packaged foods [1], and this is what has been proposed for the warning label developed in South Africa [12]. These types of foods are predominantly mass-produced, ultra-processed products (UPPs) high in energy, sugar, saturated fat and sodium manufactured by multinational corporations [14] and sold in supermarkets and smaller stores, known as spaza shops in South Africa [15], but are less likely to be sold by informal food vendors. Low-income South Africans make use of a variety of different retail food outlets to purchase food from, including supermarkets, spaza stores and informal roadside vendors [15,16]. Given that 55% of South Africans live in poverty [17] and 65% are unable to afford to eat a healthy diet [18], the

question remains as to whether or not the proposed warning label would have the potential to contribute towards improving the health outcomes of the most vulnerable in the country.

As such, this study aimed to assess the proportion of the current diet consumed by a sample of low-income South Africans that would be subject to warning labels, and the types of retail food outlets that these products are commonly purchased from to better understand the potential impact a front-of-package warning label regulation could have amongst low-income adults living in South Africa. It is important to note that this study does not take into account product reformulation, which would be a likely result of a mandatory front-of-package regulation [19] or other regulations aimed at reducing nutrients of concern such as sugar-based taxes [20,21], as it is not possible to accurately estimate the amount of product reformulation that would occur with the data available. Instead, it explores the effect of a front-of-package warning label on the current food supply.

Methods

We analysed two purposefully selected dietary datasets of low-income adults living in South Africa. The two studies made use of the same data collection methods and instruments. Participants from three areas in South Africa were included in the study: Mt Frere (also known as KwaBhaca) in the Eastern Cape and Khayelitsha and Langa in Cape Town, Western Cape.

Data collection

Although data collection methodology was consistent across studies, the sampling procedures used in the two studies (referred to here as Study One for Mt Frere and Khayelitsha and Study Two for Langa) differed slightly to meet the primary study objectives.

Study One randomly sampled 300 households at each study site in October and November of 2017. Four semi-purposive stratified sample clusters were selected per site and a purposively selected starting point and suitable sampling interval was chosen for each quadrant. One randomly selected

individual between the age of 18-50 years was chosen as a respondent per household. For Study Two, each household included in the study included one randomly selected adult between the ages of 18 to 39 years old. Data was collected by means of door-to-door sampling in Langa during February and March 2018, with a target sample size of 2250 participants.

Fieldworkers were extensively trained in data collection methods, with special attention given to dietary data collection training. A digital platform was used to collect sociodemographic data via cellphones, which included household characteristics and a question on the types of retail food outlets various pre-defined foods were most commonly purchased from. Dietary data was collected by means of a paper-based one-day standardised 24-hour dietary recall questionnaire. Interviews were conducted in the predominant languages spoken at the study sites, which fieldworkers were fluent in. Individuals were included in the studies provided informed consent was obtained and they met the inclusion criteria of the study.

Participants from these two primary studies were only included for secondary analysis if they had completed all relevant questionnaires. In total, 2521 adults between the ages of 18 and 50 years were included in this study; 169 participants from Mt Frere, 191 from Khayalitsha, and 2161 from Langa. This was 51.2%, 61.2% and 85.3% of the original sample size respectively.

This project was approved by the Human and Social Sciences Research Ethics committee HS19/6/3 of the University of the Western Cape, South Africa.

Data coding

The South Africa Medical Research Council (SAMRC) food composition tables (FCT) [22] and food quantities manual [23] were used to code dietary data from the 24-hour dietary recalls. The coding was conducted by trained dietary data capturers with tertiary level nutrition qualifications. We developed a coding manual to ensure it was carried out in a consistent and standardised manner.

The proportion of products carrying a warning label is expressed by ultra-processed intake quartile. The classification for this was done using the Nova food classification system [24,25]. This system groups foods and beverages into distinct categories based on the level of industrial processing, and for this study, products were grouped into one of four categories: 1) unprocessed / minimally processed; 2) processed culinary ingredients; 3) processed or 4) ultra-processed [24,26]. Products were then classified as ultra-processed (Nova group 4) or not ultra-processed (Nova groups 1-3); as the share of the diet attributed to UPP was of interest. This categorisation was undertaken independently by two registered dietitians who classified foods and beverages consumed according to the Nova classification system. Any classification discrepancies were resolved through consultation with a third dietitian to reach consensus.

We used the criteria of the nutrient profiling model developed for front-of-package warning labels in South Africa [12] to assess whether or not products would be subject to a front-of-package warning label (see Appendix 1). As the nutrient profiling model assesses packages foods that contain any added sodium, added saturated fat, free sugar or any non-sugar sweetener products were first evaluated to identify those that should be included in the nutrient profiling model assessment by using the SAMRC FCT, and if it did not contain adequate information, using the ingredient list and nutritional information of products in the food database used during the nutrient profiling model development (discussed elsewhere [13]). This was especially necessary for non-sugar sweetener which is not included in the SAMRC FCT, and total sugar, which has many missing values in the SAMRC FCT. Out of a potential 506 products, 202 products were identified as appropriate to be included in the nutrient profiling model assessment. Once products were identified as appropriate to be assessed by the nutrient profiling model products were then divided into liquids and solids, as the cut-point for the nutrient profiling model varied for each; and the nutrient profiling model's criteria was applied.

Data analysis

Data analysis was conducted in Stata version 17 (StataCorp, College Station, TX, USA, 2021). Participants who consumed less than 400kJ or more than 20 000kJ per day were excluded from dietary analysis [27]. Nutrient content outliers were verified by checking the original 24-hour recalls and correcting the information when appropriate. For nutrient-specific evaluations, missing values in the SAMRC FCT resulted in missing data for some of the analyses. This was particularly pronounced for total sugar, where missing data resulted in lower mean sugar values. It is important to note that although the nutrient profiling model inclusion criteria for both non-sugar sweetener and total sugar made use of additional information from the nutrient profiling model food database when the SAMRC FCT data was insufficient (as discussed above), for all dietary data analysis values in the SAMRC nutritional composition data were used.

Using the nutrient profiling model, the number of products consumed by participants on the day prior to data collection which could potentially carry warning labels was assessed overall, as well as by each nutrient of concern (sodium, saturated fat, total sugar and non-sugar sweetener). We calculated the mean energy, mean saturated fat, mean total sugar and mean sodium intake overall, as well as specifically for products that would be subject to a warning label. The share of energy intake that UPP intake accounted for was used to create UPP consumption quartiles. Participants were classified as high UPP consumers if they were in the highest quartile of UPP consumption and low UPP consumers if they were within the lowest quartile. The difference in the share of energy accounted for by products that would be subject to a warning label between high and low UPP consumers was compared using a two-sample Wilcoxon rank-sum test, with statistical significance considered at $p<0.05$.

The share of total energy that each food group accounted for was calculated, overall as well as for products in each category with and without warning labels. Food groups classification was consistent with those in the SAMRC FCT, to allow for comparison with other studies. Examples of the types of products within each food category that would or would not require a warning label were assessed

by grouping items together based on the food group categories and the nutrient profiling model criteria for the warning labels. The retail food outlet types that food products that would carry warning labels were purchased from were assessed for the food categories that accounted for the largest share of energy from warning label products.

Results

Throughout the results section, results are interpreted in terms of the likelihood of a product being subject to a front-of-packaging warning label, should there be regulation expecting products that are excessive in nutrients of concern to carry a warning label.

Share of the diet attributable to products that would be subject to a warning label

Almost all (n = 2320, 92.0%) participants consumed at least one product on the previous day that would be subject to a warning label. Most commonly (n = 887, 35.2%), participants consumed one to two products that would be subject to a warning label, followed by three to four products (n = 866, 34.4%). Just over 20 percent (n = 567) of participants consumed five or more products the previous day that would carry a warning label. Regarding nutrients of concern, participants were most likely to consume one or more products on the day prior that would be subject to a warning label for sodium (n = 2012, 79.8%), followed by total sugar (n = 1708, 67.8%) and then saturated fat (n = 1473, n = 58.4%). Participants were least likely to consume foods that contained a warning label for non-sugar sweetener, with 87.6% of participants not consuming any products that contained non-sugar sweetener (see Fig 1 for more information).

Fig 1. Percentage of participants that consumed no, one to two, three to four, or more than five products that would be subject to a warning label, by warning label type (any, saturated fat, sugar, sodium and non-sugar sweetener)

As shown in Table 1 the share of the diet attributable to products that would be subject to a warning label was examined. On average, 38.1% of energy (2960.77kJ/d) from foods reported consumed came from products that would be subject to warning labels. High UPP consumers (top quartile of energy from UPP) consumed 12 times more energy from warning label products than low UPP consumers (6267.96kJ/d vs 519.18kJ/d, $p<0.001$). This trend was also observed for saturated fat, total sugar and sodium. This was true for both the absolute intake, as well as the share of the diet; high UPP consumers consumed more of all the nutrients of concern overall, and despite their higher intake overall, the share of their diet attributable to warning label products was also significantly higher than the low UPP consumers. For high UPP consumers 79.1% of their daily sodium intake was attributed to warning label products, 60.9% of their daily total sugar and 55.6% of their daily saturated fat intake was attributable to warning label products. For low UPP consumers this was significantly lower, at 32.4% for sodium, 22.1% for total sugar and 8.1% for saturated fat respectively (Fig 2).

Table 1. Share of diet attributable to products that would be subject to a warning label, by level of ultra-processed product (UPP) consumption

		Total intake per day		Intake from products that would be subject to a warning label			
		Mean (SE)	Min-Max	Mean share of total (%)	Mean (SE)	Min-Max	Level of significance
Energy (kJ/d)	All participants	7762.13 (65.90)	460.00-19961.56	38.14	2960.77 (49.69)	0.00-17151.38	-
	High UPP consumers	10787.64 (125.27)	4700.40-19663.28	58.10	6267.96 (94.10)	617.4-17151.38	<0.001*
	Low UPP consumers	5721.10 (103.75)	4600.00-19961.56	9.07	519.18 (19.75)	0.00-3242.05	
Saturated fat (g/d)	All participants	15.50 (0.25)	0.00-115.75	36.77	5.70 (0.18)	0.00-108.87	-
	High UPP consumers	25.76 (0.62)	1.12-115.75	55.63	14.33 (0.53)	0.00-108.86	<0.001*
	Low UPP consumers	8.63 (0.29)	0.00-72.58	8.11	0.70 (0.07)	0.00-10.41	
Total sugar (g/d)	All participants	63.07 (0.94)	0.00-407.15	49.50	31.22 (0.75)	0.00-313.21	-
	High UPP consumers	92.72 (2.28)	0.00-407.15	60.94	56.50 (1.94)	0.00-313.21	<0.001*
	Low UPP consumers	36.63 (1.33)	0.00-372.00	22.14	8.11 (0.61)	0.00-69.60	
Sodium (mg/d)	All participants	1627.03 (27.48)	0.00-13636.01	70.18	1141.80 (26.27)	0.00-13184.20	-
	High UPP consumers	3044.82 (67.40)	317.36-13636.01	79.12	2409.04 (69.04)	0.00-13184.20	<0.001*
	Low UPP consumers	606.23 (20.01)	0.00-3133.93	32.44	196.64 (11.53)	0.00-1561.70	

*Level of significance assumed at p<0.05. Two-sample Wilcoxon rank-sum used to test level of significance
#Non-sugar sweetener is not included in this table as the criteria for inclusion of non-sugar sweeter as a front-of-package warning label assesses presence, rather than contribution to intake, which is different to the other dietary components assessed (saturated fat, total sugar and sodium)

Fig 2. Percentage of total daily energy, saturated fat, sugar and sodium consumed from products that would be subject to warning labels, by ultra-processed product consumption level

* Low ultra-processed consumers consumed significantly less energy, saturated fat, sugar and sodium than high ultra-processed consumers. Two-sample Wilcoxon rank-sum used to test level of significance. Level of significance assumed at p<0.05.

Food categories, share of energy, and types of products most likely to be subject to a warning label

The types of products that would be subject to a warning label were assessed by food category. The food category that contributed to the largest share of mean total energy overall (3814.07kJ/d, 49.1%), and for products that carried warning labels (1405.46kJ/d, 18.1%) was cereals and cereal products.

Products in this category that were likely to carry a warning label included sugary breakfast cereals, baked treats such as cakes, muffins and biscuits, savoury snacks (such as crisps) and some breads. This category also contributed to the largest share of energy from non-warning label products (2408.6kJ/d, 31.0%), which included products such as single ingredient products (oats, rice, flour etc), wholewheat bread and some breakfast cereals. The food category that contributed to the second highest share of energy from warning label products was sugars, syrups and sweets, at 5.1% of mean total energy per day (399.22kJ/d) from warning label products. This included products such as carbonated beverages, energy drinks, sweets and chocolates. Non warning label products in this category included plain sugar and honey. This was followed by meat and meat products, where warning label products accounted for 4.9% of total energy (376.62kJ/d) and included processed meats such as sausages, bacon, polony, salami and viennas. The products without warning labels in this category were predominantly single ingredient meats (of all types). Fresh, frozen, cooked and dried fruits, vegetables, legumes, meats and seafood were unlikely to carry warning labels; whilst products in these categories that had been canned or otherwise preserved with added sugar or sodium were more likely to be subject to warning labels. Refer to Table 2 for further details. Alcoholic beverages are not subject to warning labels as they are not assessed by the nutrient profiling model's criteria.

Table 2. Share of energy (by food category) from products that would be subject to a warning label

Food category	All products			Products with warning labels			Products without warning labels		
	Total no of unique products	Mean energy kJ/d (SE)	Share of total energy (%)	Total no of unique products	Mean energy kJ/d (SE)	Share of total energy (%)	Total no of unique products	Mean energy kJ/d (SE)	Share of total energy (%)
Cereals and cereal products	95	3814.07 (41.05)	49.14	55	1405.46 (30.50)	18.11	40	2408.61 (37.70)	31.03
				Examples: Sugary breakfast cereals, cakes/muffins, biscuits, savoury snacks, some breads			Examples: Single ingredient products (oats, rice, flour etc) wholewheat breads, some breakfast cereals		
Sugar, syrups and sweets	26	715.90 (14.93)	9.22	22	399.22 (12.36)	5.14	4	316.68 (9.22)	4.08
				Examples: Carbonated beverages, energy drinks, sweets, chocolates, syrups			Examples: Honey, sugar		
Fats and oils	18	384.21 (13.09)	4.95	10	350.87 (12.92)	4.52	8	33.34 (2.51)	0.43
				Examples: Margarine, salad dressing			Examples: Single ingredient products		
Meat and meat products	73	1163.75 (28.26)	14.99	18	376.62 (20.62)	4.50	55	787.13 (20.32)	10.14
				Examples: Processed meats, eg sausage, bacon, polony, salami, Vienna			Examples: Various fresh meats (chicken, pork, mutton, offal, beef) – minced, stewed, braised, grilled, roasted		
Beverages	22	224.54 (10.44)	2.89	21	224.34 (10.43)	2.89	1	0.20 (0.17)	<0.01
				Examples: Fruit juices, flavoured dairy drinks			Examples: Carrot juice (water not coded, also included)		
Milk and milk products	31	402.59 (13.93)	5.19	19	179.79 (10.62)	2.32	12	222.80 (9.33)	2.87
				Examples: Cheese, ice-cream, flavoured yogurt, drinking yogurt			Examples: Milk, plain yogurt, cottage cheese		
Soups, sauces, seasonings and flavourings	32	37.29 (3.73)	0.48	16	16.78 (2.70)	0.22	16	20.51 (2.61)	0.26
				Examples: Chutney, gravy, sauces, some soups			Examples: Herbs, spices, some soups		
Nuts and seeds	6	6.44 (2.27)	0.08	1	3.65 (1.93)	0.05	5	2.79 (1.19)	0.04
				Examples: Salted			Examples: Plain		
Fish and seafood	18	85.23 (6.34)	1.10	4	1.52 (0.82)	0.02	14	83.71 (6.30)	1.08
				Examples: Smoked, canned			Examples: Fresh, canned		
Vegetables	113	474.15 (15.74)	6.11	2	1.34 (0.46)	0.02	111	472.81 (15.72)	6.09
				Examples: Pickled veg, veg with added mayonnaise (commercial coleslaw)			Examples: Fresh, frozen, cooked, canned		
Fruits	32	109.96 (6.24)	1.42	3	0.44 (0.25)	0.01	29	109.51 (6.23)	1.41
				Examples: Canned, dried with sugar added			Examples: Fresh, dried		
Miscellaneous	19	168.00 (19.56)	2.16	1	0.72 (0.74)	0.01	18	167.28 (19.56)	2.16
				Examples: Bovril (high sodium spread)			Examples: Tea, coffee, alcoholic beverages		
Legumes and legume products	11	27.40 (3.97)	0.35	0	0.00 (0.00)	0.00	11	27.40 (3.97)	0.35
				Examples: n/a			Examples: Fresh, dried, canned		
Eggs	10	148.58 (7.10)	1.91	0	0.00 (0.00)	0.00	10	148.58 (7.10)	1.91
				Examples: n/a			Examples: Eggs (any cooking method)		
TOTAL	**506**	**7762.13 (65.90)**	**100.00**	**172**	**2960.77 (49.69)**	**38.14**	**334**	**4801.36 (51.53)**	**61.86**

*Food category classifications align with the food categories in the South African Food Composition Table

Retail food outlet types that products that would be subject to warning labels are commonly purchased from

The type of retail food outlet that warning label products were predominately purchased from by this sample of low-income South Africans were evaluated for food categories that contributed to the largest share of energy from warning label products (see Table 3). All products were predominately purchased from either supermarkets (which included supermarkets, wholesalers and general dealers); and informal retail food outlets, otherwise known as spaza stores in South Africa (which included spaza shops, house-shops, container shops, and permanent stalls). Products where more than 50% of participants reported purchasing predominately from supermarkets included commercial breakfast cereals, instant noodles, confectionery, processed dairy products, processed meats, margarine and fat spreads and diet soft drinks. Spaza shops were the predominant retail food outlet to purchase bread, salty snacks (such as crisps), sweets and regular soft drinks from. In all categories, very few products (less than 3.7%) were purchased from roadside vendors.

Table 3. Retail food outlet types that products that would be subject to a warning label are most commonly purchased from

Food Category	Product	Type of retail food outlets products likely to be subject to warning labels are most commonly purchased from		
		Supermarket n (%)	Spaza shop n (%)	Roadside vendor n (%)
Cereals and cereal products	Commercial bread	361 (15.80)	1921 (84.07)	3 (0.13)
	Commercial breakfast cereals	1408 (97.51)	36 (2.49)	0 (0.00)
	Instant noodles	669 (91.39)	62 (8.47)	1 (0.14)
	Salty snacks	357 (31.18)	782 (68.30)	6 (0.52)
	Confectionary	645 (59.89)	424 (39.37)	8 (0.74)
Sugar, syrups and sweets	Sweets	296 (34.66)	554 (64.87)	4 (0.47)
	Soft drink - regular	570 (25.30)	1680 (74.60)	2 (0.09)
	Soft drink - diet	171 (54.81)	141 (45.19)	0 (0.00)
Fats and oils	Margarine and fat spreads	2056 (95.14)	105 (4.86)	0 (0.00)
Meat and meat products	Processed meats	1109 (79.84)	229 (16.49)	51 (3.67)
Milk and milk products	Processed dairy products	1193 (89.43)	134 (10.04)	7 (0.52)

Food categories presented here were selected as the categories in which products with warning labels contribute the largest share to total energy consumed. Although “beverages” was one of the top five categories with warning labels that contributed to energy it was not included as dairy beverages are included in “processed dairy products” and fruit juice purchase habits were not captured in the questionnaire. Participants only answered these questions for products that they purchased regularly, and as a result totals do not equal the total number of participants in the study.

Supermarket includes: supermarkets, wholesalers and general dealers
Spaza shop includes: spaza shops, house-shops, container shops, permanent fixed stalls, and fixed municipal stalls
Roadside vendor includes: temporary stalls, mobile traders, bakkie traders, and informal abattoirs

Discussion

Concerns have been raised that a front-of-package warning label policy may predominantly benefit middle- and high-income consumers as they consume more UPP than low-income consumers [28], however, as the nutrition transition has progressed, UPP intake has increased amongst low-income consumers [29]. Our study findings supported such observations since, on average, approximately 40% of daily energy consumed by adults in this sample residing in low-income areas of South Africa, came from products that would be subject to a warning label, and more than 90% of participants consumed at least one product in the preceding 24-hours that would be subject to a warning label. These findings suggest that a front-of-package warning label policy has the potential to benefit low-income South Africans and should be considered as part of a suite of food policies or regulations to promote a healthier food environment in South Africa. Additionally, amongst low-income consumers those who consumed more UPP consumed a higher share of energy from warning label products. As high UPP consumption has been linked to higher rates of obesity and non-communicable diseases [30–33] a front-of-package warning label policy has promising prospects for preventing poor health among the most vulnerable in South Africa. Recent research into the development of a front-of-package warning label in South Africa, by means of a randomized control trial, has found that a simple, interpretative warning label is a suitable label for identifying unhealthy products, and is well-understood and effective across all income groups in the country [11].

The food retail landscape in South Africa has been shaped historically by corporate political economic strategies [34], with roadside vendors and small stores being replaced by supermarkets in recent years [35]. Likewise, products in our stud that would be subject to warning labels were predominately reported to be purchased from supermarkets and spaza stores. As front-of-package labelling policies routinely apply to products produced, packaged and labelled in factories and then distributed to stores [14], it is feasible that the majority of products expected to carry warning labels will logistically be able to carry them. Some recent research suggests that residential proximity to supermarkets increases the risk of overweight and obesity in South Africa [16]. Although spaza stores sell a variety of both local unpackaged products and commercial products, the types of

products that participants regularly purchased from spaza stores that would be subject to a warning label such as soft drinks, commercial bread and crisps are more inclined to be mass produced products emanating from factories [15] and should thus carry warning labels (if excessive in nutrients of concern). However, certain products such as sweets may be less likely to carry warning labels should the spaza shop first decant the product from original packaging into smaller packages before selling (as is sometimes observed in spaza stores [36]). This could be rectified by having a warning label on the package holder, rather than the individual packages for smaller items, as has been done elsewhere [2]. There have been some recent reports of spaza shops stocking counterfeit products [36], which could result in some monitoring and evaluation challenges should a front-of-package warning label policy be implemented in South Africa. Counterfeit packaging appears to emulate original packaging closely [36], and it is possible that even if counterfeit products are sold, they may have warning labels on their packaging should the brand-name products carry them, although this does not address the health and safety concerns of counterfeit products.

This study supports research that has been done to validate the proposed nutrient profiling model for South Africa [13]. By assessing the types of products that do or do not carry warning labels it is evident that products consumed by study participants that are generally considered to be unhealthy were more likely to be subject to a warning label. Additionally, although the underlying criteria of the nutrient profiling model does not directly assess UPPs, it is evident from the findings of this study that products that would be subject to a warning label are predominately UPPs. The types of foods in this study that were classified as subject or not subject to a warning label also align well with the South African Food Based Dietary Guidelines that encourages the intake of items like fruits, vegetables, legumes, milk, chicken, lean meat and eggs but discourages the consumption of fats, sugars and salt [37]. The one exception to promoting healthy dietary intake is that the underlying nutrient profiling model excludes alcoholic beverages from assessment and as a result they are not subject to carry warning labels. This is in line with other nutrient profiling models around the world [2,38,39], however, it is important the health harms of excessive alcohol consumption are addressed through other policies [40].

Despite the potential benefits that this study demonstrates for implementing a mandatory front-of-package warning label regulation in South Africa, it is important to note the impact that product reformulation will have, should such a policy be implemented. In other countries that have mandatory front-of-package regulations the food and beverage industry has reformulated products to avoid them being subject to warning labels [14,19]. Similar actions have been observed in South Africa after the announcement and implementation of the sugar-density based Health Promotion Levy on sugar-sweetened beverages, which resulted in the beverage industry reducing the sugar content of some of their beverages to avoid the tax or lower their tax liability[41]. A direct result of product reformulation is that, due to a reduction in nutrients of concern, less products are subject to warning labels [19]. An assumption can thus be made that, due to reformulation, if a mandatory front-of-package warning label policy is introduced in South Africa, the absolute number of products that would be subject to warning labels would likely be less than what is represented in this study. Reformulation has potential benefits for reducing the quantity of sugar, sodium, saturated fats and non-sugar sweetener in products, and thus the amount consumed by the general population. However, it does not resolve the issue of UPP consumption, as reformulated products will likely remain predominately ultra-processed. Consumption of UPPs has been found to be positively associated with obesity, cardiovascular disease, cancer, hypertension, diabetes and all-cause mortality [30,31,33,42,43].

Besides the potential for front-of-package warning labels to assist consumers to make more informed decisions whilst shopping, a front-of-package warning label policy could have further reaching effects, as is evident from the regulation implemented in Chile [14]. Warning labels have the potential to inform policies that regulate food marketing, restrict unhealthy foods in schools and other government institutions, and can be used to identify unhealthy products to tax [1]. Together, these types of policies have the potential to promote a meaningfully healthier food environment in South Africa. Additionally, front-of-package warning label policy implemented in South Africa could also have further reaching impacts for sub-Saharan Africa, as South Africa serves as a gateway for exporting packaged foods throughout the region [15].

Limitations and assumptions

As this study assessed products that would be subject to warning labels based on 2017/2018 dietary intake data, the impact that product reformulation will have, should a mandatory front-of-package warning label regulation be implemented, was unable to be accounted for. Thus, it is important to note that although this study does provide useful information on the share of the diet that could be impacted (through reformulation and/or warning labels) it likely over-estimates the percentage of the diet that would be subject to a warning label.

