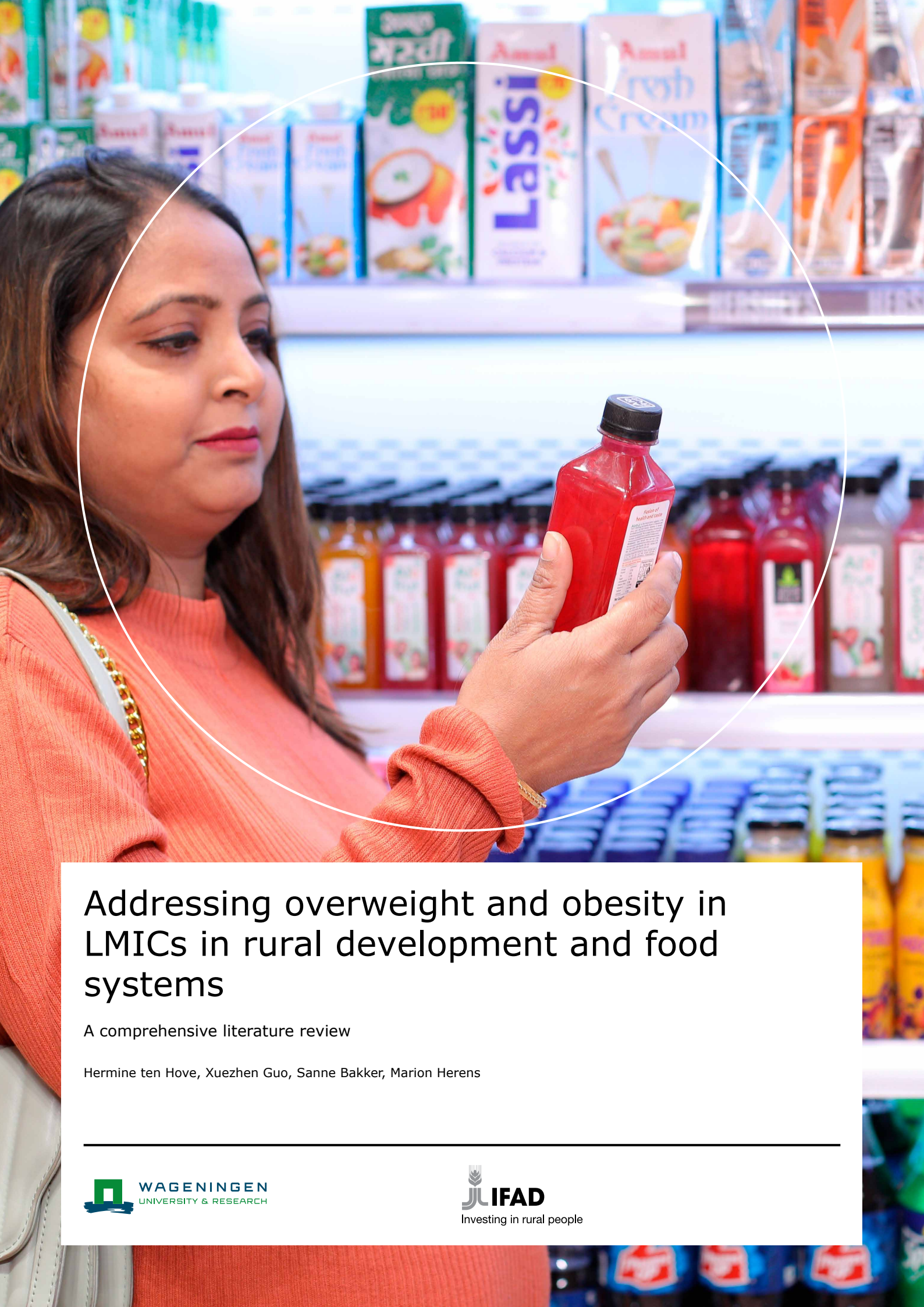

Addressing overweight and obesity in LMICs in rural development and food systems

A comprehensive literature review

Hermine ten Hove, Xuezhen Guo, Sanne Bakker, Marion Herens

WAGENINGEN
UNIVERSITY & RESEARCH

IFAD
Investing in rural people

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List of abbreviations and acronyms

BMI	Body Mass Index
DDT	Dichlorodiphenyltrichloroethane
FSN	Food Security and Nutrition
FVC	Food Value Chain
GDP	Gross Domestic Product
GHO	Global Health Observatory
GNP	Gross National Product
HIC	High Income Country
HLPE	High Level Panel of Experts on Food Security and Nutrition
IFAD	International Fund for Agricultural Development
IP	Indigenous People
JME	Joint Malnutrition Estimates
LMIC	Low or Middle Income Country
MLMC	Multi-level, multi-component
NAP	Nutrition Action Plan
NCD	Non-Communicable Disease
NSVC	Nutrition Sensitive Value Chains
PMU	Project Management Unit
POP	Persistent Organic Pollutant
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
POLG	Programme of Loans and Grants
RCP	Relative Caloric Price
SD	Standard Deviation
SDG	Sustainable Development Goal
SES	Socio-Economic Status
SSB	Sugar-Sweetened Beverages
TFA	Trans-Fatty Acids
WB	World Bank
WCDI	Wageningen Centre for Development Innovation, Wageningen University & Research
WHO	World Health Organization
WUR	Wageningen University & Research

1 Introduction

1.1 Background

Healthy diets are considered a cornerstone of good health. Unhealthy diets can lead to reduced immune responses, impaired physical and mental development, Non-Communicable Diseases (NCDs) and reduced productivity. Poor nutrition comes in multiple forms: undernutrition, micronutrient-related malnutrition, and overweight and obesity[1]. The Joint Malnutrition Estimates (JME) published in April 2021 report that, globally, 149.2 million children under five years of age are stunted (chronically or recurrently undernourished), 45.4 million are wasted (suffering from acute and severe weight loss) and 38.9 million are overweight. While countries are making progress towards the reduction of undernutrition, overweight and obesity are on the rise around the world (UNICEF, WHO, & Worldbank, 2021). Overweight and obesity have emerged as global challenges, affecting high and low-income countries alike. The figures below show the trends for adults who were overweight or obese in 2016 (Figure 1) compared to those who were overweight or obese in 2006 (Figure 2). Figure 3 provides a visualisation of the number of children who were overweight or obese in 2016 (Figure 3) compared to 2006 (Figure 4). The figures show that the share of both adults and children who are overweight or obese is increasing globally.

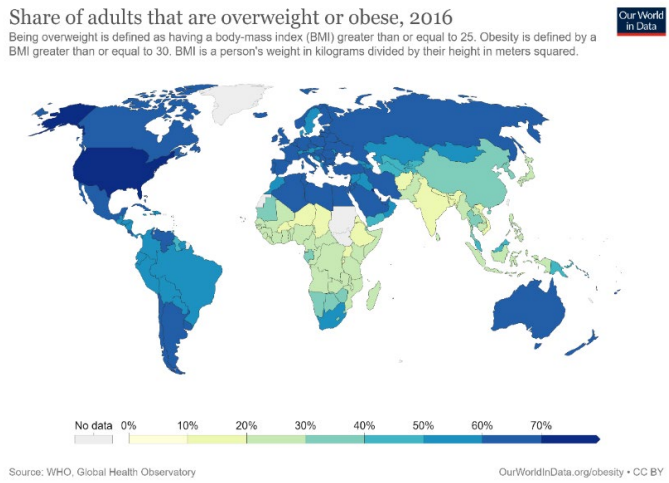

Figure 1 *Share of overweight or obese adults in 2016*

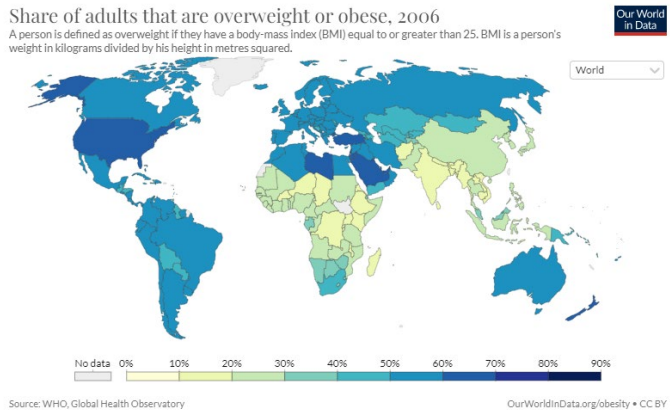

Figure 2 *Share of overweight or obese adults in 2006*

[1] A glossary containing the definitions of common terminology can be found in Appendix 1.