In order to classify products as subject to carry a warning label, or not; as well as to classify products according to the Nova classification system assumptions needed to be made, such as whether products were home-made, or store bought. The nutrient profiling model, as well as the Nova system are typically applied to individual foods, at a product/brand-name level. For some packaged products, nutritional composition can differ significantly from one brand to another. However, the secondary dietary data used for this study was coded according to the SAMRC FCT which does not have individual food level data. The SAMRC FCT does not report non-sugar sweetener content, and thus assumptions were made regarding which products contained, or did not contain non-sugar sweetener. To limit the effect of assumptions that needed to be made, classification was done independently by two trained dietitians familiar with this type of analysis, and discrepancies were resolved through discussion with a third dietitian. Sugar intake was underestimated in this study. When the SAMRC FCT was applied to the dietary intake data, 19.4% of items consumed by study participants had missing total sugar values. There were no missing values in the SAMRC FCT for energy, and less than five percent of missing values saturated fat and sodium.

The questionnaire that assessed the retail food outlet types that food products were most frequently purchased was not aligned with the SAMRC FCT food groups and thus direct comparison could not be made, although it was possible to gain an understanding of the types of retail food outlets products that would be subject to warning labels were typically purchased from. The study sample reflects two of nine South African provinces, which limits generalisability of findings. Although the same

methodologies and standardised questionnaires were used in the two included studies, some of the fieldworkers differed, and the sample size differed by study. Additionally, due to the available secondary data, dietary assessment was based on a single-day 24-hour recall. This does not capture intra-person day-to-day variation; however the large study sample size allows for sufficiently accurate means with a single-day recall [27].

Conclusion

Low-income South Africans are consuming energy dense, UPPs that would be subject to a front-of-package warning label policy should such a policy be implemented in the country. A front-of package warning label that is easily understood by consumers and informs them when products contain excessive amounts of nutrients of concern have the potential to promote health amongst low-income South Africans, and not only middle- and high income groups.

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Figure 1

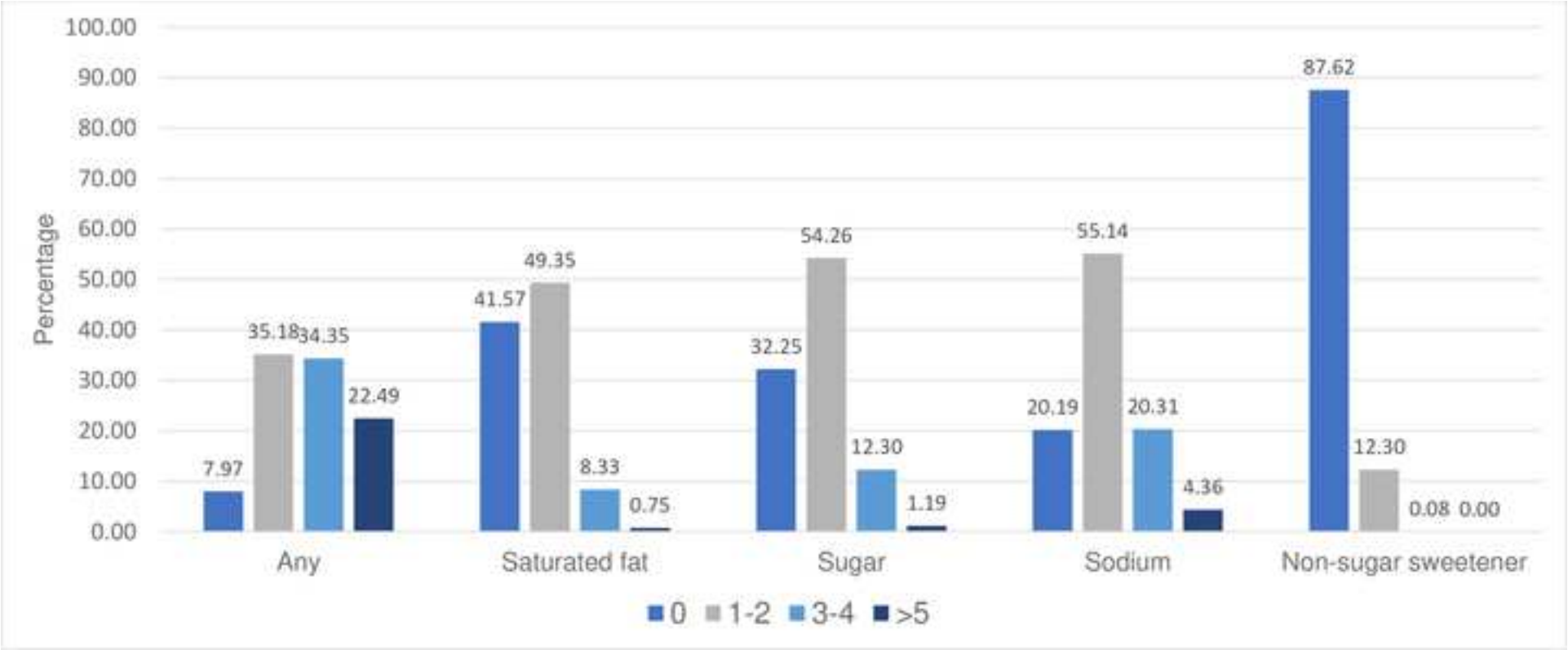
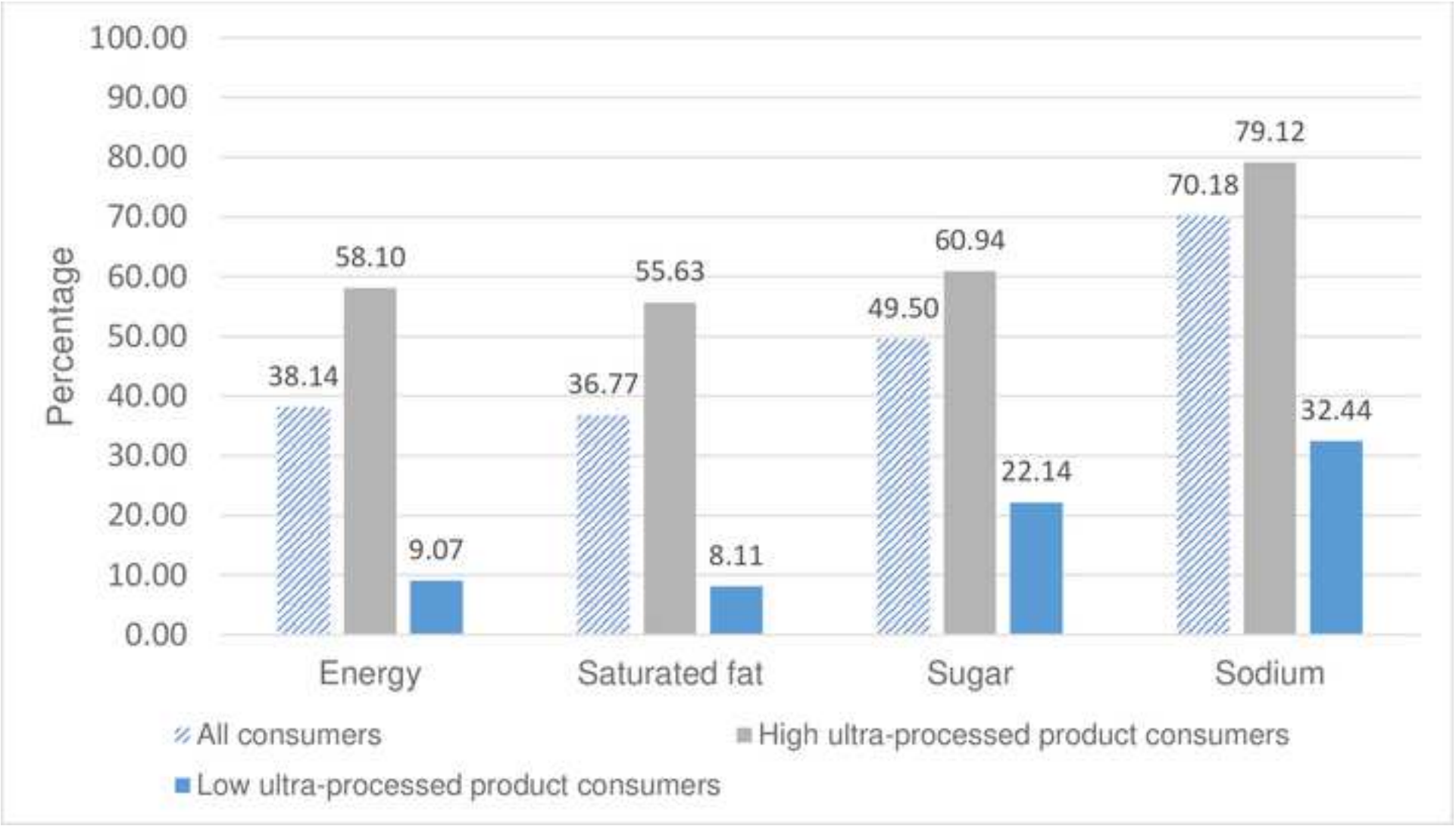


Figure 2



CHAPTER 5: Discussion, recommendations and conclusion

This chapter sets out to synthesize the main findings of this research project, by locating the results within the study's aim and objectives; and interpreting them in terms of the broader health and policy setting. I begin by providing a summary of the main findings of this research project, and how these findings align with the research aim and objectives this study set out to address. I then discuss the new contributions this study makes to this field of research, and shed light on the public health and policy implications that these findings may have for South Africa. Hereafter, I highlight the remaining gaps in this area of research, and the potential next steps that are needed, to ensure that research can be moved from theory to practice through improved policies so that a healthier food environment can be realised. Finally, the chapter ends with a short conclusion.

Please note, study limitations are discussed in the four manuscripts in Chapter 4 as well as in Chapter 3 (methodology), under each research objective. For more details, refer to Chapter 4 and sections 3.2.8, 3.3.8 and 3.4.3.

5.1 Summary of research findings aligned to study aim and objectives

This study set out to develop an NPM that would serve the vulnerable low-income population of South Africa, by providing an assessment of the healthfulness of foods in a manner that would be appropriate and useful for use to underpin a front-of-package warning label system in the country.

In doing so, the first step was to examine the dietary intake of low-income South Africans to understand the types of foods that are consumed, and thus provide supportive evidence for the types of foods that are most appropriate to include in the NPM. In doing so, I found that UPPs contribute significantly to the dietary intake of low-income adults living in South Africa. Additionally, study participants were less likely to meet the WHO dietary guidelines for nutrients of concern to limit (saturated fat, sodium and free sugar) if they were high UPP consumers than if they were low UPP consumers. High UPP consumers consumed double the daily energy of low UPP consumers. All participants, regardless of their UPP consumption level consumed inadequate protective dietary components (fibre, fruits, vegetables, nuts, legumes and wholegrains). These findings are presented

in manuscript one of the results chapter (Section 4.1) and contributed towards answering objective one of my study.

In order to answer objective two of the study, and indeed the main aim and research question of the study, I set out to develop and test an NPM that would suitable to identify packaged foods high in nutrients of concern to limit in South Africa. In following an evidence-informed process to develop an NPM, I identified that an NPM that focused on unhealthy foods to limit would be the most appropriate NPM for the South African context (Frank et al., 2021). Additional important aspects, such as the need for an easy-to-implement NPM given the resource limited setting of South Africa, using cut-points and an across the board approach, and the appropriateness of a per 100 g format were identified through the process. Together with this, in answering objective two, the key nutrients and food components most suitable to include in the NPM were identified as saturated fat, sodium, total sugar and non-sugar sweetener. Following recommendations in the scientific literature, an existing NPM similar in style and purpose to the proposed NPM was adapted to meet the inclusion criteria identified as important for the proposed NPM. After extensive review of existing NPMs, the CWO NPM was selected as most appropriate to adapt. The proposed NPM, which was adapted from the CWO NPM, assesses packaged foods and beverages that contain any added saturated fat, added sodium, free sugar, or contain any non-sugar sweetener and, using cut-points for saturated fat, total sugar, sodium and non-sugar sweetener identifies products that are excessive in nutrients of concern to limit, that should be restricted. After testing the proposed NPM against the South African packaged food supply alongside three other NPMs (the CWO NPM, the PAHO NPM and the SA HNC NPM) (Frank, Ng, Miles, & Swart, 2022), it was found to be fit-for-purpose and effective to use in restrictive food policy in South Africa, such as front-of-package labelling, marketing restrictions and restrictions in the school food environment. This answered objective two of the study, and these detailed results are found in manuscript two and three of the results chapter (Section 4.2 and 4.3).

In the final part of the research project, I applied the proposed NPM to the dietary intake of low-income adults living in South Africa to assess the potential impact of the NPM, if used to underpin a front-of-package warning label policy in the country. The findings of this study were encouraging, as I found that low-income adults living in South Africa would receive potential benefits from such a policy being implemented as they do consume the types of foods that would carry front-of-package warning labels. Additionally, those who consumed higher amounts of UPPs consumed more of their daily energy from foods that would carry a front-of-package warning label than low UPP consumers. Thus the high UPP consumers, who are more vulnerable to ill health due to their higher risk for

obesity and nutrition-related NCDs, would benefit the most from such a policy. These findings addressed research objective three of my doctoral research project. In addition to this, this part of the study also examined the types of food retail outlets that various foods are commonly purchased from, to answer the final sub-objective of objective one. I found that foods most likely to carry a front-of-package warning label were most likely to be purchased from supermarkets or spaza stores. They were typically the types of food that are commercially produced in large factories, and this confirms that they are the types of food that would be appropriate and easy to include in country-wide restrictive food policies. These findings can be found in manuscript four, in Section 4.4 of the results chapter.

5.2 New contributions from this study, and the implications for public health and policies in South Africa

This study provides several new insights into the food and nutrition environment in South Africa. Additionally, it provides a rigorously tested, context-specific NPM that can be used in a harmonised manner across national food policies in South Africa. This section is divided into five sections to highlight the significant research findings, the implications they have on health in South Africa, and the potential impact they could have on policy in South Africa.

5.2.1 Low-income adults living in South Africa are consuming high levels of UPPs

Although South Africa is classified as an upper-middle income country (Mbogori et al., 2020), it has the highest Gini-coefficient in the world (World Bank, 2022), with 55 % of the population living in poverty (Samodien et al., 2021; World Bank, 2021). Unemployment levels are high, at 34 % (Statistics South Africa, 2022), and 65 % of South Africans are unable to afford a healthy diet (FAO et al., 2022). As a result, low-income adults living in South Africa do not consume a healthy diet.

This study found that UPP consumption was high amongst low-income adults living in South Africa, contributing 38 % to mean daily energy intake overall, but those who consumed the most UPPs were more likely to consume excessive amounts of saturated fat, sugar, sodium and processed meat.

Additionally, the South African food supply has an oversupply of UPPs. In supermarkets, 76 % of packaged products included in this study were ultra-processed. This leaves little space for consumers to select healthy food choices.

These findings support literature that indicates that the nutrition transition is advanced in South Africa (Abrahams et al., 2011; Haggblade et al., 2016), which typically goes hand in hand with the proliferation of UPPs (Baker et al., 2020). What is most concerning about this UPP explosion and advancing nutrition transition, is the increased levels of obesity and nutrition-related NCDs that it contributes to. If current trends continue, South Africa is predicted to be the country with the tenth highest rate of childhood obesity, globally, by 2030 (Lobstein & Brinsden, 2019). Two-thirds of South African women are overweight or obesity, and levels of diabetes, hypertension and cardiovascular disease are continuously increasing in South Africa (Mbogori et al., 2020; Statistics South Africa, 2017). These rising rates of NCD morbidity place undue pressure on an already overburdened health care system (Botha & Vermund, 2022). In 2020, overweight and obesity accounted for 15 % of government health expenditure, and if left unresolved, this will continue to increase (Boachie et al., 2022). Additionally, the recent events of the COVID-19 pandemic have further emphasized the burden that obesity and NCDs place on the healthcare system. COVID-19 morbidity and mortality rates increase in the presence of obesity, diabetes and cardiovascular disease (Luzi & Radaelli, 2020; Malavazos et al., 2020; Popkin et al., 2020). Besides the burden of treatment costs placed on the government, the treatment of NCDs places a high out-of-pocket financial burden on individuals and households in LMICs (Kazibwe et al., 2021). There are also other costs borne by South African individuals and families such as lower ability to work and earn an income due to obesity and NCDs, conditions which negatively affect labour force participation in the country (Lawana et al., 2020). Overweight, obesity and the resulting NCDs accounted for approximately 9.4 million disability-adjusted life years in 2017 (Boachie et al., 2022; Dai et al., 2020; Gouda et al., 2019; Murray et al., 2020). These impacts have implications for the economic development and growth of South Africa.

The dramatic increase in UPP production raises concerns about environmental sustainability as UPPs have been associated with environmental degradation, such as increased greenhouse gas emissions, water use, land use and biodiversity losses (Anastasiou, Baker, Hadjikakou, Hendrie, & Lawrence, 2022). Currently, very little is known about the true environmental costs of UPPs attributed to resources used during agriculture, processing, packaging and distribution (Seferidi et al., 2020). UPPs undergo extensive manufacturing along the value-chain before they are sold in stores that have

negative environmental impacts (Anastasiou et al., 2022; Seferidi et al., 2020). The substantial amount of food packaging contributes considerably to waste production, may possibly contain carcinogenic compounds, and food additives found in UPPs may be detrimental to the environment (Seferidi et al., 2020).

These costs, both in terms of productivity and health costs, as well as environmental damage could be avoidable, if more was done to reinvent the food environment in the country, including through policy measures that limit the availability of unhealthy UPPs. Much of the proliferation of UPPs started with the introduction of large multinational food corporations into the country (Igumbor et al., 2012; Popkin & Ng, 2022). UPPs are profitable, heavily marketed, provide convenience, have a long shelf-life, and are a low risk item for manufacturers to produce and sell (Hochlaf, Quilter-Pinner, & Kibasi, 2019); but are also more likely to contain excessive amounts of nutrients linked to poor health outcomes (Pagliai et al., 2021). In recent years, there has been clear movement of the UPP food and beverage industry into LMICs due to less regulations (Hawkes et al., 2015; Stuckler et al., 2012), with these corporations angling to position UPPs as essential products (Popkin et al., 2021). If nothing is done to change the status-quo, the UPP industry will continue to penetrate the market with unhealthy UPPs leaving vulnerable low-income consumers with no choice, but to purchase these items.

5.2.2 Dietary intake of protective dietary components remains inadequate amongst low-income adults living in South Africa

Although the finding that dietary intake of protective dietary components is inadequate amongst low-income adults living in South Africa is not a novel finding (Faber et al., 2017; Labadarios, Steyn, & Nel, 2011; Madlala et al., 2022; Sambo et al., 2022), it remains an important finding worth consideration. Dietary diversity, and the consumption of protective dietary components beneficial to health, such as fibre, fruits, vegetables, nuts, legumes and wholegrains was poor amongst all participants, with less than 20 % of the participants meeting any of the dietary recommendations for healthy food components. Whether or not participants were high or low UPP consumers did not affect dietary diversity.

Adequate consumption of protective dietary components is important, not just for general health promotion, but also to improve the outcomes of numerous disease conditions. This is especially relevant in the context of South Africa, a country with historically high levels of HIV, tuberculosis and childhood stunting as well as more recent increases in nutrition-related NCDs such as diabetes, hypertension and cardiovascular disease (Mbogori et al., 2020; Roomaney et al., 2022, 2021). Unfortunately, healthy food is simply unaffordable in South Africa, with 65 % of the population unable to afford the cost of a healthy diet (FAO et al., 2022). Added to this, recent years have seen food inflation rates well above the normal trend, making healthy food less and less affordable (Habiyaremye, King, & Tregenna, 2022; Kaur, 2021). The combined effects of these factors makes access to healthy food unobtainable for most, putting the most vulnerable at the greatest risk. This is not aligned with the South African Constitution, which recognises the right to food (Constitution of the Republic of South Africa, 1996).

It is evident that the improved intake of healthy dietary components remains an area of health promotion that is inadequately addressed. If left unresolved, this will continue to have significant health, and as a result, financial implications for the country. Policy interventions that focus on unhealthy foods to limit are necessary but inadequate; it is important to incorporate a holistic approach, that considers all aspects of nutritional well-being into policy solutions (Bodirsky et al., 2020; Haggblade et al., 2016; Popkin et al., 2021). There is no one-stop solution, or one comprehensive policy that will resolve all problems. Rather, solving the nutritional crisis that South Africa faces will require addressing the triple burden of under- and over-nutrition, and micronutrient deficiencies through numerous interventions. This means looking at the broader socio-economic landscape, including improved education, improved income, more job opportunities, and food and income subsidies for the most vulnerable, as well as food system changes that increase the supply of and thus improved access to healthy foods for the most vulnerable who are most affected.

5.2.3 A context-specific NPM for restrictive food policy in South Africa

In order to identify unhealthy foods to limit, an NPM can be used. The development process of a NPM for use in South Africa identified that an NPM that accounts for nutrients of concern to limit (specifically saturated fat, sugar, sodium and non-sugar sweetener) would be most appropriate for the South African context, when compared to other options (Frank et al., 2022, 2021). The proposed NPM is able to identify unhealthy packaged products, that are predominately ultra-processed. During

evaluation, 73 % of packaged products sold in supermarkets were found to be non-compliant with the NPM (Frank et al., 2022). Moreover, this study found that low-income adults living in South Africa do consume the types of food that would be non-compliant with the NPM, proving that it has the potential to impact low-income South Africans.

The development process of this NPM has followed robust, scientifically-sound methodology, and the proposed NPM has been developed free from any interference from the food and beverage industry. This is important when developing an NPM that has the potential to underpin national policies (Dorlach & Mertenskötter, 2020; Reeve et al., 2018; Thow, Jones, Hawkes, Ali, & Labonté, 2017). This NPM has the potential to be used to underpin country-level restrictive food policies, such as front-of-package labelling regulations, marketing restrictions, taxation of unhealthy foods or to identify unhealthy foods that should be restricted in the school food environment. Other countries, such as Chile that have made use of a similar style of NPM, have observed promising results from implementing this type of NPM (Caro et al., 2020; Correa et al., 2019; Dillman Carpentier, Correa, Reyes, & Taillie, 2020; Mediano Stoltze et al., 2019; Taillie, Reyes, Colchero, Popkin, & Corvalán, 2020).

NPMs vary considerably in type, purpose and complexity. In order for an NPM to achieve it's intended objective, it important that policymakers take the suitability and purpose of the NPM into consideration (Labonté et al., 2018, 2017). A 2018 systematic review of NPMs used or proposed in government regulation around the world (78 models globally) found that only one NPM had been developed for Africa (Labonté et al., 2018), the SA HNC NPM, included in the draft R429 of 2014 (National Department of Health, 2014) for the purpose of regulating health and nutrition claims. It has also been validated for use in child-directed marketing restrictions (Wicks, Wright, & Wentzel-Viljoen, 2017, 2020). Since then, the World Health Organization (WHO) African Region has proposed an NPM for child-directed marketing (World Health Organization Regional Office for Africa, 2019), although it has yet to be implemented by any country. The SA HNC NPM model is based on NPMs that were originally designed for high-income countries, specifically the Food Standards Australia/New Zealand's (FSANZ) NPM, which was adapted from the UK Ofcom NPM (Dunford et al., 2018) and includes both nutrients to limit, and nutrients to encourage.

Some arguments have been made that, besides nutrients to limit, countries with high levels of stunting and malnutrition should also include nutrients to encourage in NPMs (Drewnowski, Amanquah, &

Gavin-Smith, 2021). However, there are concerns that the addition of nutrients to encourage in a NPM can confuse the matter when trying to identify unhealthy foods to restrict in food policy (Labonté et al., 2017; Thow, Jones, et al., 2017), by creating mixed messages on the healthfulness of foods (Acton & Hammond, 2018). Because of this, it is important that the purpose of the NPM is clearly understood. Distinguishing between unhealthy or healthy foods to regulate is challenging for policy makers as the food industry contests definitions and argues that they are vilifying foods by defining them as unhealthy. However, positive components do not neutralise the negative health consequences of consuming the unhealthy components in the same product, and classifying foods as "healthy" or "healthier" has allowed industry to manipulate products by adding nutrients to otherwise unhealthy products (Tong, Rangan, & Gemming, 2018). As a result, the inclusion of healthy food components was not identified as appropriate for the purpose of the proposed NPM. Although this study focused on developing an NPM that identified unhealthy products to limit through an NPM that identified nutrients of concern to limit, an NPM that identifies healthy products to promote may have a role to play in food policy in South Africa. For example, the NPM approach used in Israel could be considered in South Africa. Israel implemented a two-step NPM, that first identifies products with nutrients of concern to limit, and then amongst products that do not contain excessive quantities of nutrients of concern to limit, identifies products with nutrients to encourage (Gillon-Keren et al., 2020) As the SA HNC NPM has already been proposed for use to identify products that may carry health and nutrition claims in SA's draft regulation R429 (National Department of Health, 2014), it may potentially be an appropriate NPM to consider for the second step in South Africa, provided a product is compliant with the proposed NPM that identifies nutrients of concern to limit in the first step.

5.2.4 Feasibility of implementing restrictive food policies

The implementation of food policies underpinned by NPMs has been slow in LMICs. This is the result of a number of factors, such as a lack of population level nutritional data, limited financial- and human resources (Bell et al., 2017; Pitt et al., 2016; Reeve et al., 2018), struggles with multi-sectoral collaboration, and poor ability to follow-through with long term commitment to policy goals in these countries (Dodd et al., 2020).

5.2.4.1 Feasibility of implementing restrictive food policy that uses an NPM in South Africa

The proposed NPM has specifically been developed with the ease of implementation, and the practicalities of monitoring and evaluation in mind. It does not require complex nutritional information or details on the share of fruits and vegetable components in products, requiring only an ingredients list to identify products with added saturated fat, added sodium, free sugar, or containing non-sugar sweetener; and the nutritional information per 100 g (as consumed) for total saturated fat, total sugar and total sodium. There are no complex calculations that are time-consuming and increase the risk of introducing errors. Additionally, this research found that the types of stores that products that are most likely to be subject to warning labels (should the proposed NPM be used for this purpose) are purchased from (supermarkets and spaza stores), as well as the types of products that would be subject to warning labels (commercial products produced at scale in factories) make it feasible to impose regulations on the food and beverage industry, as the majority of products are produced and sold in the formal food sector. As food value chains in South Africa are predominantly limited to a small number of large supermarket chains (Habiyaremye et al., 2022), policies that target these have the potential to be impactful.

Food labelling regulations in South Africa were last updated more than a decade ago, with the 2010 Regulations pertaining to the labelling and advertising of foodstuffs (R146) (National Department of Health, 2010). Since then, draft regulations relating to the labelling and advertising of foods (R429) (National Department of Health, 2014) were proposed in 2014, but they have never been promulgated. Future regulations could require that, should a product have missing information on the packaging, a product will by default be assumed to be "excessive" in the nutrient of concern for which there is no information. This will encourage companies to comply with labelling requirements. There is a clear need to update food labelling regulations, and a number of National Department of Health policies and guidelines indicate that a system to identify unhealthy foods to limit is a necessary next step for food policy in South Africa. To this end, South Africa's current national strategy for the prevention and control of obesity (2015-2020) clearly states "*Create an enabling environment that supports the availability and accessibility of healthy food choices in various settings*" as a nutrition policy priority. The strategy emphasizes the necessity to develop norms and standards for fat and sugar content of UPPs, and also emphasizes the importance of front-of-package labelling and the ethical marketing of food (National Department of Health, 2015). Additionally, the South African Food-Based Dietary Guidelines (Vorster, Badham, & Venter, 2013b) promote minimally processed

foods that should be encouraged, but also single out fat, sugar and salt as nutrients that should be limited.

Nutrient profiling, as a tool to underpin restrictive food policy in South Africa, has the potential to be effective. If used to underpin mandatory regulations by the National Department of Health it can provide an effective, straightforward system that is fairly inexpensive to implement and will require minimal additional labour resources.

5.2.4.2 Equity considerations in developing evidence-informed nutrition policies in LMICs

Implementation of nutrition policies underpinned by NPMs has been slow in LMICs (Reeve et al., 2018). This is in-part due to the resource-limited nature of these countries, and the implications this imposes on policy implementation. After an NPM has been proposed, it is important that it be validated and tested for appropriateness by applying it to the local food supply chain (Cooper et al., 2016; Townsend, 2010). The same is true for implementing, monitoring and evaluating other nutrition policies. However, the availability of appropriate nutritional data, at all stages, from development, to implementation, to monitoring and evaluation is often lacking in LMICs. There is often insufficient population-level dietary data that is required to support policy development (Reeve et al., 2018). For instance, dietary intake instruments used in many LMICs are not appropriate to accurate measure changes in UPP consumption as they are not standardised, nor is intake measured regularly (Walls et al., 2018).

LMICs trying to promote public health on a national level, and improve financial standing through international trade find it challenging to comply with World Trade Organisation regulations (Thow, Jones, et al., 2017). In order to comply with international trade laws there is an expectation that countries use an evidence-informed NPM built on a scientific basis that supports non-discriminatory policy measures (Dorlach & Mertenskötter, 2020; Thow, Jones, et al., 2017). There needs to be clear evidence that any limitations to international trade and investment agreements due to public health policies are necessary (Garton, Thow, & Swinburn, 2020). Without adequately researched, evidence-informed regulations, LMIC governments run the risk of being forced to retract regulations due to trade and investment agreements, as was seen with the turkey tail ban in Samoa (Thow, Reeve, Naseri,

Martyn, & Bollars, 2017). Additionally, as a result of international trade agreements, actions in high-income countries, like protecting their farmers by providing agricultural input subsidies has had the inadvertent effect of indirectly raising global food prices, which negatively affects LMICs (Kaur, 2021).

A single fit-for-purpose NPM that is used to underpin various food policies in a country could be viewed as an ideal starting point for regulating the ultra-processed food environment in LMICs. If regulations are to be put in place, they need to be easy to implement, require limited resources to enforce, and not be costly.

5.2.5 Implications for policy in South Africa and Sub-Saharan Africa

Within Sub-Saharan Africa, South Africa was the only country in 2016 to have implemented any policies in an attempt to address obesity and NCDs. Other countries in the region continued to allocate their limited resources to fighting undernutrition (Haggblade et al., 2016), although the focus in the region has slowly begun to shift towards including obesity and NCD prevention in policies in recent years. South Africa is now again in the position to lead on policy initiatives in the region, by using a robust, evidence-informed NPM to implement restrictive food policies, such as front-of-package warning labels, marketing restrictions, restrictions in the school food environment and taxation of unhealthy foods.

5.2.5.1 Progressive food policies to address inequalities in South Africa

To begin addressing inequalities entrenched in the country, comprehensive policies addressing NCDs were implemented in the 1990's as South Africa emerged into a post-apartheid nation. This was long before much of the rest of the world, and certainly the rest of Africa started to implement similar strategies. Actions to redress structural inequality caused by apartheid through social and economic transformation were key focus areas of the democratically elected government (Ndinda, Ndhlovu, Juma, Asiki, & Kyobutungi, 2018). Unfortunately, despite these efforts, NCDs, as well as overweight and obesity have increased in prevalence in the country, with the lowest socio-economic groups most negatively impacted by the consequences of obesity and NCDs in South Africa (Hofman et al., 2021). Additionally, high levels of poverty, unemployment and income inequality in South Africa make healthy and nutritious food unaffordable for many people (Habiyaremye et al., 2022; Mtintsilana et

al., 2022). Rising food prices exacerbates food insecurity (Kaur, 2021), and the inability to access affordable nutritious and safe food negatively impacts health and wellbeing (Habiyaremye et al., 2022).

The poorest in the country carry the largest burden of nutrient-related NCDs. Structural inequalities, in the form of social and economic disparities play a role in the increasing NCD burden in South Africa. These socio-economic factors need to be addressed in policies that are aimed at preventing and reducing the prevalence of overweight, obesity and nutrition-related NCDs. The consequences of not resolving the socio-economic inequalities in South Africa could have a direct impact on the future health and economic outcomes of the country (Samodien et al., 2021). Policies, such as front-of-package labelling, marketing restrictions and unhealthy food taxes that are underpinned by an NPM have the potential to improve health outcomes for the most vulnerable in the country.

These restrictive food policies tend to focus on nonessential products which are not nutritious, nor necessary for health (Andreyeva, Marple, Moore, & Powell, 2022). Arguments have been made that fiscal policies are regressive, however, because taxation impacts purchasing behaviour of low-income individuals the most, taxes have the potential, when combined with food subsidies, to positively influence food choices towards healthier options amongst low-income consumers, and as a result can improve health equity and be viewed as progressive (World Health Organization, 2022). This has already been observed in South Africa, with the Health Promotion Levy. Reductions in the purchase of sugary beverages after the implementation of the this tax were greatest amongst the lowest socio-economic groups, which supports the argument that policies like taxations can improve health equity (Hofman et al., 2021). The combination of taxation and subsidization has the potential to positively affect low-income households by redistributing wealth. The proceeds raised from taxation of unhealthy products (which affects both high- and low-income consumers) can be reinvested into the subsidization of healthy foods for low-income people, potentially improving their health outcomes (Caro et al., 2020). When the price of fruits and vegetables are subsidized in low-income communities, the sale of these items increases significantly (Andreyeva et al., 2022).

Policies need to be implemented in South Africa that consider food availability and affordability, whilst also taking the nutritional composition of foods into account (Mtintsilana et al., 2022). One way to address the poor nutritional content of UPPs in South Africa is to implement policies that both disincentivise manufacturers to produce UPPs or at least reduce the nutrients of concern linked to

poor health; and effectively inform consumers about the health risks. NPMs can assist to achieve this goal. Well-designed NPMs can underpin food and nutrition policies such as food labelling, child-directed marketing restrictions, taxation, and school nutrition standards (Poon et al., 2018).

5.2.5.2 Implications for policy in Sub-Saharan Africa

Within Sub-Saharan Africa, the prevalence of obesity and related NCDs has increased rapidly in the in the past two decades, creating a barrier to the region meeting the Sustainable Development Goals. NCDs are expected to overtake communicable, neonatal and maternal morbidity and mortality rates in the region by 2030. (Bigna & Noubiap, 2019).

Although Africa's nutrition transition remains less advanced than the global nutrition transition, the transition in South Africa is further advanced than most of Africa (Haggblade et al., 2016; Steyn & Mchiza, 2014). Of importance to note here, is that South Africa exports packaged foods to other Sub-Saharan Africa countries (Reardon et al., 2021). If South Africa should implement restrictive food policies it has the potential to influence the broader Sub-Saharan Africa region, for instance if foods carrying front-of-package warning labels are exported from South Africa to other countries, it is possible that policies implemented in South Africa will have a broader impact. Additionally, South Africa has the opportunity to lead the way with front-of-package labelling policies and marketing restrictions in the region, and other countries may well follow in the footsteps afterwards. Other countries in the region have expressed concern for the negative health outcomes related to the proliferation of unhealthy foods, and there is an interest in the region to implement strategies that will promote a healthier food environment.

5.3 Remaining gaps and potential next steps

In this section I provide recommendations for further research to fill the gaps that remain unknown in the area of researching nutrient profiles and UPP food intake in South Africa. Additionally, given the findings of this research, I provide a number of recommendations for health policy and practice, that, if implemented could have the potential to improve the health and wellbeing of South Africans.

5.3.1 Recommendations for further research

- This research provided a snapshot of UPP intake in South Africa. However, the 24-hour dietary recalls that were used in this study were not specifically collected for the purpose of analysing UPP intake via the Nova classification system. Future studies designed specifically for this purpose should collect dietary consumption data at an individual product and brand name level. This will provide a more accurate and complete picture regarding UPP consumption in South Africa.
- This research assessed the potential effect of using the proposed NPM for a front-of-package warning label policy on packaged foods. However, the NPM has been developed to be used in a broader range of restrictive food policies, and its potential to be used in marketing restrictions, restrictions in the school food environment and taxation of unhealthy foods should be further studied. Additionally, the suitability of this NPM for identifying unhealthy foods that are derived from sources other than packaged foods, such as the fast food industry, should be assessed. This will evaluate whether or not the proposed NPM would be an appropriate NPM to underpin policy related to the fast food industry.
- The development of the NPM in this study focused on unhealthy foods to restrict. Some work has been done to develop an NPM for health and nutrition claims in South Africa (Wicks et al., 2017), and under current regulation the National Department of Health allows certain organization to carry health promotion logos on certain products (National Department of Health, 2014). There are lessons to be learnt from the country of Israel, where a two-step NPM has been implemented, the first step for nutrients of concern to limit, and the second step for nutrients to encourage (Gillon-Keren et al., 2020). Given the double burden of under- and overnutrition in South Africa, and the juxtaposition of both stunting and obesity occurring in the same households (Mbogori et al., 2020); as well as the findings of this study that low-income South Africans consume insufficient protective dietary components, more work should be done to evaluate the suitability of an NPM for nutrients to encourage, ideally one that aligns with the foods to promote in the South African Food Based Dietary Guidelines (Vorster, Badham, & Venter, 2013a). Further, how an NPM that promotes foods or nutrients to encourage interplays with the proposed NPM that identifies unhealthy foods to restrict should be evaluated; so that the most appropriate strategy for effectively promoting healthier foods to the South African population can be identified.
- The dietary intake data collected in this study was not collected from a nationally representative sample. Added to this, nationally representative dietary data is seldom collected in South Africa. The 2022 National Dietary Intake Survey which is currently underway is a

step in the right direction, but future research should focus on the collection of nationally representative dietary data at regular time intervals. In order to identify key intervention points to implement effective and timeous policy interventions it is important to conduct research that monitors and evaluates the nutrition transition and changing dietary patterns in the country on a regular basis.

- This research confirms the results of other studies in South Africa, that the intake of healthy foods that provide protective health benefits is insufficient amongst low-income South Africans (Faber et al., 2017; Labadarios, Steyn, et al., 2011; Madlala et al., 2022; Sambo et al., 2022). More research needs to be conducted to identify effective and sustainable solutions to improve the dietary intake of healthy food components, be it via the subsidization of the cost of healthy food as has been seen to be effective elsewhere (Andreyeva et al., 2022; Haggblade et al., 2016), or other measures.
- South Africa exports foods to the broader Sub-Saharan Africa region (Reardon et al., 2021). Should the proposed NPM be implemented for use in front-of-package warning labelling policy (as the South Africa National Department of Health has indicated as their intention); the potential effect of foods with warning labels exported and sold in the broader Sub-Saharan Africa region should be investigated, to understand whether this South African policy could have an effect on promoting health in the broader region, and if so, to understand how best to support other countries interested in implementing similar policies.

5.3.2 Recommendations for health policy and practice

- The NPM developed and proposed from this research project has been found to be fit-for-purpose and suitable for use to identify unhealthy foods to restrict in the South African context. Given the findings of high levels of UPP consumption, and the high likelihood of high UPP consumers consuming unhealthy food components in excess of WHO recommendations, the National Department of Health should use the proposed NPM to underpin mandatory restrictive food policy in South Africa. This research finds that the proposed NPM would benefit low-income South Africans if used for a front-of-package warning label policy, and this should be strongly considered by the South African National Department of Health.
- NPMs developed for similar purposes to the proposed NPM have been used effectively for marketing restrictions, and restrictions in the school food environment elsewhere around the globe (Corvalán, Reyes, Garmendia, & Uauy, 2019; Labonté et al., 2018; Popkin et al., 2021;

Sagaceta-Mejía, Tolentino-Mayo, Cruz-Casarrubias, Nieto, & Barquera, 2022). As the proposed NPM has been developed for use in restrictive food policies in South Africa, the South African National Department of Health should consider the implementation of broader policies, beyond a front-of-package warning label policy. From a policy implementation standpoint, as well as a monitoring and evaluation standpoint, these policies will be fairly straightforward to implement, provided a front-of-package label policy is in place, as this will enable easy identification of the foods to restrict through additional policies.

- Although taxation of sugar sweetened beverages has been implemented in many countries, including South Africa (Essman et al., 2021; Hofman et al., 2021; Stacey et al., 2021), taxation of unhealthy foods remains a fairly unexplored policy intervention, with few unhealthy food taxes in place (Popkin et al., 2021). However, there is evidence that this could be a beneficial policy intervention to reduce obesity and NCD risk by discouraging the intake of harmful sugar, salt and saturated fat (Popkin et al., 2021). The proposed NPM identifies unhealthy foods that should be restricted, and unhealthy food taxes using the NPM criteria to identify foods to tax should be considered as a policy intervention in South Africa.
- Together with policies to restrict the intake of unhealthy foods, subsidisation of the cost of healthy foods should be considered. Measures to restrict the intake of unhealthy food, without also promoting the intake of healthy food will fall short, and comprehensive interventions are needed. It is evident that low-income South Africans, who are most vulnerable to the shocks of price changes and inflation, consume insufficient healthy food components, and better policies need to be put in place to enable increased consumption of foods that are protective of health. Healthy food production and distribution in low-income communities may be options for the South Africa government to invest in.
- If restrictive food policies using the proposed NPM are implemented in South Africa, it is imperative that monitoring and evaluation of the efficacy of the policies is undertaken to ensure that the policies have the intended effect. Policies that intend to change dietary intake patterns tend to take years to show benefits, and as such is it crucial that the National Department of Health sets both short, and long term goals to monitor the effect of the policies. Short term goals could include (depending on the policy implemented) assessing the change in the nutritional composition of packaged foods, or foods marketed to children, or foods available in school tuck shops. Longer term goals could be assessing the change in the types of foods consumed by South Africans, and changes to health outcomes such as obesity, and nutrition-related NCDs like diabetes and hypertension.
- Besides evaluating the health benefits of any policies that are implemented, it is also important to monitor the compliance of the food and beverage industry to policies. These policies will

not be effective without compliance of the food and beverage industry as they are responsible, should regulations be implemented, for providing accurate nutritional information about the composition of their products, and complying with criteria such as which products should carry front-of-package warning labels or which products should not be marketed. It is thus important for the National Department of Health to develop and implement a system to monitor the food and beverage industry's compliance to any imposed regulations on an ongoing manner, and have an effective penalty system in place for non-compliant companies.

5.4 Conclusion

Low-income South Africans are vulnerable to the effects of being continuously exposed to an unhealthy food environment; as is evident in the high amounts of UPPs consumed, and inadequate healthy dietary components consumed. Nutrient profiling offers a promising solution to identify unhealthy foods that should be restricted in country-level food policy. With the development of a context-specific NPM that is fit-for-purpose and appropriate for use in South Africa, the South African National Department of Health now has the opportunity to implement restrictive food policies, such as front-of-package warning labels, restriction of unhealthy food marketing, taxation of unhealthy food and restriction of unhealthy foods from the school food environment. While these policies aimed at restricting unhealthy foods are necessary, they may not be sufficient to meaningfully improve health outcomes given the wide inequalities present in South Africa. Policies aimed at encouraging healthy diets and making foods promoted in the Food Based Dietary Guidelines available and financially accessible to low-income South Africans are also required.

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Appendices

Appendix 1.1: Ethics approval for this project

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
RESEARCH AND INNOVATION DIVISION

Private Bag X17, Bellville 7535
South Africa
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26 July 2019

Ms TC Jenkings
School of Public Health
Faculty of Community and Health Sciences

Ethics Reference Number: HS19/6/3

Project Title: Development of a nutrient profiling model assessing healthfulness of packaged foods for adults in the low-income context of South Africa

Approval Period: 26 July 2019 – 26 July 2020

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

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

HSSREC REGISTRATION NUMBER - 130416-049

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

Appendix 1.2: Ethics approval for ROFE project

UNIVERSITY of the WESTERN CAPE

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13 October 2017

Prof D Sanders
School of Public Health
Faculty of Community and Health Sciences

Ethics Reference Number: BM17/8/20

Project Title: Researching the obesogenic food environment, its drivers and potential policy levers in South Africa and Ghana.

Approval Period: 11 October 2017 – 11 October 2018

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

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

PROVISIONAL REC NUMBER -130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

Appendix 1.3: Ethics approval for HPL project

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
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07 August 2018

Prof CE Swart and Prof D Sanders
Dietetics and Nutrition
Faculty of Community and Health Sciences

Ethics Reference Number: BM18/6/2

Project Title: Association of the implementation of the South African Health promotion levy (HPL) with dietary intake and consumption of sugar-sweetened beverages (SSBs) in adults aged 18-39 years living in Langa.

Approval Period: 03 August 2018 – 03 August 2019

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the extension of the research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The permission from the Provincial DoH must be submitted for recordkeeping purposes.

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

PROVISIONAL REC NUMBER -130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

Appendix 2: Ethical Considerations for ROFE and HPL project

Community Considerations

During both ROFE and HPL data collection, action plans were in place in case food insecurity or ill health was identified. Appropriate guidelines for clinic, social work and NGO referrals were in place. The officer in charge at the local police station was informed of the survey and contact was made to evaluate any safety risks to the fieldworkers.

Informed consent, confidentiality and privacy

Participation was voluntary and qualifying participants partaking in the study either had the consent form read to them by a fieldworker, or they were asked to read through it themselves if they were literate. The participants were asked to sign the form if the agreed to take part in the study. The consent forms were available in isiXhosa and English. At any point during the administering of the questionnaire if a participant wished to withdraw from the study, he or she was allowed to. It did not negatively affect the person in any way. To protect the participants' confidentiality and privacy the questionnaires were filled out anonymously, using initials only as pseudonyms, and the participants' consent forms have been kept separate from their completed questionnaires.

Phase two of the study involved data collection at supermarkets, but no study participants. Before data collection commenced permission was granted by store managers or owners. Supermarket linked information, and brand names of products photographed will be kept confidential.

Data storage and disposal

For both the ROFE and HPL projects household data was/will be collected using dedicated cell phones with a dedicated open source application, Open Data Kit. Directly after each interview data is uploaded onto the Ona platform. Data has been extracted into Microsoft Excel for monitoring purposes and for data storage at the end of the survey. Only the researchers have access to the Ona platform to extract data. Dietary intake data was captured by the data capturer at the MRC using Epidata software and exported in Excel. Data sets were merged by a statistician from the MRC using the variables hh, ln and age. All data stored are anonymised using only initials as pseudonym. All extracted data and combined data sets are stored on password protected computers accessible by the researchers. Data will be disposed of after five years.

Appendix 3.1: HPL Consent Form English

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: +27-21-959 2760 Fax: +27-21-9592872
E-mail: rswart@uwc.ac.za

CONSENT FORM

Title of Research Project: **Health Promotion Levy (HPL) Evaluation (Langa)**

The study has been described to me in language that I understand. My questions about the study have been answered. I understand what my participation will involve and I agree to participate of my own choice and free will. 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. I understand that no audio-recordings will be produced from the interview with me.

Participant's name ……. ……..

Participant's signature …….

Date ……..……

Appendix 3.2: HPL Consent Form isiXhosa

UNIVERSITY OF THE WESTERN CAPE

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E-mail: rswart@uwc.ac.za

IPHEPHA MVUME

Isihloko soluphando: **Uvavanyo lwe ntlawulo ekukhuthazeni ezempilo kwa Langa**

Olu phando lucaciswe kum ngolwimi endilwaziyo kwaye endiluqondayo. Imibuzo endinayo ngoluphando iye yaphenduleka. Ndiyayazi ukuba ukuthabatha inxaxheba kwam koluphando kuzobandakanya ntoni kwaye ndizikhethele ukuthatha inxaxheba kungekho mntu undinyanzelayo. Ndiyayazi ukuba inkcukacha zam zizoba yimfihlelo azizokuxelelwa mntu. Ndiyayazi ukuba ndingarhoxa koluphando naninina kwaye ndinganikezi nesizathu kwaye ndingoyiki ukuba kukho into embi ezokwenzeka okanye kukho nto ithile ezokundiphosa. Ndiyazi ukuba akuzubakho lushicilelo oluzakwenziwa kudliwano-ndlebe nam.

Igama lomntu othabathe inxaxheba kuphando ……..

Umtyikityo womntu othabathe inxaxheba kuphando ……..

Umhla ……

Appendix 3.3: ROFE Consent Form English

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: +27-21-959 2702 Fax: +27-21-9592872
E-mail: vlawack@uwc.ac.za

CONSENT FORM

Title of Research Project: **Researching the obesogenic food environment, its drivers and potential policy levers in South Africa**

The study has been described to me in language that I understand. My questions about the study have been answered. I understand what my participation will involve and I agree to participate of my own choice and free will. 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 ……. ……..

Participant's signature ……

Date ……..……

Appendix 3.4: ROFE Consent Form isiXhosa

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IPHEPHA MVUME

Isihloko soluphando: **Ukuphanda ukutya okutyebisayo, indlela okusebenza ngayo nendlela okuqhuba ngayo nesikhokelo kwaso e Mzantsi Africa**

Olu phando lucaciswe kum ngolwimi endilwaziyo kwaye endiluqondayo. Imibuzo endinayo ngoluphando iye yaphenduleka. Ndiyayazi ukuba ukuthabatha inxaxheba kwam koluphando kuzobandakanya ntoni kwaye ndizikhethele ukuthatha inxaxheba kungekho mntu undinyanzelayo. Ndiyayazi ukuba inkcukacha zam zizoba yimfihlelo azizokuxelelwa mntu. Ndiyayazi ukuba ndingarhoxa koluphando naninina kwaye ndinganikezi nesizathu kwaye ndingoyiki ukuba kukho into embi ezokwenzeka okanye kukho nto ithile ezokundiphosa.

Igama lomntu othabathe inxaxheba kuphando ……..

Umtyikityo womntu othabathe inxaxheba kuphando …….

Umhla ……

Appendix 3.5: Information sheet for ROFE English

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: codes): +27-21-959 2132/2402 Fax: +27-21-959 2872
E-mail: sandersdav5845@gmail.com

INFORMATION SHEET

Project Title: Researching the obesogenic food environment, its drivers and potential policy levers in South Africa

What is this study about?
This is a research project being conducted by the School of Public Health at the University of the Western Cape. We are inviting you to participate in this research project because you live in Khayelitsha or Mt Frere or Langa. The purpose of this research project is to understand what people in Khayelitsha/MtFrere/Langa eat, where they get their food, and why they get it there. This information will help us understand how people's eating habits could contribute to health issues.

What will I be asked to do if I agree to participate?
You will be asked to participate in an interview which will take about 40 minutes of your time. *We will be asking you about what foods you have eaten, and also about things that you have in your home which let us know how well-off you are compared with others, and about what kinds of lack you have experienced.*

Would my participation in this study be kept confidential?
The researchers undertake to protect your identity and the nature of your contribution. To ensure your anonymity, ***your name will not be included on the surveys and other collected data; a code will be placed on the survey and other collected data; through the use of an identification key, the researcher will be able to link your survey to your identity; and only the researcher will have access to the identification key.*** To ensure your confidentiality, we will ***use identification codes only on data forms, and use password-protected computer files.*** If we write a report or article about this research project, your identity will be protected.

In accordance with legal requirements and/or professional standards, we will disclose to the appropriate individuals and/or authorities information that comes to our attention concerning child abuse or neglect or potential harm to you or others. In this event, we will inform you that we have to break confidentiality to fulfil our legal responsibility to report to the designated authorities.

What are the risks of this research?
There may be some risks from participating in this research study. The questions may cause you to feel embarassed or sad about your living situation or the food you eat in order to get by. 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 personally, but the results may help the investigator learn more about diets and poverty. We hope that, in the future, other people might benefit from this study through improved understanding of how people's eating habits are influenced by the foods they are able to find locally. We hope that this research will enable us to make useful recommendations to politicians and officials that will help make better food available to people living in areas like Khayelitsha and MtFrere.

Do I have to be in this research and may I stop participating at any time?
Your participation in this research is completely voluntary. You may choose not 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 *Prof David Sanders from the School of Public Health* at the University of the Western Cape. If you have any questions about the research study itself, please contact Prof David Sanders at: Private Bag X 17, Bellville 7535, Western Cape, South Africa, codes): +27-21-959 2132/2402.
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 Uta Lehmann
Head of Department
University of the Western Cape
Private Bag X17
Bellville 7535
ulehmann@uwc.ac.za

Prof Anthea Rhoda
Acting Dean: Faculty of Community and Health Sciences
University of the Western Cape
Private Bag X17
Bellville 7535
chs-deansoffice@uwc.ac.za

This research has been approved by the University of the Western Cape's Senate Research Committee. (REFERENCE NUMBER: *17/8/20*)

Appendix 3.6: Information sheet for HPL English

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: codes): +27-21-959 2132/2402 Fax: +27-21-959 2872
E-mail: rswart@uwc.ac.za

INFORMATION SHEET

Project Title: Health Promotion Levy (HPL) Evaluation (Langa)

What is this study about?
This is a research project being conducted by the School of Public Health at the University of the Western Cape. We are inviting you to participate in this research project because you live in Langa (between the ages of 18-39). The purpose of this research project is to understand how the implementation of the Health Promotion Levy implemented as of 1 April 2018 affects what people in Langa eat. This information will help us understand people's eating habits and how it could contribute to health issues.

What will I be asked to do if I agree to participate?
You will be asked to participate in an interview which will take about 40 minutes of your time. *We will be asking you about what foods you have eaten, and also about things that you have in your home which let us know how well-off you are compared with others, and about what kinds of lack you have experienced.*

Would my participation in this study be kept confidential?
The researchers undertake to protect your identity and the nature of your contribution. To ensure your anonymity, ***your name will not be included on the surveys and other collected data; a code (using initials only) will be placed on the survey and other collected data. Through the use of this identification key, the researcher will be able to link your survey to your identity, but only the researcher will have access to the identification key.*** To ensure your confidentiality, we will ***use identification codes only on data forms, and use password-protected computer files.*** If we write a report or article about this research project, your identity will be protected.

In accordance with legal requirements and/or professional standards, we will disclose to the appropriate individuals and/or authorities information that comes to our attention concerning child abuse or neglect or potential harm to you or others. In this event, we will inform you that we have to break confidentiality to fulfil our legal responsibility to report to the designated authorities.

What are the risks of this research?
There may be some risks from participating in this research study. The questions may cause you to feel embarassed or sad about your living situation or the food you eat in order to get by. 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 personally, but the results may help the investigator learn more about diets and policies that impact on diets. We hope that, in the future, other people might benefit from this study through improved understanding of how people's eating habits are influenced by the foods they are able to find locally and policies that affect the price and availability of food. We hope that this research will enable us to make useful recommendations to politicians and officials that will help make healthier food available to people living in areas like Langa.

Do I have to be in this research and may I stop participating at any time?
Your participation in this research is completely voluntary. You may choose not 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 *Prof Rina Swart from the Department of Dietetics and Nutrition* at the University of the Western Cape. If you have any questions about the research study itself, please contact Prof Rina Swart at: Private Bag X 17, Bellville 7535, Western Cape, South Africa, codes): +27-0834824113.
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:

Dr Ernie Kunneke
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The Research Ethics Office
University of Western Cape
Private Bag X17
Bellville, 7535
research-ethics@uwc.ac.za
Tel: 021 959 2948

This research has been approved by the University of the Western Cape's Senate Research Committee. (REFERENCE NUMBER: BM18/6/2)

Appendix 4.1: HPL & ROFE Diet Questionnaire

RESEARCHING THE OBESOGENIC FOOD ENVIRONMENT **24 HR RECALL QUESTIONNAIRE**							
dateint	Date of interview	d d / m m / y y ☐☐/☐☐/1 8	day	Day of the week (yesterday) being recalled	Sun 1 Mon 2 Tues 3 Wed 4 Thurs 5 Fri 6		
teamid	Area identifier	Langa 0 3	intidd	Interviewer identifier	☐☐		
respid	Unique number	yy mm dd country area intid sequence hh ___ / ___ / ___ / ___ / _____ / _____			ln	Respondent line number	☐☐
Sex	Sex	M / F			age	Age of respondent	☐☐

ALL INFORMATION WILL BE TREATED CONFIDENTIALY

WHAT FOOD AND DRINKS	HOW WAS IT PREPARED? WHAT WAS ADDED?	HOW MUCH WAS EATEN
Breakfast time (waking up to about 9 o'clock)		
Mid-Morning (09h00 – 12h00)		
Lunch Time (12h00 – 14h00)		

Afternoon (14h00 – 17h00)		
Supper Time (17h00 – sunset)		
After supper, at bedtime and through the night		

dsp1	Was this a usual day in terms of eating? *(CIRCLE ONLY **ONE** ANSWER.)*	Yes……1 No……2	Skip to anthropometry section if answer is yes
dsp2	If not, what was the reason?		

CHECK THE QUESTIONNAIRE & THANK THE RESPONDENT FOR PROVIDING INFORMATION ON YESTERDAY'S FOOD INTAKE. PROCEED WITH SSB CONSUMPTION QUESTIONNAIRE.

SUPERVISOR INITIAL FOR CHECKING 24HR RECALL	
INITIAL FOR CODING OF 24HR RECALL	

INDIVIDUAL CHARACTERISTICS					
respid	Unique number	yy mm dd country area intid sequence hh ___ / ___ / ___ / ___ / _____ / _____	ln	Respondent line number	☐☐
Sex	Sex	M / F	age	Age of respondent	☐☐

No.	QUESTIONS	ANSWERS	SKIPS
gc1	How many of the children in this household are your own?	☐☐	
gc2	Do you have any other children who are alive who are not currently living with you in this household?	☐☐	
gc3	What is your employment status?	Unemployed..... 1 Self-employed..... 2 Wage earner..... 3 Part-time employment..... 4 Casual worker..... 5 Other (specify)..... 99	
gc4	What is your marital status?	Single..... 1 Married ..... 2 Widowed and not remarried..... 3 Divorced and not remarried ..... 4 Married but separated ..... 5 Living together..... 99 Other (specify).....	Skip to Question he1 if respondent is male
gc5	FOR FEMALE RESPONDENTS How long ago was your last pregnancy?	Never pregnant..... 77 Currently pregnant ..... 0 Time since last pregnancy in A. years ☐☐ or B.months ☐☐	Skip to question he1 if time since last pregnancy is >= 2 years/ never
gc6	FOR FEMALE RESPONDENTS Are you currently breastfeeding?	Yes ..... 1 No..... 2	Only ask question if time since last pregnancy is <2years

HEALTH

No.	QUESTIONS	ANSWERS		SKIPS
he1	Has a professional ever diagnosed you with one of the following diseases? *(PROMPT FOR EACH ITEM; CIRCLE ONLY ONE ANSWER FOR EACH ITEM)*	Diabetes Mellitus.....	Yes.....1 No.....2	
		Heart disease.....	Yes.....1 No.....2	
		High cholesterol.....	Yes.....1 No.....2	
		Hypertension/high blood pressure.....	Yes.....1 No.....2	
		Cancer.....	Yes.....1 No.....2	
		Overweight / Obesity.....	Yes.....1 No.....2	
he2	Do you currently smoke?	Yes..... No, but smoked previously..... Yes, occasionally..... No, never smoked.....	1 2 3 4	
he3	What do you smoke most of the time?	Cigarettes..... Pipe..... Hookah pipe.....	1 2 3	
he4	Do you ever drink any alcohol?	Yes..... No.....	1 2	
he5	Do you ever exercise?	Yes..... No.....	1 2	
he6	How many days a week do you usually do at least 20 minutes the following type of exercise?	A. Walking ..... B. Moderate exercise..... C. Vigorous exercise	☐ ☐ ☐	
he7	For how many hours in an average week, do you watch movies / television / series/ play electronic games	<1 hour per week..... 1-3 hrs / week..... 4-7hrs / week..... 8-14hrs / week (2hrs/day)..... 15-21hrs / week (3hrs/day)..... >21hrs/week.....	1 2 3 4 5 6	
he8	How do you perceive your own weight?	Underweight..... Normal weight..... Overweight..... Obese.....	1 2 3 4	
he9	Is the following statement true or false when you shop for food?	I pay attention to the information on a package like "no sugar added"	True.....1 False.....2	

KNOWLEDGE ATTITUDE AND PERCEPTION

(Rivard et al 2012; Madiba et al 2017; Vital Strategies)

I would like to ask you some questions about your understanding of foods and health. Please remember that there is no right or wrong answer, I am just trying to get an understanding of your perception.

No.	QUESTION		ANSWERS	SKIPS
sb1	When you think of the term "sugary drinks" which ones come to mind? ***(DO NOT PROMPT. PROBE... ANYTHING ELSE?)*** *(CIRCLE YES FOR EACH ITEM MENTIONED AND NO FOR EACH ITEM NOT MENTIONED)*	A. Bottled water (still, sparkling, flavoured)	Yes.....1 No.....2	
		B. 100% fruit juice (eg. Liquifruit, Ceres, Appletiser)	Yes.....1 No.....2	
		C. Nectars or canned juices that contain fruit (eg. Tropicana)	Yes.....1 No.....2	
		D. Milk (full cream, low fat, fat free) (unflavoured)	Yes.....1 No.....2	
		E. Milk (sweetened and flavoured) (eg. Nesquick, Steristumpie, Yogisip)	Yes.....1 No.....2	
		F. Soda or soft drinks (eg. Coca Cola, Sprite, Ginger beer Iron Brew, Dry lemon, Kingsley)	Yes.....1 No.....2	
		G. Diet soda / artificially sweetened beverages (eg. Coca Cola Light, Tab, Diet Sprite)	Yes.....1 No.....2	
		H. Sweetened Iced Tea (eg. BOS, Lipton ice tea, Fuze)	Yes.....1 No.....2	
		I. Coffee/tea with sugar (incl. cappuccino, frapuccino)	Yes.....1 No.....2	
		J. Energy drinks (eg. Red Bull, Monster, Dragon)	Yes.....1 No.....2	
		K. Sports drinks (eg. Energade, Powerade, Lucozade)	Yes.....1 No.....2	
		L. Powdered drinks (eg. Game)	Yes.....1 No.....2	
		M. Cordials and concentrates (eg. Oros)	Yes.....1 No.....2	
		N. Other specify	Yes.....1 No.....2	

No.	QUESTION		ANSWERS				SKIPS
			Not sugary (1)	Some what (2)	Sugary (3)	Don't Know (99)	
sb2	***(PROMPT FOR EACH ITEM)*** *(MARK ONLY ONE ANSWER FOR EACH ITEM)*	A. Bottled water (still)					
		B. Bottled water (sparkling)					
		C. Bottled water (flavoured)					
		D. 100% fruit juice (eg. Liquifruit, Ceres, Appletiser)					
		E. Nectars or canned juices that contain fruit (eg. Tropicana)					
		F. Milk (full cream, low fat, fat free) (unflavoured)					
		G. Milk (sweetened and flavoured) (eg. Nesquick, Steristumpie, Yogisip)					
		H. Soda or soft drinks (eg. Coca Cola, Sprite, Ginger beer, Iron Brew, Dry lemon, Kingsley)					
		I. Diet soda / artificially sweetened beverages (eg. Coca Cola Light, Tab, Diet Sprite)					
		J. Sweetened Iced Tea (eg. BOS, Lipton ice tea, Fuze)					
		K. Coffee/tea with sugar (incl. cappuccino, frapuccino)					
		L. Energy drinks (eg. Red Bull, Monster, Dragon)					
		M. Sports drinks (eg. Energade, Powerade, Lucozade)					
		N. Powdered drinks (eg. Game)					
		O. Cordials and concentrates (eg. Oros)					
		P. Alcohol (beer)					
		Q. Alcohol (wine)					
		R. Alcohol (spirits)					
		S. Alcohol (ciders)					

No.	QUESTION		ANSWERS	SKIPS
sb3	**NOTE: For the purpose of this survey, what we mean by sugary drinks, is all soda or carbonated drinks, energy drinks, sports drinks, flavoured milk or fruit concentrates/nextars or powders for preparing soft drinks. All of them are high in either natural or added sugar**. To the best of your knowledge, does the consumption of sugary drinks increase the risk of suffering from .....? *(PROMPT FOR EACH DISEASE)* *(CIRCLE ONLY ONE ANSWER FOR EACH DISEASE)*	A. HIV	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
		B. Diabetes	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
		C. High blood pressure	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
		D. Obesity	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
		E. Dental problems	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
		F. Cancer	Not at all ....1 A little.....2 Somewhat..3 A lot .....4 Not sure/dk.5	
sb4	To the best of your knowledge, does obesity increases the risk of suffering from...?	HIV	Not at all.....1 Just a little ...2 Somewhat....3 A lot.....4 Not sure.....99	
		Diabetes (Sugar diabetes)	Not at all.....1 Just a little ...2 Somewhat....3 A lot.....4 Not sure.....99	
		High blood pressure	Not at all.....1 Just a little ...2 Somewhat....3 A lot.....4 Not sure.....99	

	To the best of your knowledge, does obesity increases the risk of suffering from…?		Dental problems	Not at all……1 Just a little …2 Somewhat….3 A lot……4 Not sure…..99		
			Cancer	Not at all……1 Just a little …2 Somewhat….3 A lot……4 Not sure…..99		
sb5	Are you aware of the new Health Promotion Levy (also called Sugary Beverage Tax)?		Yes…….. 1 No…… 2			
sb6	Do you support the taxation of foods that are less healthy or unhealthy?		Strongly oppose…….. 1 Oppose…… 2 Support…… 3 Strongly support……. 4			
sb7			Yes	No	Maybe	Don't know
	Government has approved a new tax on sugary sweetened beverages which will come into effect on 1 April 2018. If this tax will result in an increase in price of about R2 for 2liters of sugary beverages, how likely will it have the following effect on your purchasing intentions? *(PROMT. MARK ONLY ONE ANSWER FOR EACH OPTION)*	C. I will switch to untaxed drinks				
		B. I will cut back on my sweetened beverage consumption				
		A. I will continue to consume the same drinks. The tax will have no impact at all.				
sb8	If you will cut back or switch to untaxed drinks, which drinks are you most likely to drink more of….? *(DO NOT PROMPT)* *(MARK YES IF AN OPTION IS MENTIONED. MARK NO IF OPTION IS NOT MENTIONED)*		A. Diet soda	Yes……1 No……..2		
			B. Fruit juice	Yes……1 No……..2		
			C. Water	Yes……1 No……..2		
			D. Milk	Yes……1 No……..2		
			E. Alcohol	Yes……1 No……..2		
			F. Other (specify) ……	Yes……1 No……..2		

SSB CONSUMPTION AND ACQUISITION

During the past month how often did you (personally) consume any of the following beverages? (*please check the relevant box*) Please read the food category to participants. If they respond positively (i.e. yes we consume this) then ask about the volume most commonly consumed and how often consumed. *Please remember there is no right or wrong answer. We would like to get the most accurate description of the beverages you consumed over the last month. Please tell me about your own consumption of beverages. I would like you to tell me if you drank any of the items that I am going to mention to you. You can also look at the pictures to identify the beverages you drink. If you drink these items, please tell me how often you drink it, and the volume you usually consume.*

Beverage unit MOST commonly consumed

01	200ml	03	440ml	05	750ml	07	1.5l	09	other specify…
02	330ml	04	500ml	06	1l	08	2l		

Code	Food Item	Unit most often consumed	Never <1/mo	1-3/ mo	1/ wk	2-4/ wk	5-6/ wk	1/ day	2-3/ day	≥4/ day
bev1	Water from a tap, not commercial									
bev2	Bottled water (unflavoured) (still, sparkling)									
bev3	Bottled water (flavoured)									
bev4	100% fruit juice (e.g. Liquifruit, Ceres, Appletizer)									
bev5	Nectars or canned juices that contain fruit (e.g. Tropica, Cabana, Halls, Elvin, Dalys, Take5)									
bev6	Cordials/concentrates (e.g. Oros, Fusion, Wild Island)									
bev7	Milk unflavoured and unsweetened (e.g. full cream/low fat/fat free/ amasi)									
bev8	Milk products sweetened & flavored (e.g. Nesquik, Steristumpi, Yogisip)									
bev9	Magheu									
bev10	Regular soda or soft drinks (e.g. Coca Cola, Sprite, Fanta, Stoney Ginger Beer, Cream Soda, Dry Lemon, Jive, Twizza, Refresh)									
bev11	Diet soda/artificially sweetened (e.g. Coca Cola light, Tab, Sprite Zero)									
bev12	Energy drinks (e.g. Score, Red Bull, Monster, Play, Dragon)									
bev13	Sports drinks (e.g. Energade, Powerade, Lucozade)									
bev14	Powdered drinks (e.g. Game)									
bev15	Sweetened iced tea (e.g. BOS Lipton, Fuze)									
bev16	Coffee/tea with sugar (bottled or served; including cappuccino etc)									
bev17	Coffee/Tea without sugar									
bev18	Frozen ice-lollies (e.g. Bompies /JC's)									

Code	Food Item	Unit most often consumed	Never <1/mo	1-3/ mo	1/ wk	2-4/ wk	5-6/ wk	1/ day	2-3/ day	≥4/ day
bev19	Alcohol Wine									
bev20	Alcohol Beer									
bev21	Alcohol Spirits									
bev22	Alcohols Ciders (e.g. Smirnoff Spin)									
bev23	Traditional beer (Umqubothi)									
bev24	Other (specify):									

No.	QUESTION		ANSWER
bev25	Have you changed your beverage consumption because of the drought in the Western Cape?		Yes.....1 No.....2
bev26	If yes, please tell me what you drink more or less of as a result of the drought….	A. Drink more of…(specify)	
		B. Drink less of ….(specify)	

THANK THE PARTICIPANTS FOR THEIR TIME
SHARE TOKEN OF APPRECIATION WITH THE HOUSEHOLD

Appendix 4.2: HPL & ROFE Anthropometry Questionnaire

RESEARCHING THE OBESOGENIC FOOD ENVIRONMENT **ANTROPOMETRY**							
dateint	Date of interview	d d / m m / y y ☐☐/☐☐/1 8					
teamid	Area identifier	Langa 0 3	intidd	Interviewer identifier	☐☐		
respid	Unique number	yy mm dd country area intid sequence hh __ / __ / __ / __ / ____ / ____			ln	Respondent line number	☐☐
Sex	Sex	M / F			age	Age of respondent	☐☐

ALL INFORMATION WILL BE TREATED CONFIDENTIALY

Now we would like to take your weight and measure your height. Can you please remove your shoes as well as all heavy clothing before we proceed? Please note that we will repeat each measurement twice to ensure that we do not make a mistake.

Weight 1	Taken to the nearest 0.1kg				.		Kg
Weight 2					.		Kg

Height 1	Taken to the nearest 0.1cm				.		cm
Height 2					.		cm

CHECK THE QUESTIONNAIRE & THANK THE RESPONDENT

SUPERVISOR INITIAL FOR CHECKING QUESTIONNAIRE	

RESEARCHING THE OBESOGENIC FOOD ENVIRONMENT

HOUSEHOLD FOOD CONSUMPTION AND FOOD ACQUISITION QUESTIONNAIRE

dateint	Date of interview	DD / MM / YY ☐☐/☐☐/1 7			
teamid	Team identifier	☐☐	intid	Interviewer identifier	☐☐
ctryid	Country	01. South Africa 02. Ghana			☐☐
eaid	Area identifier	01 Khayelitsha 02 Mt Frere 03 Langa		04 Accra 05 Kumasi urban 06 Kumasi rural	☐☐
hh	Household identifier	Geolocation			
Now we would like to obtain information on the food that household members usually eat.					
lnr	Line number of respondent *Write in the number from the household roster in household questionnaire.*				☐☐
cons	Written consent obtained?	Yes.....1 No.....2			If **yes**, begin If **no**, end
visitno	Number of attempts to visit household (up to one return visit) *Record at the time of completing the interview or after second household visit*				☐
outfood	Outcome of household consumption questionnaire *Fill in only after questionnaire has been completed for this woman.*	Completed.....1 Refused.....2 No household member at home or no adult respondent at home at time of visit(s).....3 Household member incapacitated or intoxicated.....4 Other: _____.....99			If 3 or 4, return later for a second visit.

EAID ☐☐☐☐☐☐☐☐☐ HH ☐☐

HOUSEHOLD FOOD CONSUMPTION AND FOOD ACQUISITION QUESTIONNAIRE

(PURE ABBREVIATED FFQ, NOVA CLASSIFICATION AS PER INFORMAS FOOD PRICE MODULE, DIETARY DIVERSITY SCORE)

Instructions

Milk: includes whole milk and products from whole mild such as full cream, low fat and fat free milk, yoghurt (unsweetened), amasi, or curdled milk.
Other milk: any processed products made of milk such as flavoured & sweetened milk/youghut, condensed/ideal milk, powdered milk, non-dairy creamers and alternative types of milk such as soy, almond, or coconut milk.
Red Meat: includes beef, pork, lamb, mutton, goat, veal consumed as main dish or as sandwich or mixed dish.
Fish, cooked: includes any type of fish that is steamed, boiled, grilled, BBQ, roasted or baked
Vegetables: potato is not included in vegetable group
Root vegetables: potatoes, sweet potato, cassava, plantain
Legumes: includes dried beans, peas, lentils
Rice: includes sticky rice, rice noodle, white rice, brown rice
Maize: includes maize meal, samp and cooked mealies
Bread: includes chapati, paratha, roti, gluten bread, steamed bread, bread rolls, etc.

Soft drink: includes Coke, Pepsi, delister, Guarana, Gingerale, Fanta, Freezit (light and regular), Thums up. Sweetened sports drinks
Snack (salty): includes chips, crisps, puffs and other food similar to these.
Sweets: includes all types of chocolate, candy, drops, sweetened bars etc.

During the past month how often did you and your household consumed the following foods and drinks? (please check the relevant box). Please read the food category to participants. If they respond positively (i.e yes we consume this) then ask how often, where they get the food from (source). If they indicate that they purchase, proceed to ask the type of store/place, the name of the place as well as the brand name. Do not read the list of options, but ask an open question and select the corresponding code based on their answer.
Please remember there is no right or wrong answer. We would like to get the most accurate description of the food your household usually eat in a month.

EAID ☐☐☐☐☐☐☐☐ HH ☐☐

Food item	Never/ <1/ mo	1-3/ mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	≥4/day	Source of food	If food was purchased, please indicate: Where (type)	Where (store name)	What brand	How often do you buy this?	Is there any particular reason why you purchase this item at this particular place?
Milk, amasi, or curdled milk. Do you use full cream, low fat, or skim milk														
Other dairy (processed) e. ice cream , sweetened yoghurt, flavoured milk, powdered milk or creamers, condensed milk														
Eggs														
Chicken (do you remove the skin?)														

EAID ☐☐☐☐☐☐☐☐ HH ☐☐

Food item	Never/ <1/ mo	1-3/ mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	≥4/day	Source of food	If food was purchased, please indicate: Where (type)	Where (store name)	What brand	How often do you buy this?	Is there any particular reason why you purchase this item at this particular place?
Red meat (do you remove the fat?)	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Organ meats	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Highly processed meats eg. Polony, Russians	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Fish (raw, cooked, smoked or canned)	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Fish fried	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Fish salted or dried	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Fruit	☐	☐	☐	☐	☐	☐	☐	☐	☐					
Vegetables fresh/raw	☐	☐	☐	☐	☐	☐	☐	☐	☐					

If food was purchased, please indicate

EAID ☐☐☐☐☐☐☐☐ HH ☐☐

Food item	Never/ <1/ mo	1-3/ mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/ day	≥4/day	Source of food	Where (type)	Where (store name)	What brand	How often do you buy this?	Is there any particular reason why you purchase this item at this particular place?
Vegetables cooked														
Vegetables fried/stirfry														
Fried potatoes/hot chips														
Root vegetables														
Legumes														
Rice														
Maize														
Pasta														
Instant noodles														
Bread (home baked)														

EAID ☐☐☐☐☐☐☐☐☐ HH ☐☐

Food item	Never/ <1/ mo	1-3/ mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	≥4/day	Source of food	If food was purchased, please indicate: Where (type)	Where (store name)	What brand	How often do you buy this?	Is there any particular reason why you purchase this item at this particular place?
Bread commercial Do you usually eat white, brown or WW														
Do you use margarine or butter to spread on your bread?														
Vetkoek														
Confectionary, sugary baked goods, biscuits														
Commercial Breakfast cereals														
Sugar														
Sweets														

EAID ☐☐☐☐☐☐☐☐☐ HH ☐☐

Salty Snacks ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Food item	Never/ <1/ mo	1-3/ mo	1/wk	2-4/wk	5-6/wk	1/day	2-3/day	≥4/day	Source of food	If food was purchased, please indicate: Where (type)	Where (store name)	What brand	How often do you buy this?	Is there any particular reason why you purchase this item at this particular place?
Soft drink regular	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Soft drink diet	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Nuts (peanuts & tree nuts)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tea, coffee	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Meals from a fast food restaurant (formal / informal)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Meals from sit-down restaurants (formal/informal)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ready to eat meals / heat&eat meals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

EAID ☐☐☐☐☐☐☐☐☐ HH ☐☐

Codes to be used in food frequency questionnaire

Source	Where (type)	Brand	Frequency
1=Purchased *2 = Own production.* *3= Other such as barter, Part – pay – employment, clinic, NGO, donation, etc* *If own production is selected, then indicate* *21=Reared* *22=Grown* *23=Picked – wild* *24=Hunted / Fished* *25=Homemade*	1 Wholesaler (eg Makro) 2 Supermarket 3 Small Shop / Convenience store/Spaza 4 General dealer 5 House-shop 6 Market trader 7 Vendor with fixed municipal stall (with shelter and display) 8 Container shop 9 Semi-permanent roadside stall 10 Temporary stall 11 Bakkie trader 12 Butchery 13 Informal abattoir 14 Formal restaurant 15 Informal restaurant 16 Corporate fast food shop 17 Independent take away 18 Informal take-away 19 Shebeen/informal tavern 20 NGO/CBO/FBO Food kitchen 99 Other	Write down the name of the specific brand usually purchased for main components of a dish or a food item. Eg. If Ice cream consumed ask which brand did they buy.	0=Never 1= Daily 2=2-3times/ week 3=Weekly (1x/w) 4=Fortnightly 5=Monthly 6=Special Occasion 7=Infrequently 99=Other
	Where (store name)		
	Allow for name to be written in For supermarket it can be pre-coded 1=Shoprite 2=Checkers 3=Pick & Pay 4=Woolworths 5=SPAR 6=OK groceries 7=Boxer 99=other (specify).....		Add notes on any special comment the interviewee makes such as "every afternoon on my way from work"

EAID ☐☐☐☐☐☐☐☐☐ HH ☐☐

Food Sourcing: Thank you for sharing the information on your household consumption pattern. Just to be sure that we recorded everything, can we quickly review the places where you obtain your food from. With each type of food outlet, can you just indicate how frequently you will obtain food from that outlet.

Do you ever purchase food at a? If y, how often?	Never/ <1x/month	Daily	2-3X p week	Weekly	Fortnightly	Monthly	Special Occasion	Other
Wholesaler (eg Makro)								
Supermarket (eg. Shoprite)								
Small Shop / Convenience store / Spaza								
General dealer (Stand-alone building with a sign; trading bulk groceries and a large variety of non-food items)								
Fixed municipal stall) with shelter and display)								
House-shop (informal shop attached to or part of a home; no sign; not dedicated to food retail only)								
Container shop								
Permanent roadside stall (fixed shelter, table and display shelves which stay in place after trading hours)								
Temporary stall (boxes with board removalable stall and shelter, trader with wheels)								
Mobile trader (trolley, wheelbarrow, carry-trade, basket or buckets)								
Bakkie trader or trike								

EAID ☐☐☐☐☐☐☐☐ HH ☐☐

Do you ever purchase food at a? If y, how often?	Never/ <1x/month	Daily	2-3X p week	Weekly	Fortnightly	Monthly	Special Occasion	Other
Informal abattoir								
Formal restaurant (Sit-down meals with service; certified/permit)								
Informal restaurant (Sit-down meals with service; no certificate/permit)								
Corporate fast food shop								
Independent take away								
Informal take-away (Ready meals without service) or roadside grill (Shesa-nyama)								
Shebeen/informal tavern								
NGO/CBO/FBO Food kitchen								
Other								

Appendix 4.4: HPL & ROFE Household Questionnaire

RESEARCHING THE OBESOGENIC FOOD ENVIRONMENT

HOUSEHOLD QUESTIONNAIRE

dateint	Date of interview	DD / MM / YY	☐☐ / ☐☐ / 1 8			
teamid	Team identifier	☐☐	intid	Interviewer identifier		☐☐
ctryid	Country	01. South Africa 02. Ghana				☐☐
eaid	Area identifier	01 Khayelitsha 02 Mt Frere 03 Langa		04 Kumasi urban 05 Kumasi rural		☐☐
hh	Household identifier	☐☐	GPS	GPS coordinates		

Hello, my name is _____. I work for the UWC / KNUST. We are interested in learning about your family, your household environment and food in your house. Who is the person in your household who is most knowledgeable about purchasing and preparing most of the food for your family? For example, we would like to know how often you usefully eat the different types of food items. May we speak to this person?
(Do not interview a household member <18 years of age.)

If this person is available:

- *Share the information sheet with this person and ask him/her to complete the Consent Form. Complete the Household Questionnaire. Explain that you would also like to speak to one individual about what they ate the day before, and measure the weight and height of this person. (Alternate between male and female – starting your first interview of the day with a female). Complete the consent forms for this person. Do not interview anybody younger than 18 years. Complete the 24 hr recall / Anthropometric measurements.*

If this person is not available:

- *Schedule a second visit to return to complete the Household Questionnaire when the person knowledgeable about food in the household is available.*

On the second visit:

- *If the person knowledgeable about food is available, ask him/her to complete Consent Form and Household Questionnaire. If that person is not available, ask the next most knowledgeable person. Share the information sheet and ask him/her to complete Consent Form and the Household Questionnaire;*
- *Explain that you would also like to speak to one individual about what they ate the day before, and measure the weight and height of this person. (Alternate between male and female – starting your first interview of the day with a female). Complete the consent forms for this person. Do not interview anybody younger than 18 years. Complete the 24 hr recall / Anthropometric measurements.*

Cons	Written consent obtained?	Yes.....1 No.....2	If **yes**, begin If **no**, end
visitno	Number of attempts to visit household (up to one return visit) *Record at the time of completing the interview or after second household visit*		☐
outhh	Outcome of HH questionnaire *Fill in only after questionnaire has been completed for this household.*	Completed.....1 Refused.....2 No household member at home or no adult respondent at home at time of visit(s).....3 Household member incapacitated or intoxicated.....4 Other: _____.....99	If 3 or 4, return later for a second visit.
		Supervisor check	Initial for yes _____

HOUSEHOLD ROSTER						
Now we would like some information about persons who usually stay in your household. This will include anybody who sleeps in this household for at least 4 nights of the week and eats from the same pot of food. *Start by listing the head of the household.*						
Line number	A. Name or initial of person	B. Sex	C. Age *(in years OR months).*		D. Currently attending school or college?	E. Highest educational level (grade) completed. Enter the grade nr mentioned.
			Years *(Record in years if >5 years*	Months *(Record in months if <60 months*		
01	Head of Household	M / F	☐☐		Yes.....1 No.....2	
02		M / F	☐☐	☐☐	Yes.....1 No..... 2	
03		M / F	☐☐	☐☐	Yes.....1 No.....2	
04		M / F	☐☐	☐☐	Yes.....1 No..... 2	
05		M / F	☐☐	☐☐	Yes.....1 No.....2	
06		M / F	☐☐	☐☐	Yes.....1 No..... 2	
07		M / F	☐☐	☐☐	Yes.....1 No.....2	
08		M / F	☐☐	☐☐	Yes.....1 No..... 2	
09		M / F	☐☐	☐☐	Yes.....1 No.....2	
10		M / F	☐☐	☐☐	Yes.....1 No..... 2	
11		M / F	☐☐	☐☐	Yes.....1 No.....2	
12		M / F	☐☐	☐☐	Yes.....1 No..... 2	
13		M / F	☐☐	☐☐	Yes.....1 No.....2	
14		M / F	☐☐	☐☐	Yes.....1 No.....2	

hh1a	*Just to make sure that I have a complete listing:* Are there any other persons such as small children or infants that we have not listed? *If YES, add name to table.*	
hh1b	Are there any other people who may not be members of your family, such as domestic servants, lodgers, or friends who usually live here and share the same pot of food for at least 4 days of the week? *If YES, add name to table.*	
ote: Add a new page if more people in the household		
Lnr	Line number of respondent *(WRITE IN THE NUMBER FROM THE HOUSEHOLD ROSTER)*	☐☐

Check the roster regarding completion!

SHORT BIRTH HISTORY			
N°	QUESTIONS	ANSWERS	SKIPS
bh1	Altogether, how many live births have there been in your household in the last 5 years? Please include any baby who cried or showed other signs of life. *(WRITE IN THE NUMBER.)* *(IF 'NONE', RECORD 00. IF 'DON'T KNOW', RECORD 88.)*	☐☐	If **00** or **88**, skip to **household characteristics** module.
bh2	Is this child / are these children still alive? *(CIRCLE ONLY **ONE** ANSWER.)*	All alive.....1 One or more has died in the past 5 years.....2 Don't know.....88	

UNIQE IDENTIFYER NUMBER .....

ANTHRO SECTION REMOVED FOR CAPE TOWN PRINTED VERSION

HOUSEHOLD CHARACTERISTICS			
N°	QUESTIONS	ANSWERS	SKIPS
hc1	Does your household have electricity? *(CIRCLE ONLY **ONE** ANSWER.)*	Yes.....1 No.....2	
hc2	What fuel does your household mainly use for cooking? *(CIRCLE ONLY **ONE** ANSWER.)*	Electricity.....1 LPG.....2 Natural gas.....3 Biogas.....4 Kerosene / Parafin.....5 Coal / Lignite.....6 Candles.....7 Firewood.....8 Straw / Shrubs / Grass.....9 Animal dung.....10 Sun/solar cooker.....11 No food cooked in household.....12 Don't know.....88 Other: _____ 99	
hc3	Does your household or anyone in the household have … ? ***(PROMPT FOR EACH ITEM**; RECORD ALL ITEMS IN THE HOUSEHOLD.)* *(CIRCLE ONLY **ONE** ANSWER FOR EACH ITEM.)*	A. Radio (other than a car radio) Yes.....1 No.....2 B. Television Yes.....1 No..... ...2 C. DVD player Yes.....1 No.....2 D. MNet-DSTV / Multi-TV (Ghana) subscription Yes.....1 No.....2 E. Air conditioner Yes.....1 No.....2 F. Computer / desktop / laptop Yes.....1 No.....2 G. Vacuum cleaner / floor polisher Yes.....1 No.....2 H. Dishwashing machine Yes.....1 No.....2 I. Tumble dryer Yes.....1 No..... ...2 J. Home telephone (landline) Yes.....1 No... .....2 K. Deep freezer Yes.....1 No... .....2 L. Refrigerator / combined fridge/freezer Yes.....1 No.....2	

	Does your household or anyone in the household have … ? ***(PROMPT FOR EACH ITEM**; RECORD ALL ITEMS IN THE HOUSEHOLD.)* *(CIRCLE ONLY **ONE** ANSWER FOR EACH ITEM.)*	M. Cooking stove (electric) Yes……1 No……2 N. Cooking stove (gas) Yes……1 No……2 O. Microwave oven Yes……1 No……2 P. Built-in kitchen sink Yes……1 No……2 Q. Home security system Yes……1 No……2 R. Home theatre system Yes……1 No……2 S. Bicycle or tricycle Yes……1 No……2 T. Motorcycle, scooter, trike, car, truck, jeep, or tractor Yes……1 No……2 V. Animal-drawn cart Yes……1 No……2 W. Domestic worker /house help Yes ……1 No……2 X. Hot water running from a geyser Yes……1 o……2 Y. Cell phone Yes……1 No……2 Z. 2 cell phones in household Yes……1 No……2 AA. 3 or more cell phones in household Yes……1 No……2
hc4	Does this household or a household member owns the house? If not, do they rent it or live there without paying rent or live there temporarily? *(CIRCLE ONLY **ONE** ANSWER.)*	Owns the house……1 Rents the house ……2 Uses without paying rent …… 3
hc5	How many rooms in this house are used for sleeping? (WRITE IN THE NUMBER)	☐☐
hc6	In the past year has anyone been paid to clean house or do laundry for this household? (CIRCLE ONLY **ONE** ANSWER.)	Yes, daily……1 Yes, weekly …… 2 Yes, monthly ……3 Yes, quarterly …… 4 Yes, annually …… 5 No …… 6 Don't know……88 Other: _____ …… 99

hc7	Does any member of this household own any land?	Yes .....1 No 2	If **2**, skip to **hc11**
hc8	What is the total amount of land owned by household member(s) together?	Total amount of land .....hectares (Enter 0 if less than 1 ha)	
hc9	Do you grow anything on the land?	Yes .....1 No 2	If **2**, skip to **hc11**
hc10	How much do you grow per year on the land?	Grains in bags ..... How many months does this last? ..... Vegetables (how many months do you have vegetables for the hh)..... ..... Fruit (how many months do you have fruit for HH)... Roots and tubers (how many sacks?).....	
hc11	Does any member of this household owns live-stock?	Yes .....1 No 2	If **2**, skip to **hc15**
hc12	How many heads of large sized live-stock (eg. cattle, horses, oxen) are currently owned by the household in total? *(ONLY COUNT ADULT/GROWN ANIMALS*	Total number of large sized live-stock.....	
hc13	How many medium sized live-stock (eg. sheep, goats, pigs) are currently owned by the household? *(ONLY COUNT ADULT/GROWN ANIMALS*	Total number of medium sized live-stock.....	
hc14	How many small sized live-stock (eg. chicken, ducks, rabbits, guinea fowl, turkey) are currently owned by the household? *(ONLY COUNT ADULT/GROWN ANIMALS*	Total number of small sized live-stock.....	
hc15	*WHAT IS THE MAIN MATERIAL OF THE FLOOR OF THE DWELLING?* *(OBSERVATION.)* *(CIRCLE ONLY **ONE** ANSWER.)*	Natural floor Earth / sand.....1 Dung.....2 Rudimentary floor Wood planks.....3 Palm / bamboo.....4 Finished floor Parquet / polished wood.....5 Vinyl / asphalt strips.....6 Ceramic tiles.....7 Cement.....8 Carpet.....9 Other: _____ 99	

hc16	*WHAT IS THE MAIN MATERIAL OF THE ROOF OF THE DWELLING?* *(OBSERVATION.)* *(CIRCLE ONLY **ONE** ANSWER.)*	Natural roofing No roofing.....1 Thatch / palm leaves.....2 Sod.....3 Rudimentary roofing Rustic mat.....4 Palm / bamboo.....5 Wood planks.....6 Plastic .....7 Finished roofing Metal./corrugated iron.....8 Calamine / cement fiber..... 9 Ceramic tiles.....10 Cement.....11 Roofing shingles.....12 Other: _____ 99	
hc17	*WHAT IS THE MAIN MATERIAL OF THE EXTERIOR WALLS OF THE DWELLING?* *(OBSERVATION.)* *(CIRCLE ONLY **ONE** ANSWER.)*	Plastic / Cardboard..... 1 Mud or mud and cement ..... 2 Corrugated iron / zinc..... 3 Prefab ..... 4 Bare brick or cement blocks..... 5 Plaster / finished..... 6 Other: _____ 99	

WATER, SANITATION, AND HYGIENE (WASH)			
N°	QUESTIONS	ANSWERS	SKIPS
w1	What is the main source of drinking water for the members of your household? *(CIRCLE ONLY **ONE** ANSWER.)*	Piped water Piped into dwelling.....1 Piped to yard / plot.....2 Public tap / standpipe.....3 Tube well / borehole.....4 Dug well Protected /covered well.....5 Unprotected / open well.....6 Water from spring Protected spring.....7 Unprotected spring.....8 Rainwater.....9 Tankertruck.....10 Cart with small tank.....11 Surface water River / stream .....12 Dam .....13 Lake / Pond .....14 Water vendor / Bottled / sachet .....15 Don't know.....88 Other: _____ 99	

w2	Where is that water source located? *(CIRCLE ONLY **ONE** ANSWER.)*	In own welling.....1 In own yard/plot.....2 Elsewhere.....3	If **1 or 2**, skip to **w4**
w3	How long does it take to go there, get water and come back? *(WRITE IN THE NUMBER.)* *(IF 'DON'T KNOW', RECORD 888)*	Minutes..... ☐☐☐	
w4	Do you **usually** do anything to your drinking water to make it safer to drink? *(CIRCLE ONLY **ONE** ANSWER.)*	Yes.....1 No.....2	If **No**, skip to **w6**
w5	What do you **usually** do to the water to make it safer to drink? *(DO **NOT** PROMPT. PROBE "ANYTHING ELSE?")* *(CIRCLE YES FOR EACH ITEM MENTIONED AND NO FOR EACH ITEM NOT MENTIONED.)*	A. Boil Yes / No B. Add bleach / chlorine Yes / No C. Strain through a cloth Yes / No D. Use a water filter (ceramic / sand / composite ...) Yes / No E. Solar disinfection Yes / No F. Let it stand and settle Yes / No G. Smoking Yes / No H. Don't know Yes / No I. Other: _____ Yes / No	
w6	What kind of toilet facility do members of your household usually use? *(DO **NOT** PROMPT.)* *(CIRCLE ONLY **ONE** ANSWER.)*	Flush / pour floush toilet Flush to piped sewer system.....1 Flush to septic tank.....2 Flush to pit latrine.....3 Flush to elsewhere.....4 Flush, don't know where.....5 Pit latrine Ventilated improved pit latrine.....6 Pit latrine with slab.....7 Pit latrine without slab / open pit.....8 Composting toilet.....9 Bucket toilet.....10 Hanging toilet / hanging latrine.....11 No facilities / bush / field.....12 Don't know.....88 Other: _____ 99	
w7	Do you share this facility with other households? *(CIRCLE ONLY **ONE** ANSWER.)*	Yes.....1 No.....2	

w8	How do you dispose your household waste? (DO NOT PROMPT.) (CIRCLE ALL ANSWERS MENTIONED.)	Composting .....1 Recycle some items .....2 Burning .....3 Municipal garbage pick-up.....4 Designated municipal dumping container/area ...5 Dump in rivers, streams .....6 Dump in forest .....7 Dump on open land.....8 Don't know.....88 Other: _____ 99	

HEALTH SERVICES ACCESS			
N°	QUESTIONS	ANSWERS	SKIPS
hs1	How long does it take to travel to the nearest primary health care facility? *(A. WRITE IN THE NUMBER.)* *(B. CIRCLE THE UNIT.)* *(IF 'DON'T KNOW', RECORD 88.)*	A. Duration ☐☐ ☐ B. Minute(s).....1 Hour(s).....2 Day(s).....3	If **A** is **88**, skip to **income** module.

HOUSEHOLD INCOME			
N°	QUESTIONS	ANSWERS	SKIPS
hi1	How many of the following social grants are received in this household? *(FILL IN THE **NUMBER** OF PERSONS RECEIVING EACH SPECIFIC GRANT. FILL IN 0, IF NOBODY RECEIVES A GRANT, 88= Don't know*	Child support grant..... ☐☐ State Old age pension..... ☐☐ Disability grant..... ☐☐ Foster care grant,,..... ☐☐ LEAP (Ghana)..... ☐☐ Other _____ ☐☐	
hi2	How many people contribute to the total income (money) in this household? *(CIRCLE ONLY **ONE** ANSWER.)*	None.....1 1 person.....2 2 persons.....3 3-4 persons.....4 5-6 persons.....5 More than 6 persons.....6 Don't know.....88 Other: _____.....99	

hi3	What is the total household income per month before deductions (including wages, rent, grants, sales of vegetables, etc.) of everybody in the household added together? If you can tell me the amount off hand please do so, otherwise I will read out various income brackets. Please stop me when I say the amount that you think represents the total monthly income of the household. *(CIRCLE ONLY **ONE** ANSWER.)*	South Africa Less than R3001……1 R3001-4000……2 R4001-5000……3 R5001-R7500……4 R7501-R10,000……5 R10,0001-R15,000……6 R15,001-R20,000……7 R20,0001-R30,000……8 R30,0001-R40,000……9 R40,001 or more……10 Don't know…… 88	Ghana Less than 964……1 965-1285……2 1286-1606……3 1607-2409……4 2510-3212……5 3213-4819……6 4820-6425……7 6426-9638……8 9639-12851……9 12852 or more……10 Don't know……88	

"I would like to ask some questions about the availability of food in your household over the last month."

HOUSEHOLD HUNGER SCALE (BALLARD ET AL. 2011)			
N°	QUESTIONS	ANSWERS	SKIPS
hh1	In the past month, was there ever no food to eat of any kind in your house because of lack of resources to get food?	Yes ……1 No ……2	If no, skip to hh2
hh1a	How often did this happen in the past month?	Rarely (1-2 times) ……1 Sometimes (3-10times) …2 Often (>10 times) ……3	
hh2	In the past month, did you or any household member go to sleep at night hungry because there was not enough food?	Yes ……1 No ……2	If no, skip to hh2
hh2a	How often did this happen in the past month?	Rarely (1-2 times) ……1 Sometimes (3-10times) …2 Often (>10 times) ……3	
hh3	In the past month. Did you or any household member go a whole day and night without eating anything at all because there was not enough food?	Yes ……1 No ……2	If no, skip to hh2
hh3a	How often did this happen in the past month?	Rarely (1-2 times) ……1 Sometimes (3-10times) …2 Often (>10 times) ……3	

LIVED POVERTY INDEX (AFRIBAROMETER – MATTES, DULANI & GYIMAH-BOADI 2016)			
N°	QUESTIONS	ANSWERS	SKIPS
lpi1	Over the past year, how often, if ever, have you or anyone in your family: Gone without enough food to eat? *(CIRCLE ONLY **ONE** ANSWER)*	Never .....1 Just once or twice .....2 Several times .....3 Many times .....4 Always .....5 Don't know.....88	
lpi2	Over the past year, how often, if ever, have you or anyone in your family: Gone without enough clean water for home use? *(CIRCLE ONLY **ONE** ANSWER)*	Never .....1 Just once or twice .....2 Several times .....3 Many times .....4 Always .....5 Don't know.....88	
lpi3	Over the past year, how often, if ever, have you or anyone in your family: Gone without medicines or medical treatment? *(CIRCLE ONLY **ONE** ANSWER)*	Never .....1 Just once or twice .....2 Several times .....3 Many times .....4 Always .....5 Don't know.....88	
lpi4	Over the past year, how often, if ever, have you or anyone in your family: Gone without enough fuel to cook your food? *(CIRCLE ONLY **ONE** ANSWER)*	Never .....1 Just once or twice .....2 Several times .....3 Many times .....4 Always .....5 Don't know.....88	
lpi5	Over the past year, how often, if ever, have you or anyone in your family: Gone without a cash income? *(CIRCLE ONLY **ONE** ANSWER)*	Never .....1 Just once or twice .....2 Several times .....3 Many times .....4 Always .....5 Don't know.....88	

CHECK THE QUESTIONNAIRE & THANK THE RESPONDENT**

Appendix 5.1: Reviewer comments and responses to manuscript two

A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa

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Reviewer 1: Anonymous

Reviewer 2: Anonymous

First email: Minor revisions

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to: Tamryn Frank <tfrank@uwc.ac.za>

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subject: [Nutrients] Manuscript ID: nutrients-1270510 - Minor Revisions

Dear Ms. Frank,

Thank you again for your manuscript submission:

Manuscript ID: nutrients-1270510

Type of manuscript: Article

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Authors: Tamryn Frank *, Anne-Marie Thow, Shu Wen Ng, Jessica Ostrowski,

Makoma Bopape, Elizabeth C Swart

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Submitted to section: Nutrition and Public Health,

https://www.mdpi.com/journal/nutrients/sections/Nutrition_Public_Health

Your manuscript has been reviewed by experts in the field. Please find your manuscript with the referee reports at this link:

https://susy.mdpi.com/user/manuscripts/resubmit/18c47f475bc6c3eddd18ec67b1cd1e2d

(I) Please revise your manuscript according to the referees' comments and upload the revised file within 3 days.

(II) Please use the version of your manuscript found at the above link for your revisions.

(III) Any revisions made to the manuscript should be marked up using the "Track Changes" function if you are using MS Word/LaTeX, such that changes can be easily viewed by the editors and reviewers.

(IV) Please provide a short cover letter detailing your changes for the editors' and referees' approval.

If one of the referees has suggested that your manuscript should undergo extensive English revisions, please address this issue during revision. We propose that you use one of the editing services listed at https://www.mdpi.com/authors/english or have your manuscript checked by a native English-speaking colleague.

Please do not hesitate to contact us if you have any questions regarding the revision of your manuscript or if you need more time. We look forward to hearing from you soon.

Kind regards,

Ms. Lindsey Guo

Assistant Editor

General Comments:

Reviewer one: This is an excellent paper.

Reviewer two: The paper is very well-written and properly structured. But I do have some minor comments, which I outline below:

Response: Thank you for the time you have taken to review this paper, and the feedback you have provided. This is much appreciated.

Please note: Line numbers referred to in the responses refer to line numbers when the "simple markup" track changes option is applied (and not the "all markup" option).

Reviewer one:

This is an excellent paper.

Line 131 needs a minor structural amendment.

Response: Thank you, we have corrected this by deleting unnecessary spaces (line 132).

Line 166 - there's a repeat of Australia and New Zealand - reword the sentence to avoid repetition

Response: We have deleted the repetition (line 167).

Line 415 - section 3.25. While describing how prolific their use is, this paragraph doesn't describe WHY it is worth restricting the use of Non Sugar Sweeteners (NSS) - what is their potential damage to health? Why should we try to reduce their use. e.g. LIne 447 "Given the current evidence regarding NSS intake"..... you should elaborate what you mean by this.

Response: Please see lines 431-435 where we acknowledge that there is not consensus amongst researchers regarding the safety of NSS. In earlier versions of the article we included reference to studies that show potential damage to health, but removed this (given the conflict amongst researchers). We instead focused on what is known (e.g concern amongst children).

However, the words "given the current evidence regarding NSS intake" have made the focus of the sentence unclear, so we have edited the sentence by changing the wording in the sentence.

Line 448-450: "It is impossible to set a cut-point for NSS - unlike for other nutrients of concern like sodium, saturated fat or sugar which have evidence-based cut-points, as there is currently inadequate evidence to identify a NSS cut-point."

Overall, I think it's an excellent paper and it is addressing a very complex issue. I don't support the concept of 'nutrients to limit' or 'nutrients to encourage' as I think the totality of the diet MUST be

taken into account rather than specific foods. However, the issue of profiling has to be addressed at the same time - it's a difficult conundrum and one this paper addresses well!

Response: We agree that understanding totality of diets is important. The purpose of the NPM is not to replace/negate measurement and monitoring of diet patterns, quality or other assessments of total diets. However, policies will be critical to address existing NCD and obesity concerns, so there need to be operationalizable approaches for implementation.

Reviewer two:

1.Introduction:

a.The contributions of this study are not clear. What are the main contributions of this study to the existing literature? What kind of knowledge gap that this study is going to fill up?

Response: The last sentence of the introduction has been edited. It now reads:

Line 105-108: "This paper contributes to existing scientific research on NPMs by investigating the various aspects to consider when developing a fit-for-purpose NPM for restrictive food policies in SA, which has the potential to influence food policy in South Africa, and more broadly, other LMICs in Africa."

b.The authors may clearly mention the main objective of this study in the introduction section. They did mention the objective of the study (lines 107-108) under the materials and methods section, which I believe is not the right place.

Response: This has been moved from materials and methods, to introduction. Introduction now includes:

Line 101-102: "The objective of this paper is to identify a suitable, context-specific NPM for food policy in SA, using an established stepwise approach."

2.Material and methods:

a.As mentioned above, I would recommend moving lines 107-108 under the introduction section.

Response: Deleted from materials and methods, and moved to introduction (line 101-102)

3.Data

a.Fix lines 131-132

Response: Thank you. We have corrected this by deleting unnecessary spaces (line 132).

b.How did the authors collect nutritional information on 6747 packaged foods and beverages? Did the authors hire people? Where are the appendices?

Response: The detailed data collection methods are included in Appendix A (which was submitted in a separate word document together with the article). We have edited the sentence in the article to make it clearer.

Line 132-133: "Nutritional information on packaged foods and beverages (n = 6747) with nutrition information panels (NIP) was collected photographically by trained fieldworkers from large supermarkets in SA (Pick 'n Pay, Woolworths, Checkers, Spar and Shoprite) in 2018."

Lines: 142-144: "To determine the purpose and target population, we reviewed relevant population-level data and the policy context to identify the key nutritional problems faced by the SA population." What is relevant population-level data?"Please be specific about the data source.

Response: The appropriate references have been added to the sentence as recommended (line 144). As the research activity (as explained in the methodology) was to review this; the various nutrition studies in South Africa reviewed are included and included under "results" – specifically in section 3.1 "The purpose and target population in South Africa" (line 230-255). Unfortunately, South Africa lacks extensive, and up-to-date information on population-wide nutrition surveys, which is why it is a fairly short section.

4.Limitations and strengths of the studya.Incorrect section number.

Response: We have corrected this to 4.1 (line 639)

Second email: Accepted for publication

from: Nutrients Editorial Office <nutrients@mdpi.com>

reply-to: Nutrients Editorial Office <nutrients@mdpi.com>

to: Tamryn Frank <tfrank@uwc.ac.za>

date: 13 Jul 2021, 02:53

subject: [Nutrients] Manuscript ID: nutrients-1270510 - Accepted for Publication

Dear Ms. Frank,

Congratulations on the acceptance of your manuscript, and thank you for your interest in submitting your work to Nutrients:

Manuscript ID: nutrients-1270510

Type of manuscript: Article

Title: A fit-for-purpose nutrient profiling model to underpin food and nutrition policies in South Africa

Authors: Tamryn Frank *, Anne-Marie Thow, Shu Wen Ng, Jessica Ostrowski, Makoma Bopape, Elizabeth C Swart

Received: 6 June 2021

E-mails: tfrank@uwc.ac.za, annemarie.thow@sydney.edu.au, shuwen@unc.edu, jessica.ostrowski@unc.edu, makoma.bopape@ul.ac.za, rswart@uwc.ac.za

Submitted to section: Nutrition and Public Health, https://www.mdpi.com/journal/nutrients/sections/Nutrition_Public_Health

https://susy.mdpi.com/user/manuscripts/review_info/18c47f475bc6c3eddd18ec67b1cd1e2d

We will now edit and finalize your paper, which will then be returned to you for your approval. Within the next couple of days, an invoice concerning the article processing charge (APC) for publication in this open access journal will be sent by email from the Editorial Office in Basel, Switzerland.

If, however, extensive English edits are required to your manuscript, we will need to return the paper requesting improvements throughout.

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We also invite you to contribute to Encyclopedia (https://encyclopedia.pub), a scholarly platform providing accurate information about the latest research results. You can adapt parts of your paper to provide valuable reference information, via Encyclopedia, for others both within the field and beyond.

Kind regards,

Lluis Serra-Majem, Maria Luz Fernandez

Editors-in-Chief

Appendix 5.2: Reviewer comments and responses to manuscript three

Initial Communication:

from: Public Health Nutrition <onbehalfof@manuscriptcentral.com>

reply-to: phn.edoffice@cambridge.org

to: tfrank@uwc.ac.za

date: 30 May 2021, 05:32

subject: Public Health Nutrition - Manuscript ID PHN-RES-2021-0697

30-May-2021

Dear Ms. Frank:

Your manuscript entitled "Evaluation of various nutrient profiling models against the packaged food supply in South Africa" has been successfully submitted online for consideration for publication in Public Health Nutrition. Your manuscript ID is PHN-RES-2021-0697. If we have any queries regarding your submission we will contact you within the next few days.

Please mention the above manuscript ID in all future correspondence. If there are any changes in your contact details, please log in to ScholarOne Manuscripts at https://mc.manuscriptcentral.com/phnutr and edit your user information as appropriate. You can view the status of your manuscript at any time by checking your Author Centre after logging in to https://mc.manuscriptcentral.com/phnutr

Please note that PHN will be a fully Open Access journal from January 2022 onwards, making it permanently and freely available to read, download and share around the world. This will mean that original papers submitted to the journal after 31st March 2021 will be subject to payment of an article processing charge if accepted. You can find out more about this here:

https://www.cambridge.org/core/journals/public-health-nutrition/public-health-nutrition-open-access-frequently-asked-questions

Thank you for submitting your manuscript to Public Health Nutrition.

Sincerely,

Alice Gooch

Public Health Nutrition Editorial Office

phn.edoffice@cambridge.org

https://mc.manuscriptcentral.com/phnutr

Second communication

from: Public Health Nutrition <onbehalfof@manuscriptcentral.com>

reply-to: phn.edoffice@cambridge.org

to: tfrank@uwc.ac.za

date: 3 Sept 2021, 05:00

subject: Public Health Nutrition - Decision on Manuscript ID PHN-RES-2021-0697

Dear Author,

Thank you for submitting your manuscript entitled "Evaluation of various nutrient profiling models against the packaged food supply in South Africa" to Public Health Nutrition. Your manuscript has now been reviewed. Although the work was considered to be interesting, several substantive points were raised during the review process. As such, we are not able to accept your article for publication in its present form.

We would be willing to consider a revised version of the paper that takes into account the comments made by the Editor and reviewers, included at the bottom of this email. If you wish to revise your manuscript, please could you submit a copy of the revised manuscript highlighting (directly in the text using a red font and NOT track changes) the changes that you have made. Please note that submitting a revision will not guarantee its acceptance.

To ensure a double blind review process please ensure your comments and/or attachments in response to reviewers and/or editors are anonymous i.e. no headed paper etc and no reference to your institution or name. If you have any questions regarding anonymity please contact the editorial office (phn.edoffice@cambridge.org).

To start your revision now, click the link below:

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Alternatively, you may log into your Author Centre at https://mc.manuscriptcentral.com/phnutr, where you will find your manuscript under "Manuscripts Awaiting Revision". When submitting your revised manuscript, please use the space provided to document any changes you make to the original manuscript. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response.

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Publication agreement form:

https://www.cambridge.org/core/journals/public-health-nutrition/information/author-publishing-agreement

If English language editing has been requested in the below comments, we list a number of third-party services specialising in language editing and/or translation. Use of any of these services is voluntary, and at your own expense.

Because we are trying to facilitate timely publication of manuscripts submitted to Public Health Nutrition, your revised manuscript should be uploaded by 03-Nov-2021. If it is not possible for you to submit your revision by this date, please contact the Editorial Office to rearrange the due date, otherwise we may have to consider your paper as a new submission.

Once again, thank you for submitting your manuscript to Public Health Nutrition and I look forward to receiving your revision.

Sincerely,

Dr. Cindy Leung

Deputy Editor, Public Health Nutrition

phn.edoffice@cambridge.org

Associate Editor Comments to Author:

This manuscript presents a policy relevant and rigorous study.

Response: Thank you

As indicated by the reviewers, the authors should focus on condensing the manuscript. Currently there is quite a lot of text and some of the main points are lost. It may help to consider the key research aims, and therefore what needs to be presented in the main text. Consider moving some of the tables/ figures to the appendix.

Minor comments

Line 60. replace "disincentive" with "disincentivise"

Response: We have corrected this. It now reads "…to implement policies that both disincentivise manufacturers to produce ultra-processed foods; and…"

Figure 1- All of the main "N"s in the flow diagram should have a description e.g. "NPM assigned"

Response: We have added descriptions to figure 1 as suggested.

Figures and tables should be able to stand alone- remove acronyms from figures or include in figure/ table footnotes

Response: Figure/table footnotes have been included were relevant

Line 195- Delete "categories"

Response: We have deleted this.

Line 231 and throughout. The phrase "twice as strict" is not clear- this could be interpreted as meaning the nutrients caps were half as high. Suggest using alternative wording to "strict" when making numerical comparison, though may be appropriate when speaking in general policy terms later in discussion.

Response: Thank you for highlighting this. The word strict has been replaced with non-compliant in the results section. E.g. instead of "twice as strict" we have used "twice as many non-compliant products" / instead of "stricter" we have used "more non-compliant" etc.

Independent Reviewer(s)' Comments to Author:

Reviewer: 1

Comments to the Author

General comments:

This paper provides South African specific information by investigating four nutrient profile models using a sample of SA groceries. It is useful to inform SA policy development.

Response: Thank you

This paper is written as a comprehensive report rather than a journal manuscript. It is too long and has too many tables for a manuscript for PHN. Part of journal writing skills is to be able to condense a manuscript to something that conveys the information and is easy for the reader to read and understand. Number of tables, references, and the size of the appendix as well as text in the results can be reduced. The discussion should provide more of a critique than a summary of results only.

Response: This feedback is well noted. We have sought to make the paper more concise and have reduced the number of tables, references, appendix, and results to the most relevant and important ones.

Please consider only using the most appropriate reference in the introduction. As well, references need to be checked- some are not the primary source of the information in the sentence e.g. references 50, 53. 54, 55

Response: This has been checked, and the number of references reduced.

The word "restrictive" when referring to food policy is not necessary. I suggest it is removed. The term "policy" implies that there are restrictions e.g. line 74.

Response: This suggestion was considered at length, and we have decided to retain this. Although many policies contain some form of restriction, we believe that not all policy is restrictive, e.g. a policy that provides a grant to enable purchasing of healthier foods is not restrictive. As mandatory front-of-package labels, marketing restrictions, taxes etc. are referred to (which are considered restrictive) the word seems appropriate – especially as the purpose of the proposed NPM discussed in this paper is to underpin these "restrictive" policies.

One decimal place for %

Response: We have corrected this throughout paper.

The paper should establish the criteria it is going to use to determine the "best" model.

Response: There were a number of reviewer comments about validity, and the way we tested/described it in our paper; as well as identifying the CAM model as the "best" or "most appropriate". On reflection, we have decided it best to rephrase this throughout the paper, to prevent any confusion. Additionally, after this paper was submitted for review, a publication that discusses the development process, and decision-making for the criteria in the proposed NPM (referred to as CAM in this paper) has been published (A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa; Nutrients 2021; available at https://doi.org/10.3390/nu13082584). This published paper has now been referenced to provide better context for this study.

Our main purpose (which did not come across clearly in the previous version of the article) was to evaluate how the proposed NPM (referred to as CAM in this paper) compared to other existing NPMs, that were developed for similar purposes; or proposed in South Africa. As such, the reference to the "best" model has been removed. We have instead framed it as evaluating whether or not the proposed model is appropriate for its intended use.

Abstract

No need for % and numbers in abstract

Response: We have removed the numbers, and only kept %.

Line 20: is there something missing as there are two percentages shown? "CWO 2019 for foods (71.19%, n=3766 and 71.13%, n=3763 respectively).

Response: Sentence edited to make the comparison between CAM and CWO clearer.

It now reads: "The CAM had an overall non-compliance level of 73. 2%, and was comparable to the CWO 2019 for foods (71.2% and 71.1% respectively)."

Line 23: suggest clarify- "due to the inclusion of nutrients to encourage in the model"

Response: We have corrected this.

This sentence now reads: "This was largely due to the inclusion of nutrients to encourage, which is a criterion for this NPM."

Line 24: 56.35% is confusing- is the word "food" missing?

Response: This has been deleted (due to amended wording in response to comment 9 above).

Line 25: no need for the word "restrictive"

Response: This sentence has been edited, and does not include reference to restrictive.

It now reads: "For the purpose of discouraging products high in nutrient associated with poor health in SA, the CAM is a suitable NPM"

Keywords- suggest "food policy" not "restrictive food policy"

Response: We have corrected this.

Introduction

Line 32: too many references

Response: We have reduced the number of references.

Line 33: It's not clear what "nutrition transition" means without going to the reference.

Response: We have reworded the sentence to read "Changing lifestyles and food systems are synonymous with the nutrition transition, with changing diets shifting away from traditional diets to an increased consumption of ultra-processed, refined foods"

Line 35: too many references

Response: We have reduced number of references.

Line 79: this sentence does not explain to the reader what the food labelling regulation is. Does it cover everything on the label? And is the draft to replace it or only about claims? Does the draft cover anything mentioned in the rest of this paragraph e.g. the NIP?

Response: This paragraph has been updated. Please refer to lines 84-90.

It now reads: "The current regulations relating to the labelling and advertising of foods in SA, R146, was implemented in 2010. According to R146, it is mandatory to include an ingredient list on packaged food labels but a nutrition information panel (NIP) is optional. An updated draft of these regulations, R429 of 2014 exists, but has not been promulgated. This draft R429 recommended a mandatory nutrition information panel (NIP) to promote transparency of the nutritional content of the foodstuff and to verify compliance to nutrient profiling recommendations for health and nutrition claims."

Line 96: "developed" may not be the best word as it wasn't developed in SA

Response: We have changed "developed" to "proposed".

Line 112: doesn't read well, perhaps "flagging since it is considered free sugar" is not needed.

Response: The words "flagging since it is considered free sugar" have been remove.

Line 112: It needs to be clear if inclusion of 100% juice is the only difference between added sugars and free sugars in this NPM?

Response: No, it is not only in 100% fruit juice (although this is the category were the difference is evident). As it is not only 100% fruit juice, we did not amend the current wording.

Line 116: why was energy excluded in this model?

Response: Have added a sentence: "Energy was excluded during the NPM development process as only 2.3% of products evaluated were exclusively high in energy, but not any other nutrient (described

elsewhere in detail)" (The reference used in this sentence was published after submission of the previous version of this paper.)

Table 1: the comparison doesn't accurately capture the SA HNC as you have shown how the product obtains a score of zero but that isn't how the model works. I suggest you add a footnote to clarify.

Response: Table 1 has an allocation for a score of minimum score (of zero), as well as maximum score (which differs based on category). As an example, this is how the score for total sugar is worded: "Score of 0 (≤5.0g /100g) to 10 (>45.0g /100g)".

A footnote has been added which reads: "An overall score is calculated for the SA HNC, by first assigning a base score by food category, according to the energy content, saturated fats, total fats, total sugars and sodium. Thereafter, additional points are assigned for content of FVNL, fiber and proteins per 100 grams of product. The CWO, CAM and PAHO have cut-points for each nutrient of concern, and thus do not calculate an overall score."

Table 1 should be in the methods

Response: Table 1, as well as the accompanying section "models selected for comparison" have been moved to the beginning of the methods section

The introduction should conclude with the objective of the study.

Response: We have added this. Please see lines 98-100.

It now reads: "This study aimed to apply a newly developed NPM to the packaged food supply in SA and compare its' performance to other existing NPMs as an indication of suitability for use given the SA Department of Health's interest in it."

Methods

Sampling- how did you handle multiple sizes of the one product?

Response: Assessment and analysis was based on unique barcodes. This means that in some instances multiple sizes of one product were included. However, this was done indiscriminately, affecting both compliant and non-compliant products.

Line 171-176: methodology should state how many products or what proportion had to be estimated so that the reader understands where errors may enter the data.

Response: This has now been added. Please see line 179-180 which now reads "FVLN scores were calculated based on the percentage of FVLNs in ingredient lists when reported and manually estimated for products without this information (out of 957 products 62% were manually estimated)."

Results

Line 205: the term category is confusing as it is used here in the context of food/beverage but later there are food categories that are also referred to as 'categories' in the text.

Response: The sentence has been reworded (please see line 213).

It now reads: "Table 2 presents the percentage of products non-compliant for each NPM for foods, beverages and overall; as well as by category"

Line 214-240: no need to repeat so many results here when they are in the table.

Response: We have edited the paragraph to reduce words. (Please see line 213-228)

The paper has an excessive number of tables. Consider if Table 4 is necessary.

Response: We have considered this, and moved table 4 to the appendix (now part of appendix 1).

Line 272: these overall results should be at the start of the results section.

Response: The results section starts by discussing overall results, in terms of levels of compliance of each NPM (please see lines 213-220). We have not moved this, as this section is regarding level of agreement (and thus differences between each NPM).

Line 275-277: there are too many percentages quoted here for the reader to enjoy reading the paper. This information does not add to the paper as it can be gleaned elsewhere.

Response: We have deleted the percentages (please see lines 263-264).

It now reads: "Categories in which more than half the products were non-compliant according to all NPMs included confectionary and desserts, soups and sauces, sodas and snack foods."

Line 292 and tables 6 and 7: It isn't necessary to have both these alignment tests, choose one to report on.

Response: We have moved table 6 to the appendix (appendix 3), and edited text to reflect this. Please see line 280-281) which reads "None of the NPMs are completely aligned (pairwise correlation coefficients, table 4; and level of agreement, appendix 3."

Table 5 could be an appendix table.

Response: Although we have not removed table 5 (now table 3) other tables/figures have been moved to the appendix/deleted. We are of opinion that the comparison of how the various NPMs perform in different food groups adds value to the interpretation of the findings of this paper.

Table 4 was deleted, as a more detailed version was already included in the appendix (in what is now appendix 1).

Figure 2 and table 2 were deleted (as there is adequate information in what is now table 2 of the paper)

Table 6 was moved to the appendix (as appendix 3)

Line 317- 341 and Table 8: I do not think this adds to the paper and it does not achieve the outcome outlined in Line 318 "to compare how effectively the various NPMs cut-points achieved the desired outcome for the nutrients of concern" as there is no measure of effectiveness. The authors have points related to this in line 389 and 402-409 of the discussion. If this data is thought central to the papers findings then it could be in the appendix and a short summary included in the results- in fact lines 402-409 might be appropriate and are more results than discussion.

Response: Other tables/figures have been moved to the appendix/deleted. We think that the comparison of the nutrients across NPMs (in the old table 8/new table 5) adds to the findings of the paper.

Table 4 was deleted, as a more detailed version was already included in the appendix (in what is now appendix 1).

Figure 2 and table 2 were deleted (as there is adequate information in what is now table 2 of the paper)

Table 6 was moved to the appendix (as appendix 3)

Please also refer to the answer to comment 36 below.

Line 393: this paragraph repeats results and doesn't add to the discussion

Response: The discussion around free sugar is deemed important to highlight (the results does not discuss the "why" behind the result). As part of an internal review prior to submission, critical readers indicated that aspect of free and total sugar is confusing and therefor the discussion on this aspect was expanded. This is one of the key areas were the CAM differs to other NPMs.

Discussion

Line 367: elaborate on "nutrition transition" with a clause explaining it

Response: We have now explained the term in the introduction (please see answer to comment 14 above).

Line 402-409- see comment in results section

Response: We have considered this; and deleted some unnecessary text. However, we feel that moving this to the results (rather than discussion) takes away from the focus of the discussion. As we

have now improved on explaining the purpose of this study, it is important in the discussion to make reference to how the CAM differs/is similar to the other models.

This section now reads: "The CAM which does not include a criterion for energy had a similar mean energy content to the CWO 2019 which does include a threshold for total energy for compliant products. The mean saturated fat and trans-fat values are slightly higher for the CAM than the other models, which is likely due to the exclusion of an energy criteria for this NPM. However, although the CAM has the highest mean for saturated fat in the compliant group, it is still well-below the cut-point for foods (4g) and beverages (3g). Similarly, the mean trans-fat content in the compliant group is well below the cut-point provided in the SA trans-fat regulation."

Line 411-432: there is not a good explanation why it is the best model. The paper needs to address this issue better. This paragraph reiterated findings without justifying the statement. What criteria are there for best model? And CAM is not very different to PAHO when it comes to drinks but by combining these two paragraphs it can be explained why more succinctly.

Response: Please see answer to comment 6. We have removed "most suitable"– and rather focused on the model being suitable for its intended purpose. These paragraphs have been reworded (please see lines 360-382)

Line 470: Based on Chilean experience? The paper hasn't established it appropriate for these policies so these are examples of policies only.

Response: We have removed the word "appropriate".

Appendix

Appendix 1 is a detailed summary of what can already be found in the original references for the NPMs. I suggest the details are not needed for this paper and only any modifications are included in the methods.

Response: Noted, we have now deleted appendix 1

Page 35 Line 5: the sentence doesn't explain what it qualifies for- it should mention nutrition content and health claims in this sentence

Response: Deleted, as per recommendation to delete appendix 1 in comment 39 above.

Reviewer: 2

Comments to the Author

This is an important and thorough research article, with great relevance to the debate on the use of nutrient profiling models for policy purposes. However, minor revisions are recommended. In particular, the aim needs to be clearer about the purpose of the study, and the conclusion needs stronger justification.

Response: Thank you. We have tried to address the purpose and justification of the study more clearly throughout the paper.

There were a number of reviewer comments about validity, and the way we tested/described it in our paper; as well as identifying the CAM as the "best" or "most appropriate" model. On reflection, we have decided it best to rephrase this throughout the paper, to prevent any confusion. Additionally, after this paper was submitted for review, a publication that discusses the development process, and decision-making for the criteria in the proposed NPM (referred to as CAM in this paper) has been published (A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa; Nutrients 2021; available at https://doi.org/10.3390/nu13082584). This published paper has now been referenced to provide better context for this study.

Our main purpose (which did not come across clearly in the previous version of the article) was to evaluate how the proposed NPM (referred to as CAM in this paper) compared to other existing NPMs, that were developed for similar purposes; or proposed in South Africa. As such, the reference to the "best" model has been removed. We have instead framed it as evaluating whether or not the proposed model is appropriate for its intended use.

Major comments:

1. Lines 468-470: A stronger justification is needed for the conclusion that CAM is a suitable NPM for SA policies. Why is it the best NPM for SA compared to the multiple NPMs developed worldwide but not compared in this study? Construct validity needs to be defined earlier on in the article. Was the study testing the validity of CAM? How is it valid if there is no gold standard for comparison?

Response: Please see response to comment 1, as well as reworded conclusion, which now reads: "Based on the assessment of four NPMs against the SA packaged food supply, the CAM is a suitable NPM to underpin restrictive food policies in SA. It is able to identify unhealthy products high in saturated fat, sugar, sodium, or containing non-sugar sweetener. Policies it can support include those

that require the identification of unhealthy foods to be regulated, such as for the restriction of marketing to children, regulation in the school food environment and for warning FOPLs."

2. Line 123: how is construct validation defined in this study? What NPM is being validated and what is the construct being used for this purpose?

Response: Please see response to comment 1, as well as reworded methodology. We have considered at length, and opted not to use the term "best", or "validity" – but rather frame it as evaluating whether or not the proposed model is appropriate for its intended use.

This section now reads: "Currently, there is no gold standard for classifying the healthfulness of foods to use for NPM validation. The current study developed algorithms to apply four NPMs to a cross-sectional analysis of the SA packaged food supply collected in 2018. The purpose is to show how similarly or differently the same set of products available in SA would be considered as compliant or not under these four NPMs."

Minor Comments:

Abstract:

1. Lines 7-9: the aim could be more specific. Isn't the aim to identify the most effective/appropriate/suitable NPM for policy in SA? Rather than simply identifying "a" NPM?

Response: We have updated the aim. It now reads: "This study aimed to apply a newly developed nutrient profiling model (NPM) to the food supply in South Africa (SA) and compare its' performance against existing NPMs as an indication of suitability for use to underpin food policies targeted at discouraging consumption of products high in nutrients associated with poor health."

2. Line 25: The conclusion needs further explanation. Why was it the most suitable NPM?

Response: The conclusion in the abstract has been updated. It now reads: "For the purpose of discouraging products high in nutrient or ingredients associated with poor health in SA, the CAM is a suitable NPM".

Please also refer to the answer to comment 1 for further information.

Introduction:

3. In the introduction the authors have interchanged the terms used for "unhealthy" foods, from processed foods high in risk nutrients, to ultra-processed foods, to energy dense foods. One term should be used throughout. If ultra-processing is one of the concerns being addressed, it would be relevant to include some analysis on the UPF status of foods in the sample.

Response: The term processed has been changed to ultra-processed where relevant throughout. Unhealthy has not been changed, as it was used intentionally. Although the proposed NPM predominantly identifies ultra-processed food (due to the added salt/added fat/free sugar criteria) ultra-processing is not part of the criteria, and thus it does not exclusively identify processed/ultra-processed foods high in nutrients of concern, so the differentiation is necessary.

Methods:

4. Line 88: How were the models chosen? An overall justification for why these specific models were evaluated is needed.

Response: Please see lines 104 to 112. Paragraph has been edited, and a reference to recent publication that explains the development process followed for the proposed NPM has been added.

It now reads: "A rigorous process has previously been followed to identify a NPM suitable for use in restrictive food policy in South Africa. This newly developed NPM is referred to as the Chile Adjusted Model (CAM) in this paper. Its performance needed to be tested alongside existing NPMs developed for similar purposes. The models chosen for the comparison included those that have some resonance with the restrictive food policies under consideration. These include the Chilean Warning Octagons (CWO) which Chile has successfully used to implement a comprehensive package of restrictive food policies, and the Pan-American Health Organisation (PAHO) model, as the first proponent of restrictive food policies. It was also appropriate to include the existing NPM, developed in SA for application when Nutrition and Health claims are considered, in the assessment."

5. Line 151: Excellent flowchart of the sample. It would be relevant to know what types of products were excluded because of the missing NIP (n=9110).

Response: Unfortunately, this data is not available. We kept a record that a photograph was taken, but did not enter any data about the product if there was no NIP. Given the time (and thus expense) of data entry, this was not feasible.

Discussion:

6. Line 365: It's stated that over half of foods in the marketplace were non-compliant, however it's not clear if the sample is representative of the marketplace, as n=9110 products were not analysed due to missing NIP. This also needs to be acknowledged in the limitations.

Response: Agreed, sentence amended to remove reference to marketplace (line 316-317). It now reads: "According to the criteria of the four NPMs assessed, between half and eighty percent of all products assessed contained excessive amounts of nutrients of concern and are considered non-compliant."

This is acknowledged in the limitations (line 403-404). It reads: "Additionally, products were only included in the study if a NIP was present. As NIPs are not currently a legal requirement in SA many products had to be excluded from NPM analyses."

7. Line 411-421: Further justification is needed as to why CAM is the most appropriate model. Why does it perform better than CWO and PAHO, and why is this better for policy outcomes?

Response: Paragraph reworded. Please see response to comment 1, as well as reworded methodology.

Reference to "the best" has been removed, and instead reference is made to it being appropriate. "Based on the results of the current study, the CAM is an appropriate NPM for its intended purpose…"

8. Lines 425-426: Yes, a strict NPM would initially mean few compliant products, but wouldn't this also encourage reformulation?

Response: Agreed, added to sentence "although this could encourage reformulation by manufacturers".

Reviewer: 3

Comments to the Author

This is an interesting paper and could help inform policy decisions in South Africa. In the introduction, I think that more focus needs to be on the point of NPMs, which are typically policy-related to help describe what foods are 'healthy' or 'less healthy' and therefore products can be categorized and this is useful for policies. I'm not sure this point comes across, as you only briefly describe restrictive policies.

Response: There has been a recent publication on this, that discusses this in detail (A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa; Nutrients 2021;

available at https://doi.org/10.3390/nu13082584). We have referenced this in the introduction. Please see lines 81-82, which read: "In SA, a NPM has recently been proposed to identify unhealthy foods and beverages that can be restricted through relevant policies".

It would also be helpful to have more SA context – are there restrictive nutrition policies being considered? This is critical in demonstrating the importance of your paper.

Response: The South African National Department of Health has expressed interest in these types of policies in the media. This has been added to the introduction (see lines 92-96)

It now reads: "The SA National Department of Health has been working to finalize R429, with the intention to include a NPM that is suitable for the SA context and discourages the supply and demand of ultra-processed foods and beverages containing high-amount of nutrients or ingredients linked to poor health outcomes. Additionally, they have expressed interest in restrictive policies, such as front-of-package warning labels"

It appears to me that you are trying to test the development of a new NPM (the CAM) against other previously employed NPMs, each with unique qualities. I feel you could add some additional description in your objectives to test different TYPES of NPMs (and not just a random assortment) to see which might be best applied in the SA context. This overall message didn't come across to me in the introduction or in the discussion.

Response: Agreed. This has been reworked in the paper – and reasons for inclusion of specific models discussed under methodology.

The introduction to the methods section now reads (lines 104 to 112): "A rigorous process has previously been followed to identify a NPM suitable for use in restrictive food policy in South Africa. This newly developed NPM is referred to as the Chile Adjusted Model (CAM) in this paper. Its performance needed to be tested alongside existing NPMs developed for similar purposes. The models chosen for the comparison included those that have some resonance with the restrictive food policies under consideration. These include the Chilean Warning Octagons (CWO) which Chile has successfully used to implement a comprehensive package of restrictive food policies, and the Pan-American Health Organisation (PAHO) model, as the first proponent of restrictive food policies. It was also appropriate to include the existing NPM, developed in SA for application when Nutrition and Health claims are considered, in the assessment."

I found that the conclusion that the CAM was the best model was not entirely clear to me through your discussion (although from the evidence you provide I agree it holds promise). Your discussion describes why it is superior to the SA HNC, but for reasons of feasibility mostly, and doesn't include your agreement or alignment or correlation findings.

Response: We have removed “most suitable” – and instead focused on it being suitable for its intended purpose.

There were a number of reviewer comments about validity, and the way we tested/described it in our paper; as well as identifying the CAM as the “best” or “most appropriate” model. On reflection, we have decided it best to rephrase this throughout the paper, to prevent any confusion. Additionally, after this paper was submitted for review, a publication that discusses the development process, and decision-making for the criteria in the proposed NPM (referred to as CAM in this paper) has been published (A Fit-for-Purpose Nutrient Profiling Model to Underpin Food and Nutrition Policies in South Africa; Nutrients 2021; available at https://doi.org/10.3390/nu13082584). This published paper has now been referenced to provide better context for this study.

Our main purpose (which did not come across clearly in the previous version of the article) was to evaluate how the proposed NPM (referred to as CAM in this paper) compared to other existing NPMs, that were developed for similar purposes; or proposed in South Africa. As such, the reference to the “best” model has been removed. We have instead framed it as evaluating whether or not the proposed model is appropriate for its intended use.

I might also add that just in general, the addition of free sugars criterion to the CWO is an interesting but controversial addition. While I agree with you that the evidence is moving in this direction to suggest we should avoid consuming fruit juice, you might state that most of these NPMs were developed prior to this evidence being as clear, and that it is likely that they will incorporate this as the knowledge advances (or something to that effect). It feels to me like if a free sugar criteria were added to the SA HNC it might perform equally well to the CAM… and then the superiority of the CAM lies within the feasibility aspect only (which isn’t to be ignored).

Response: The inclusion of the free sugar criteria was discussed in detail a complimentary paper (available at https://doi.org/10.3390/nu13082584). Because of the criteria for positive points earned for fibre, protein and FVNL in the SA HNC it is unlikely that the SA HNC would score similarly to the CAM.

I have provided several suggestions below that I think will help make the paper more clear.

Abstract

Line 19-20 – I'm not sure where the respectively applies? Is there meant to be another system listed here?

Response: Sentence edited to make the comparison between CAM and CWO clearer. It now reads: "The CAM had an overall non-compliance level of 73. 2%, and was comparable to the CWO 2019 for foods (71.2% and 71.1% respectively)."

Line 37 – I suggest that you incorporate person-first language and use 'people with obesity' rather than 'obese people'. (E.g., 28% of children will have obesity)

Response: Sentences edited to reflect person-first language. It now reads: "In South Africa (SA), one-third (31%) of men and two-thirds (68%) of women have overweight or obesity, and 20% of women live with severe obesity. If the current trend for children continues, 28% of South African children (aged 5 to 19) will have obesity by 2030"

Line 40 – While I appreciate the importance of undernutrition, stunting and wasting in SA, I'm not clear of it's relevance to your paper. The next paragraph goes on to describe energy-dense, processed foods which to my knowledge haven't been associated directly with undernutrition and stunting/wasting. I suggest you amend this to make the link more explicit.

Response: We have removed the undernutrition text and reworded the paragraph to focus on the link between undernourished children becoming overweight/obese adults.

The paragraph now reads (lines 43-48): "The double burden of malnutrition (overweight and undernutrition) occurs within an individual over their lifecycle, and across generations within households (stunted/wasted child with an overweight mother). It has long-term consequences for individuals, communities and the economic future of the country. Malnutrition in any of its forms leaves one vulnerable to nutritional deficiencies, chronic diseases of lifestyle and infectious diseases including tuberculosis, HIV and coronaviruses."

Line 53 – while I appreciate that this is correct, stating that 'ultra-processed foods are beomcing the food of choice for many' implies that people WANT and CHOOSE to consume this food (e.g., an individual behaviour) rather than an environmental issue. I might suggest a reframing to further and more appropriate discuss the environment and societal factors that are driving these changes in dietary patterns rather than just an issue of individual 'choice'.

Response: The paragraph was not intended to reflect individual behaviour. It discusses the effect of unemployment, poverty, food price, type, availability and marketing on consumption habits. However, it is apparent now that using the word "choice" does not reflect this sentiment – the paragraph has been edited (lines 50-60).

This section now reads: “Poor nutrition in SA is largely driven by what is available and accessible. Ultra-processed foods high in sugar and fat are cheap sources of energy. High levels of unemployment and poverty make healthier options unattainable for most. Both rural and urban poor communities rely heavily on formal supermarkets and/or both formal and informal fast food outlets and small shops (spazas) to purchase their food. Resource constraints drive poor South Africans towards cheap foods resulting in regular consumption of ultra-processed food. Multinational food companies account for the majority of the market share of ultra-processed foods. A recent study found that 76% of assessed packaged foods in SA supermarkets is ultra-processed. Consumption habits are continually shifting towards ultra-processed products due to economic, environmental and societal factors such as the price, food type, availability and marketing strategies employed by large corporations.”

Line 60 – disincentivize (not disincentive)

Response: We have corrected this. It now reads “…to implement policies that both disincentivise manufacturers to produce ultra-processed foods; and…”

Line 67 – the implementation of NPMs is only relevant when linked to a policy – so do you mean to say that the adoption of policies that require NPMs is slow? Or that most that are used are adapted from other countries? I’m unclear what this statement means.

Response: We have amended the sentence for clarity. It now reads: “In low-to-middle-income countries (LMICs), the implementation of policies underpinned by NPMs has been slow, possibly due to limited resources and a lack of population-level dietary data required to support the development of NPMs”.

Line 79 – What is the R429? This paragraph is very confusing to someone who isn’t familiar with the SA policy sphere.

Response: This paragraph has been updated. Please refer to lines 84-90.

It now reads: “The current regulations relating to the labelling and advertising of foods in SA, R146, was implemented in 2010. According to R146, it is mandatory to include an ingredient list on packaged food labels but a nutrition information panel (NIP) is optional. An updated draft of these regulations, R429 of 2014 exists, but has not been promulgated. This draft R429 recommended a mandatory nutrition information panel (NIP) to promote transparency of the nutritional content of the foodstuff and to verify compliance to nutrient profiling recommendations for health and nutrition claims.”

Line 84 – remove 'This is unfortunate' and perhaps change to something like "The lack of transparency with a NIP makes it challenging to apply and verify compliance with a NPM criteria, and thus understand ..."

Response: This text has been removed (please see answer to comment 12 above).

Line 94 – It has been validated in what countries?

Response: We have added "South Africa".

Table 1 – Can you clarify if the CWO 2019 apples to foods or beverages that have added sodium and added saturated fat or just have sodium or saturated fat? Response: Have clarified this for the CWO in the table, by adding "added" for each nutrient. This is clear with the CAM but now in the description of the CWO 2019 – if not, you should highlight that this is an additional change. I'm trying to understand why in Table 5 there are so many additional products with the CWO 2019 that aren't captured by the CAM – is this possibly why? Please discuss, and make amendments if necessary to where you describe the CAM and in the results.

Response: There are only 43 products (out of a total of 6747) that are only excessive according to the criteria of the CWO 2019, and not the CAM/other NPMs. The reason for these products has been explained in the discussion (line 346-361).

Line 123 – I'm not sure that your statement about criterion (or in addition, convergent) validity is accurate – it's not 'too expensive', but it is time consuming and more expensive. On the flip side, I would argue that just comparing various systems without stating if any of them have been validated using convergent or criterion validity is not particularly useful. I suggest you discuss why your work is important rather than why other types of validation are not feasible. Can you state something about the criterion or convergent validity about any of the systems you are using to bolster why they would be an important comparison NPM to consider? Perhaps even building on why the Chilean system has been successful – was it the policy or the NPM? Or both?

Response: Agreed. Introduction to methods section has been reworded, to better express the purpose of this study (and the concept of "validity" removed).

This section now reads: "Currently, there is no gold standard for classifying the healthfulness of foods to use for NPM validation. The current study developed algorithms to apply four NPMs to a cross-sectional analysis of the SA packaged food supply collected in 2018. The purpose is to show how similarly or differently the same set of products available in SA would be considered as compliant or not under these four NPMs."

Please also see responses to comment 3 and 4 above.

Line 145 – and when it wasn't available, how was the 'as consumed' form contrived? I'm somewhat unclear how this statement compares with the NPM unable to be assigned in Figure 2 – wouldn't this be soups, sauces, etc.?

Response: We think you are referring to figure 1 here. Some products (especially beverages) provide information on the packaging about reconstitution, eg Dilute 1 part concentrate to 7 parts water etc. In these cases, we could accurately calculate the "as consumed" nutritional information. However, in instances where this information was not provided / it was unclear we excluded the products (which is presented in figure 1).

Table 2 (and abstract) - suggest you go with 1 decimal place on percentages throughout (either way, be consistent in text and tables for number of decimal points).

Response: We have corrected to 1 decimal place throughout.

Figure 2 and Table 3 have the exact same information. Suggest you remove Figure 2 and the description, as it is all repeated below.

Response: Agreed, figure 2 deleted, as table 3 (now referred to as table 2) contains adequate information. The paragraphs have been restructured (please see lines 213-239).

Table 4 – you have shown some of the contrasts – why not all (e.g., why not PAHO vs. CWO-2019)?

Response: As per one of the other reviewer's recommendations, table 4 has been removed from the article (as there were too many tables).

Line 263 – remind me again why they are expected to have the largest number of excessive products?

Response: The words "as expected" have been removed from the text to prevent any confusion.

Line 274 – according to all four NPMS assessed.

Response: We have amended this; it now reads "according to all four NPMs assessed"

Table 6 – Suggest you make the last row, first column SA HNC to be consistent.

Response: We have removed this table (per another reviewer's comment).

Line 338 – I suggest that you clarify that this was for the nutrient level analysis, and not the entire analysis. I'm unclear why you are comfortable with using the added sugar algorithm but not the FVNL algorithm – please confirm why?

Response: Words "nutrient level" added.

There was adequate information on total sugar content in the NIP to calculate free sugar. It was estimated using the PAHO method. However, as the FVNL estimate is a percentage and often did not rely on a value estimated from the NIP/ingredients list (percentage fruit and veg is not routinely reported), it was less accurate. These calculations are explained in the methods section (please refer to lines 177-189).

Line 368 – do you really think that 50% is predominant? I'm not sure I agree.

Response: This was referring to the products that were excessive in all 4 models. However, as this is unclear, this sentence has been edited. It now reads: "According to the criteria of the four NPMs assessed, between half and eighty percent of all products assessed contained excessive amounts of nutrients of concern and are considered non-compliant."

Line 382 – please describe why it is easy to score positive points.

Response: This sentence has been edited. It now reads: "In all of these categories it is easy to score positive points for fiber protein and/or FVNL as these categories of food often contain these ingredients."

Line 391 – bias against

Response: We have corrected this by adding "against".

Line 411 – This paragraph needs additional discussion. Just because the CAM and CWO 2019 are aligned doesn't mean they are the most appropriate. I think providing an overall summary sentence or two on why, and then going into detail. Do they capture the most products that you would hope without being too restrictive? You describe the PAHO model being too strict, but this is a purely qualitative consideration – please provide some numbers to describe why this is so… e.g., the categories where this is particularly high.

Response: Please see response to comment 4. These two paragraphs have been edited (lines 360 – 382), and details of categories have been added where PAHO is stricter than other models.

I expect others would argue that the inclusion of free sugars in juices make this policy option unpalatable to most governments at present – is this a consideration?

Response: We based our recommendations on guidelines on free sugar restrictions which includes addressing free sugars in fruit juices (Collin, L.J.; Judd, S.; Safford, M.; Vaccarino, V.; Welsh, J.A. Association of Sugary Beverage Consumption with Mortality Risk in US Adults. JAMA Netw. Open 2019, 2, e193121 https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2733424).

Informal discussions with the South African Department of Health have indicated that this is an area of concern in SA, and that they are interested in regulation to address this.

Line 440 – I would think that, again, an additional screening step might be unpalatable for policy decisionmakers in this process.

Response: The purpose of the NPM we proposed is to inform the criteria to identify unhealthy products. This additional recommendation was based on findings that where, without a measure to regulate how positive health/nutrition claims are made, both warning labels and health/nutrition claims may occur on the same product (as is currently seen in Chile), which creates confusion for consumers. This should be avoided in South Africa, and so this recommendation was added should the Department of Health in SA be considering both warning labels and health and nutrition claims on products.

This section now reads: "This model is currently recommended in SA's draft regulation R429, to identify products permitted to carry a health or nutrition claim rather than to identify harmful nutrients of concern. As such, it may still have a role to play in policy specifically for health claims as a subsequent step to the CAM. It is important that products do not carry both a warning for excessive nutrients of concern as well as a health claim encouraging consumption of certain healthy components as this has been found to create mixed messages on the healthfulness of foods, and confuse consumers. In other words, provided a product is first classified as not excessive in nutrients of concern according to the CAM criteria a health claim could be allowed for products that also meet the SA HNC criteria."

Finally, in your conclusion you might add a bit more about why the CAM is the most appropriate in a really succinct way (feasibility, agreement and alignment with other systems implemented elsewhere, but captures sugary drinks). Or something to this effect.

Response: Please see response to comment 4, as well as reworded conclusion, which now reads: "Based on the assessment of four NPMs against the SA packaged food supply, the CAM is a suitable NPM to underpin restrictive food policies in SA. It is able to identify unhealthy products high in saturated fat, sugar, sodium, or containing non-sugar sweetener. Policies it can support include those that require the identification of unhealthy foods to be regulated, such as for the restriction of marketing to children, regulation in the school food environment and for warning FOPLs."

from: Public Health Nutrition <onbehalfof@manuscriptcentral.com>

to: tfrank@uwc.ac.za

date: 27 Jan 2022, 04:57

subject: Public Health Nutrition - Decision on Manuscript ID PHN-RES-2021-0697.R1

Dear Author,

We have assessed the revised version of your manuscript titled "Applying and comparing various nutrient profiling models against the packaged food supply in South Africa". While many of the comments made on the initial version have been addressed, there are some minor remaining concerns; these are detailed on the report at the bottom of this letter. I regret the need for additional revision, but the points identified are of importance.

We would be willing to consider a revised version of the paper that takes into account the comments made by the Editor and reviewers, included at the bottom of this email. If you wish to revise your manuscript, please could you submit a copy of the revised manuscript highlighting (directly in the text using a red font and NOT track changes) the changes that you have made. Please note that submitting a revision will not guarantee its acceptance.

To ensure a double blind review process please ensure your comments and/or attachments in response to reviewers and/or editors are anonymous i.e. no headed paper etc and no reference to your institution or name. If you have any questions regarding anonymity please contact the editorial office (phn.edoffice@cambridge.org).

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If English language editing has been requested in the below comments, we list a number of third-party services specialising in language editing and/or translation. Use of any of these services is voluntary, and at your own expense.

https://www.cambridge.org/core/services/authors/language-services

Because we are trying to facilitate timely publication of manuscripts submitted to Public Health Nutrition, your revised manuscript should be uploaded by 27-Feb-2022. If it is not possible for you to submit your revision by this date, please contact the Editorial Office to rearrange the due date, otherwise we may have to consider your paper as a new submission.

Once again, thank you for submitting your manuscript to Public Health Nutrition and I look forward to receiving your revision.

Sincerely,

Dr. Cindy Leung

Deputy Editor, Public Health Nutrition

phn.edoffice@cambridge.org

Associate Editor Comments to Author:

The authors have responded well to the extensive reviewer comments. There a just a few minor remaining issues. I agree with reviewer 1 that the use of the term "restrictive" is not very informative, or particularly relevant to the focus of the paper. It is not clear that the accuracy of NPM would need to be different for "restrictive" policies than for "non-restrictive" policies. There are only 5 references to "restrictive food polices" in the paper. I suggest simplifying the phrasing to just "food policies" or being more specific where required (e.g. food labelling, supply, marketing and taxation policies). It's fine to include "restrictive" when used to describe a specific policy like "Restriction of marketing to children"

Response: Thank you for your feedback. We have followed your recommendations and replaced "restrictive food polices" with "food policies" throughout the paper.

As in the main manuscript tables, the tables and figures in the appendix should be able to stand alone. Remove acronyms from figures or include in figure/ table footnotes.

Response: Thank you for identifying this. Acronyms have been removed, or a footnote added to the tables and figures in the appendix

Figure 2. Stacked bar charts should ideally sum to 100%. Suggest include category for "0" excessive nutrients

Response: This is well noted. An additional category for "no excessive nutrients" has been added to the stacked bar chart.

Line 8 replace "its' " with "its"

Response: This has been corrected.

Independent Reviewer(s)' Comments to Author:

Reviewer: 1

Comments to the Author

The paper is more succinct and better places it in the SA context.

I still have a problem with the term "restrictive food policy". We don't usually categorize policies with adjectives and I feel while the authors may think it describes what the policy does it isn't good public health practice. The adjective "restrictive" may be taken by the public and decision makers to be taking something away from people and has negative connotations. As public health researchers it is often difficult to convince policy makers that a policy is worthwhile and to get the most positive response we need to present it in a positive way. The use of this adjective does our policy work a disservice. I would like the journal to get a second opinion on this point.

Response: Thank you for taking time to review this paper again, and for your feedback. We appreciate your important comment on framing. We agree that it is important to create an enabling environment that encouraged buy-in from policy makers. As suggested by the editor, we have rephrased "restrictive food policy" to "food policy" throughout the paper.

Reviewer: 3

Comments to the Author

The authors have addressed all of my comments thoroughly, but I have one additional comment given the new framing of the study for them to consider.

In the Abstract, in the Design section, it is not immediately clear which is the newly developed NPM and which are the comparators. I think this requires some distinction. I suggest you highlight the CAM, and then list the other established systems to which it is compared.

Response: Thank you for taking time to review this paper again, and we are pleased to note that comments have been addressed adequately. We have updated the objective and design sections of the abstract as suggested (keeping the 250 abstract word count in mind). It now reads:

"Objective: This study aimed to apply the newly developed Chile Adjusted Model (CAM) nutrient profiling model (NPM) to the food supply in South Africa (SA) and compare its performance against existing NPMs as an indication of suitability for use to underpin food policies targeted at discouraging consumption of products high in nutrients associated with poor health.

Design: Cross-sectional analysis of the SA packaged food supply comparing the CAM to three other NPMs: SA health and nutrition claims (SA HNC), Chilean warning octagon (CWO) 2019, and Pan-American Health Organization (PAHO) NPM."

Final communication

from: Public Health Nutrition <onbehalfof@manuscriptcentral.com>

reply-to: phn.edoffice@cambridge.org

to: tfrank@uwc.ac.za

date: 14 Feb 2022, 05:56

subject: Public Health Nutrition - Decision on Manuscript ID PHN-RES-2021-0697.R2

14-Feb-2022

Please ensure that all co-authors are made aware of the content of this email

Dear Author,

Thank you for submitting your manuscript titled "Applying and comparing various nutrient profiling models against the packaged food supply in South Africa" to Public Health Nutrition. I am pleased to confirm that your manuscript is acceptable for publication in Public Health Nutrition in its current form.

PLEASE NOTE: Your accepted manuscript will be published online in its current format (before copy-editing or typesetting) within approximately a week of final acceptance, provided we have received all final files and a completed publication agreement form. At this point, the article will have a DOI and be considered published and citable. You will subsequently receive a proof of your typeset, edited article, which will eventually replace the accepted manuscript online and be considered the

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The Nutrition Society welcomes new members world wide at all stages of their career, and offers a variety of member benefits. If you would like to become a member of the Nutrition Society, please visit our website here: https://www.nutritionsociety.org/become-member.

Thank you for submitting your interesting study to Public Health Nutrition.

Sincerely,

Dr. Cindy Leung

Deputy Editor, Public Health Nutrition

phn.edoffice@cambridge.org

Appendix 6.1: Manuscript one supplementary material

Appendix A. Total, and ultra-processed food (UPF) products consumed by participants with missing nutrient values in the food composition table, by food group

	Number of unique food codes in dataset		Number of products consumed by participants		Number of products with missing total fat values		Number of products with missing saturated fat values		Number of products with missing total sugar values		Number of products with missing added sugar values		Number of products with missing sodium values		Number of products with missing fibre values	
Food group	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**	**UPF n (%)**	**Total n (%)**
Cereal and cereal products	58 (61.05)	95 (100.00)	2759 (42.77)	6451 (100.00)	0 (0.00)	0 (0.00)	41 (97.62)	42 (0.65)	1993 (54.87)	3632 (56.30)	2069 (53.35)	3878 (60.11)	1 (4.76)	21 (0.33)	0 (0.00)	1 (0.02)
Vegetables	4 (3.54)	113 (100.00)	44 (1.03)	4266 (100.00)	0 (0.00)	233 (5.46)	0 (0.00)	86 (2.02)	0 (0.00)	11 (0.26)	13 (3.78)	344 (8.06)	0 (0.00)	1 (0.02)	0 (0.00)	0 (0.00)
Fruits	0 (0.00)	32 (100.00)	0 (0.00)	612 (100.00)	0 (0.00)	18 (2.94)	0 (0.00)	91 (14.87)	0 (0.00)	0 (0.00)	0 (0.00)	10 (1.63)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Legumes and legume products	2 (18.18)	11 (100.00)	5 (4.03)	124 (100.00)	0 (0.00)	0 (0.00)	5 (62.50)	8 (6.45)	5 (12.50)	40 (32.36)	5 (5.68)	88 (70.97)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Milk and milk products	0 (0.00)	6 (100.00)	0 (0.00)	15 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (13.33)	0 (0.00)	14 (93.33)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Eggs	11 (44.00)	25 (100.00)	237 (17.12)	1384 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	167 (97.09)	172 (12.43)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Meat and meat products	0 (0.00)	10 (100.00)	0 (0.00)	436 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Fish and seafood	17 (23.29)	73 (100.00)	675 (17.11)	3945 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	44 (1.12)	514 (64.82)	793 (20.10)	0 (0.00)	23 (0.58)	0 (0.00)	0 (0.00)
Fats and oils	1 (5.56)	18 (100.00)	2 (0.71)	281 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	187 (66.55)	2 (12.50)	16 (5.69)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.00)
Sugar, syrups, and sweets	10 (55.56)	18 (100.00)	1164 (70.08)	1661 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	36 (94.74)	38 (2.29)	182 (26.88)	677 (40.76)	1 (10.00)	10 (0.60)	0 (0.00)	0 (0.00)
Soups, sauces, and seasonings	23 (88.46)	26 (100.00)	1649 (49.12)	3357 (100.00)	211 (100.00)	211 (6.29)	31 (0.00)	31 (0.92)	347 (100.00)	347 (10.34)	1287 (94.22)	1366 (40.69)	16 (100.00)	16 (0.48)	36 (100.00)	36 (1.07)
Beverages	24 (75.00)	32 (100.00)	346 (82.38)	420 (100.00)	0 (0.00)	0 (0.00)	20 (95.23)	21 (5.00)	235 (81.60)	288 (68.57)	90 (91.84)	98 (23.33)	0 (0.00)	0 (0.00)	45 (100.00)	45 (10.71)
Other	8 (42.11)	19 (100.00)	556 (90.85)	612 (100.00)	0 (0.00)	31 (5.07)	0 (0.00)	48 (7.84)	57 (55.34)	103 (16.83)	62 (87.32)	71 (11.60)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.49)
Total	170 (33.60)	506 (100.00)	7947 (29.51)	26928 (100.00)	211 (15.51)	1360 (5.05)	99 (8.12)	1219 (4.53)	2919 (55.75)	5236 (19.44)	4672 (56.66)	8246 (30.62)	18 (20.00)	90 (0.33)	82 (94.25)	87 (0.32)

Note: The percentage indicated in the UPF column indicates the share of UPF products consumed with missing values within each food group. The percentage indicated in the total column indicates the share of total products consumed that had missing values within each food group. No products had missing energy values.

Appendix B. Participants with a dietary intake of 0g for nutrients of concern, by high and low ultra-processed food (UPF) consumption, and whether or not this was a true reflection of intake, or due to missing data on nutrient values in the food composition table

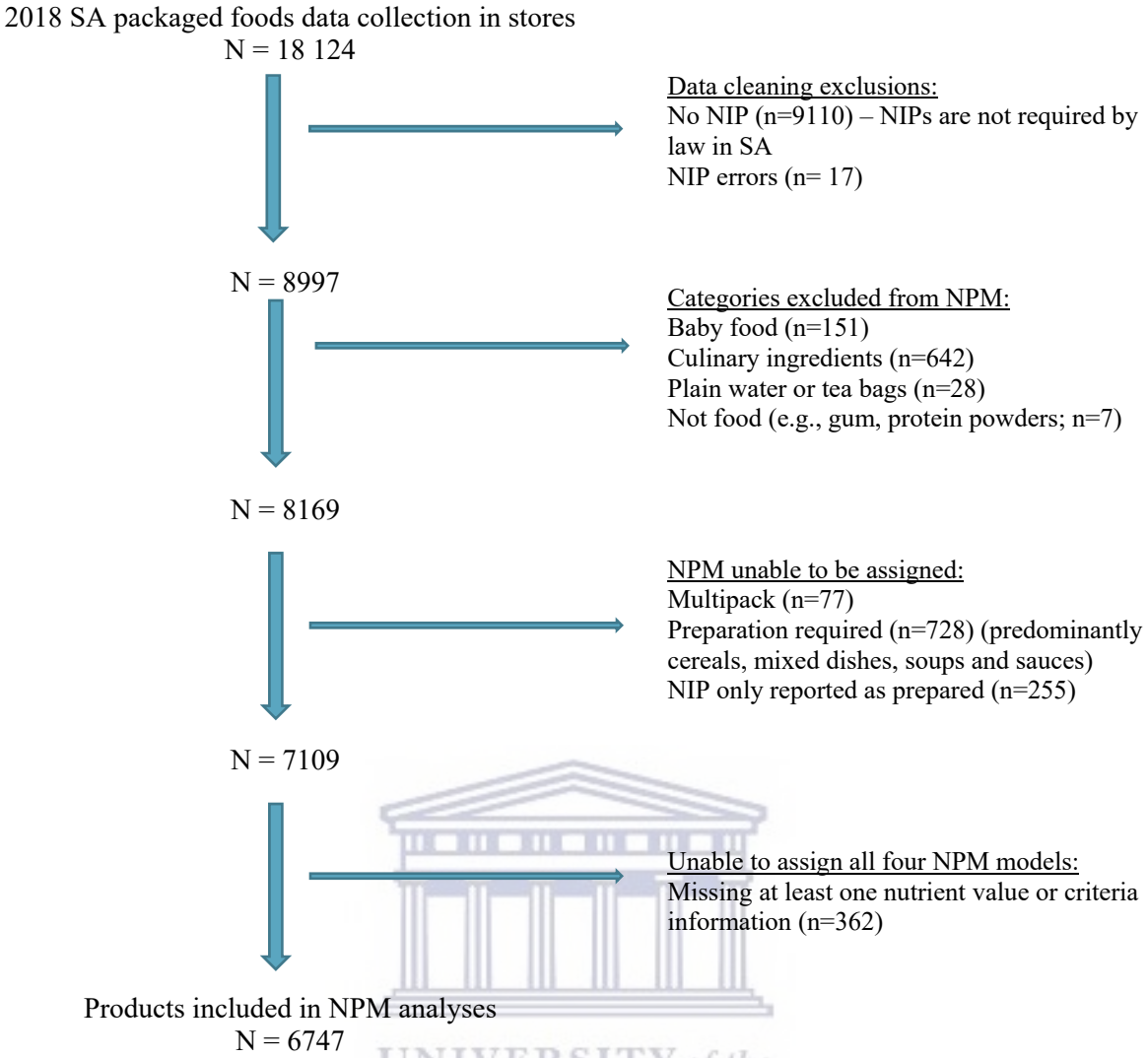
	Total number of participants (N=2521) with intake of 0g			Total number of participants included in regression analysis (n=2111) with intake being 0g			Number of participants included in regression analysis (n=2111) who actually consumed 0g			Number of participants included in regression analysis (n=2111) who have an intake set as 0g due to missing data		
	Low UPF consumer	**High UPF consumer**	**Total**	**Low UPF consumer**	**High UPF consumer**	**Total**	**Low UPF consumer**	**High UPF consumer**	**Total**	**Low UPF consumer**	**High UPF consumer**	**Total**
Total fat	2	0	2	1	0	1	1	0	1	0	0	0
Saturated fat	3	0	3	2	0	2	1	0	1	1	0	1
Total sugar	13	2	22	9	1	17	2	0	2	7	1	15
Added sugar	271	172	832	233	139	705	30	0	35	203	139	670
Sodium	2	0	2	1	0	1	0	0	0	1	0	1
Fibre	5	0	5	3	0	3	3	0	3	0	0	3

Note: This only table only reflects intake by nutrient intake was 0g. Participants who consumed more than 0g per day may still have some missing values (as reflected in Appendix A). High UPF consumers reflect those with the highest quartile of UPF consumption (for share of total energy), and low UPF consumers reflect those in the lowest quartile of UPF consumption. Totals do not necessarily equal the sum of low and high UPF consumers, as total number of participants also include moderate UPF consumers (quartile 2 and 3 of UPF intake).

Appendix 6.2: Manuscript two supplementary material

Supplementary Table S1: Primary data collection methodology

Primary data collection methodology
Nutritional information on packaged food and beverages was collected through observation in supermarkets, to create a database of the nutritional content of packaged and processed foods available in the SA marketplace. In order to capture nutritional information on the product packaging photographs of all sides of all packaged food and beverage containers were taken in each store. At minimum, the bar code, package size, product name and NFP were captured. To obtain a representative sample of packaged foods available in SA market stores were purposefully selected. Supermarkets in Cape Town (Western Cape) in Durbanville (at Pick 'n Pay, Woolworths, Checkers and Spar), Langa (Shoprite) and Khayelitsha (Boxer and Pick 'n Pay) were visited in February and March 2018. To ensure the variety of brands and products carried by different supermarkets were included, the four largest supermarket chains in SA where included. The stores together represented the majority of the grocery retailer market share, holding more than fifty percent of the share in SA in 2018 [1]. As supermarket stock in different socio-economic areas is likely to differ, different areas were sampled. As all packaged products were being explored it was necessary to include stores that carry a large product selection, which is the case in middle-income suburbs. Durbanville was included as the middle-class suburb, and Khayelitsha and Langa as the low-income suburbs. A standardised protocol developed by The George Institute (TGI) was used to capture and submit in-store photographs (using cellphone cameras) of food labels during data collection. All packaged foods and beverages in the store at the time of data collection were included. Fieldworkers were university graduates, and trained in the data collection protocol. Nutrition information was captured using standardized methods and quality control measures by TGI appointed data capturers. Foods and beverages were grouped into food categories for easier comparison. Conversion of foods and beverages requiring reconstitution (e.g. liquid concentrate beverages) from an "as sold" form to an "as consumed" form was done using information retrieved from product photographs when available. The raw dataset comprised of 9099 products, but after exclusion for insufficient and missing information (in SA a NFP is not required by law) the final dataset comprised of 6747 products (see figure S.1 for more information on excluded products). STATA (version 15, StataCorp, College Station, TX, USA) was used for data analyses and data cleaning. The nutrient content of products in the database were verified by identifying outliers and cross-checking against the original photographs of each product. Similarly missing nutrient information was verified, and corrected when possible.



Supplementary Figure S1: Flow diagram representing initial and final datasets, and reasons for exclusion

Supplementary Table S2: Number and proportion of products included in analysis (N = 6747), overall and by food category

FOOD	n	%	BEVERAGES	n	%
Breakfast cereals	110	1.63	Dairy drinks	306	4.54
Cereals & cereal products	254	3.76	Other beverages	478	7.08
Confectionery & desserts	1119	16.59	Sodas	288	4.27
Dairy	791	11.72	100% fruit juice	385	5.71
Fruits	196	2.90	**Total**	**1457**	**21.59**
Vegetables	510	7.56			
Legumes	100	1.48			
Mixed dishes	299	4.43			
Protein	602	8.92			
Snack foods	699	10.36			
Soups & sauces	610	9.04			
Total	**5290**	**78.40**			

Supplementary Table S3: Non-sugar sweetener (NSS) search terms used to identify NSS ingredients in products

acesulfame	mannitol	sweet'n low	E-952
advantame	monatin	sweetnlow	E-953
alitame	monellin	sweetn low	E-954
altern	monk fruit extract	sweet nlow	E-955
aspartame	natrataste	sweet one	E-957
brazzein	natra taste	sweetone	E-959
candy leaf	nectasweet	syclamate	E-960
candyleaf	necta sweet	trichlorogalactosucrose	E-961
curculin	neohesperidine	twinsweet	E-962
cweet	dihydrochalcone	twin sweet	E-964
cyclamate	neotame	truvia	E-965
cyclamic acid	nutrasweet	thaumatin	E-966
enliten	nutra sweet	xylitol	E-967
acesulfame	osladin	E 420	E-968
equal	oubli	E 421	E-969
erythritol	pentadin	E 950	E420
galactitol	polyglycitol	E 951	E421
glucitol	purevia	E 952	E950
hydrogenated	reb a	E 953	E951
isomaltulose	reb-a	E 954	E952
instasweet	rebaudioside A	E 955	E953
insta sweet	rebiana	E 957	E954
isomalt	saccharin	E 959	E955
kaltame|	sorbitol	E 960	E957
lactitol|	splenda	E 961	E959
lumbah|	stevia	E 962	E960
luo han guo	steviol	E 964	E961
luohanguo	stevioside	E 965	E962
luohan guo	sucralose	E 966	E964
luo hanguo	sucrolase	E 967	E965
luo han kuo	sugar leaf	E 968	E966
luohankuo	sugarleaf	E 969	E967
luohan kuo	sugartwin	E-420	E968
luo hankuo	sugar twin	E-421	E969
mabinlin	sunett	E-950	
maltitol	sweetleaf	E-951	

Supplementary Table S4: Number and proportion of food and beverages (N = 6747) in the SA marketplace (2018), overall and by food category classified as ultra-processed according to the NOVA classification system

Food category	Number of products classified as minimally processed	Number of products classified as processed	Number of products classified as ultra- processed	% of processed / ultra-processed foods (according to NOVA classification)
Breakfast cereals n=110	12	1	97	89.09
Cereals & cereal products n = 254	28	11	215	88.98
Confectionery & dessert n = 1119	25	7	1087	97.77
Dairy n = 791	109	71	611	86.22
Fruits n = 196	72	37	87	63.27
Vegetables n = 510	141	96	273	72.35
Legumes n = 100	2	57	41	98.00
Mixed dishes n = 299	1	5	293	99.67
Protein n = 602	31	70	501	94.85
Snack foods n = 699	112	120	467	83.98
Soups & sauces n = 610	39	19	552	93.61
FOOD TOTAL n = 5290	**572**	**494**	**4224**	**89.19**
Dairy drinks n = 306	127	3	176	58.60
Other beverages n = 478	62	5	411	87.03
Sodas n = 288	1	2	285	99.65
100% juice n = 385	375	2	8	2.60
BEVERAGE TOTAL n = 1457	**565**	**12**	**880**	**61.22**
FOOD & BEV TOTAL N = 6747	**1137**	**506**	**5104**	**83.15**

Supplementary Table S5: Definitions of sugar and non-sugar sweetener used in this paper

Term	Definition
Total sugar	Includes intrinsic sugars, which are incorporated into the structure of intact fruit and vegetables; sugars from milk (lactose and galactose); and free sugars, which are monosaccharides and disaccharides added to food and beverages by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates [2].
Added sugar	Monosaccharides or disaccharides added to food and does not include sugars naturally present in food, e.g. lactose in milk and fructose in fruit. Added sugar also includes honey [3].
Free sugar	Monosaccharides and disaccharides added to food and beverages by the manufacturer, cook or consumer and sugars naturally present in honey, syrups, fruit juice and fruit juice concentrates [2].
Non-sugar sweetener (NSS)	The definition used in the PAHO nutrient profiling model will be adopted: "Food additives that impart a sweet taste to a food, including artificial non-caloric sweeteners (e.g. aspartame, sucralose, saccharin and acesulfame potassium); natural non-caloric sweeteners (e.g. stevia); and caloric sweeteners such as polyols (e.g. sorbitol, mannitol, lactitol and isomalt). This does not include fruit juices, honey, or other food ingredients that can be used as a sweetener" [4].

Supplementary Table S6: Characteristics of nutrient profiling models considered for inclusion

	Chile 2019 [5]	**Mexico 2020** [6]	**Peru 2020** [7]	**Israel 2020** [8]	**PAHO NPM 2016** [4]	**WHO African Region NPM 2019** [9]	**Food Standards Australia New Zealand (FSANZ) NPSC (updated 2016)** [10]
Name of NPM	Chilean warning octagons (CWO) 2016, 2018 and 2019 criteria	Mexico warning octagons 2020	Peru warning octagons 2020 (Part of Law on the Promotion of Healthy Diets)	Israel labelling 2020	Pan American Health Organization (PAHO) model	Nutrient profile model for the WHO African Region	Food Standards Australia New Zealand (FSANZ) Nutrient profiling score criteria (NPSC) Current SA HNC NPM based on FSANZ NPM
Country	Chile	Mexico	Peru	Israel	Latin America and the Caribbean countries	African countries	Australia New Zealand South Africa
Mandatory/ voluntary	Mandatory	Mandatory	Mandatory	Mandatory	Voluntary	Voluntary	FSANZ NPSC: Mandatory if making claims
Aim	Restrictions on marketing to children under 14 years; FOP warning label	FOP warning label	Restrictions on marketing to children under 14 years; FOP warning label	FOP warning label	Restrictions on marketing and promotion to children; regulation in the school environment; FOP warning labels; application of taxes to limit consumption	Restrictions on marketing foods to children Also: Used for tax policy to limit consumption of unhealthy foods, developing benchmarks for foods sold in public institutions; driver of reformulation, food labelling	For the regulation of health claims Reformulation of products
Rationale/ basis	Implement the thresholds progressively in a period of 3 years from most permissive (June 2016) to more restrictive (June 2018) to final criteria (June 2019)	PAHO NPM used as a basis. Law and final regulations passed 27 March 2020	Guidance from PAHO, but final NPM very similar to Chile. Implemented in 2 phases	Chile used as guideline	Based on WHO Population Nutrient Intake Goals (PNIGs); changes to the WHO PNIGs will be automatically incorporated into the PAHO NPM	Based on WHO PNIGs	Guiding consumers to the selection of foods consistent with the Australian and New Zealand Dietary Guidelines and developed with the collaboration of food industry. Based on guideline daily amounts (GDA) 2000kCal for women

Foods included by NPM	Across the board – applies to all national/ imported packaged foods and beverages with added sugars, sodium or saturated fat	Across the board – applies to all national/ imported packaged foods and beverages with added free sugars, sodium or saturated fat	Across the board – applies to all national/ imported packaged foods and beverages with added sugars, sodium or saturated fat	Across the board – applies to all national/imported packaged foods and beverages with added sugars, sodium or saturated fat (excluding certain products – 1 ingredient foods)	Across the board for all processed and ultra-processed foods (based on NOVA classification)		Across the board, all foods included 3 food groups (beverages; cheese and fats; all other foods)
Foods excluded by NPM (i.e. no cut offs)	*Unpackaged foods *Packaged foods with no added sugar, sodium or saturated fats	*Unpackaged foods; foods for medicinal purposes *Dietary supplements *Infant formula and follow-up milk	*Unpackaged foods *Unclear what else	*Unpackaged foods *Dietary supplements *Infant formula *Alcoholic beverages *Specific products (tea, coffee)	*Unprocessed/min processed foods: vegetables, legumes, grains, fruits, nuts, roots and tubers, meat, fish, milk and eggs *Freshly prepared dished, culinary ingredients (oils, sugar, honey, salt) *Breast milk substitutes, food supplements, alcoholic beverages	*Special foods and supplements recommended for people with specific disease conditions *Alcoholic drinks *Breastmilk substitutes, including follow-up formula and growing-up milk	None
Approach used in calculation/ cut-off used	Threshold per nutrient	Threshold per nutrient	Threshold per nutrient	Threshold per nutrient	Threshold per nutrient	Category-based (18 categories and 10 sub-categories)	Scoring: final score determines whether a food is eligible to make a health claim
Reference amount	100g (solids) or 100ml (liquids)	Energy (kCal) and energy density	100g (solids) or 100ml (liquids)	100g (solids) or 100ml (liquids)	Energy (kCal)	100g (solids) or 100ml (liquids) Except category 18 (sauces and dressings) – per serving	100g or 100ml
Negative nutrient selection	Energy Saturated fat Total sugar Sodium	Energy Saturated fat Trans fat Free sugar Sodium Non-sugar sweetener Caffeine	Saturated fat Trans fat Total sugar Sodium	Saturated fat Total sugar Sodium	Total fat Saturated fats Free sugar Sodium Any other sweetener Trans fat	Energy Total fat Saturated fat Total sugar Added sugar Sodium	Baseline points: Energy Saturated fats Sugars Sodium
Positive nutrient selection	No positive nutrients included	No positive nutrients included	No positive nutrients included	No positive nutrients included in mandatory FOPL.	No positive nutrients included	No positive nutrients included	Modifying points: % fruits, vegetables, nuts and legumes (fvnl)

				However, voluntary positive FOPL is allowed for whole, unprocessed foodstuffs that do not carry an FOP warning label (and meet the voluntary positive FOPL criteria)[11].			Protein Dietary fibre Final score = Baseline points – modifying points Can carry claim if score ≤4 (food); bev ≤ 1 and ≤28 (cheese & fats)

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Appendix 6.3: Manuscript three supplementary material

Appendix 1. Test of proportions of South African pre-packaged foods and beverages that are non-compliant per nutrient profiling model overall; for foods and beverages; and by select categories (using the CAM and SA HNC nutrient profiling models as reference models)

	Difference in % non-compliant (CAM NPM as reference)			Difference in % non-compliant (SA HNC NPM as reference)	
	CAM% - SA HNC%	CAM% - CWO%	CAM%-PAHO%	SA HNC% -CWO%	SA HNC% -PAHO%
FOODS					
1. Breakfast cereals	35.45**	-10.00*	-0.91	-45.46**	-36.36**
2. Cereals & cereal products	17.32**	-1.58	-44.49**	-18.90**	-61.81**
3. Confectionary & Desserts	4.74**	2.06*	-0.72	-.02.68*	-5.45**
4. Dairy	28.43**	5.82*	-15.17**	-22.63**	-43.62**
5. Fruits	38.27**	-3.57	-4.59	-41.84**	-42.86**
6. Vegetables	17.65**	0.39	-30.39**	-17.25**	-48.04**
7. Legumes	28.00**	0.00	-66.00**	-28.00**	-94.00**
8. Mixed dishes	20.07**	-0.33	-29.43**	-20.40**	-49.50**
9. Protein	12.46**	-0.50	-26.58**	-12.96**	-39.04**
10. Snack foods	13.02**	-4.44*	-2.58	-17.45**	-15.59**
11. Soups & sauces	0.82	-1.8	-16.56**	-2.62	-17.38**
Total All Foods	**14.84****	**0.06**	**-15.86****	**-14.78****	**-30.70****
BEVERAGES					
12. Dairy drinks	5.56	5.23	-7.19	-0.33	-12.75**
13. Other beverages	22.59**	25.10**	-9.00**	2.51	-31.59**
14. Sodas	29.17**	29.51**	-4.17**	0.35	-33.33**
15. 100% Juice	96.88**	95.84**	94.81**	-1.04	-2.08*
Total All Beverages	**39.95****	**40.50****	**19.77****	**0.549**	**-20.19****
TOTAL FOOD & BEVS	**20.26****	**8.79****	**-8.17****	**-11.47****	**-28.43****

NPM – Nutrient profiling model; CAM – Chile adjusted model; SA HNC – South African health and nutrition claims; CWO – Chile warning octagon 2019; PAHO – Pan American Health Organization

*p<0.05 **p<0.01

Appendix 2. Comparison in mean number of products with "excess nutrients" of South African pre-packaged foods and beverages that are non-compliant per nutrient profiling model overall; for foods and beverages; and by select categories (using ttest in Stata)

	Difference in mean number of products with "excess nutrients"		
	CAM NPM as reference		CWO 2019 NPM as reference
	CAM – CWO 2019	CAM - PAHO	CWO 2019 - PAHO
FOODS			
1. Breakfast cereals	-0.856**	-0.300**	0.555**
2. Cereals & cereal products	-0.154**	-1.075**	-0.921**
3. Confectionary & Desserts	-0.688**	-0.517**	0.172**
4. Dairy	-0.005	-1.235**	-1.230**
5. Fruits	-1.020**	-0.061**	0.041
6. Vegetables	-0.008	-0.982**	-0.975**
7. Legumes	-0.030	-1.010**	-0.980**
8. Mixed dishes	-0.087**	-1.759**	-1.672**
9. Protein	-0.116**	-1.515**	-1.399**
10. Snack foods	-0.707**	-0.425**	0.282**
11. Soups & sauces	-0.343**	-1.200**	-0.857**
Total All Foods	**-0.328****	**-0.934****	**-0.606****
BEVERAGES			
12. Dairy drinks	0.062	-0.605**	-0.667**
13. Other beverages	0.439**	-0.494**	-0.933**
14. Sodas	0.549**	-0.528**	-1.076**
15. 100% Juice	0.958**	0.935**	-0.023*
Total All Beverages	**0.519****	**-0.146****	**-0.665****
TOTAL FOOD & BEVERAGES	**-0.145****	**-0.764****	**-0.619****

NPM – Nutrient profiling model; CAM – Chile adjusted model; CWO 2019 – Chile warning octagon 2019; PAHO – Pan American Health Organization

*p<0.05 **p<0.01

Appendix 3. Pairwise k values for the four nutrient profiling models

		CAM	SA HNC	PAHO
CWO 2019	**Food**	0.9176 (Almost perfect)	0.5517 (Moderate)	0.4814 (Moderate)
	Beverages	0.2715 (Fair)	0.8829 (Almost perfect)	0.6025 (Moderate)
	All	0.7349 (Substantial)	0.6370 (Substantial)	0.5501 (Moderate)
CAM	**Food**	-	0.5417 (Moderate)	0.5310 (Moderate)
	Beverages	-	0.1909 (Slight)	0.2941 (Fair)
	All	-	0.4501 (Moderate)	0.4573 (Moderate)
HNC	**Food**	-	-	0.2538 (Fair)
	Beverages	-	-	0.5278 (Substantial)
	All	-	-	0.3398 (Fair)

Level of agreement using the Kappa statistic				
Slight: 0.0-0.20	Fair: 0.21-0.40	Moderate: 0.41-0.60	Substantial: 0.61-0.80	Almost perfect: 0.81-0.99

CAM – Chile adjusted model; SA HNC – South African health and nutrition claims; PAHO – Pan American Health Organization; CWO 2019 – Chile warning octagon 2019