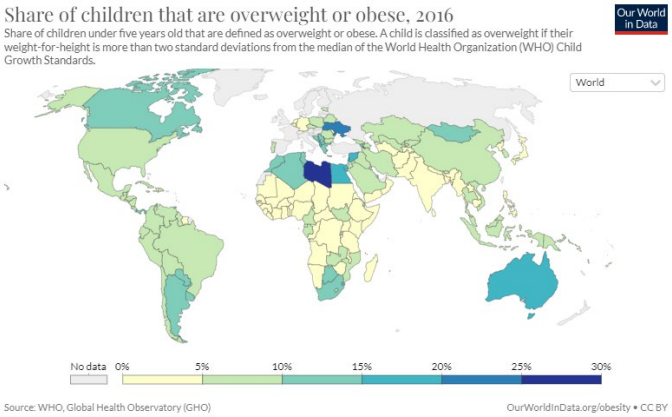

Figure 3 *Share of overweight or obese children in 2016*

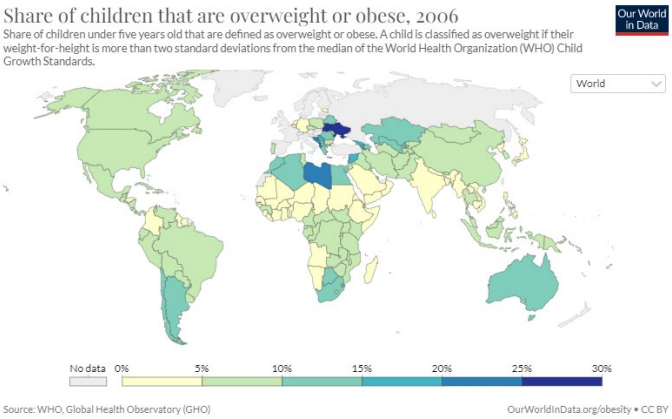

Figure 4 *Share of overweight or obese children in 2006*

Globally, overweight and obesity cost an estimated 2 trillion USD per year or 2.8% of global GDP (Dobbs et al., 2014); 74% of all deaths in 2019 were caused by NCDs (World Bank, 2020). The World Health Organization (WHO) identifies unhealthy diets as one of the risk factors that can cause overweight and obesity, which in turn increases the risk of NCDs. Indeed, three of the four most common NCDs are diet-related, namely cardiovascular diseases, certain forms of cancers, and diabetes (Global Nutrition Report, 2020). It is estimated that 77% of deaths from NCDs occur in low and middle-income countries, meaning obesity is no longer a challenge unique to high-income countries (World Health Organization, 2021c). While overweight and obesity are more prevalent in urban areas, their prevalence is also on the rise in rural areas. A 2014 study in low and middle-income countries found that, in about half of all countries surveyed (33%), overweight in women in rural areas had increased over the past decades at a rate greater than that in urban areas (Jaacks, Slining, & Popkin, 2015a, 2015b). These trends of increasing overnutrition, however, do not negate the need to address problems with undernutrition. Undernutrition (i.e. underweight and/or micronutrient deficiencies) can occur alongside overweight and obesity, and diet-related NCDs (the double or triple burden of malnutrition). They can co-exist at the individual, household, community and population levels and across the life course.

Dietary patterns globally are changing in response to consumer demands and market developments, triggered by rapid urbanisation and socioeconomic improvements of the middle class (Popkin, 2004; Popkin & Gordon-Larsen, 2004). For example, the manufacturing and consumption of ultra-processed foods are on the rise (Global Food Research Program - University of North Carolina at Chapel Hill, 2021). An increasing amount of research focuses on food environments and food system factors, such as production, marketing, affordability and accessibility of foods, which affect dietary choices; this focus is intended to more systematically prevent and control diet-related diseases and overweight and obesity (Crino, Sacks, Vandevijvere, Swinburn, & Neal, 2015; Driessen, Cameron, Thornton, Lai, & Barnett, 2014; Hall, 2018; Herforth & Ahmed, 2015; Williams et al., 2014). Good nutritional outcomes require good consumer and caregiver knowledge, good health, safe water and hygiene practices, as well as safe, diverse and healthy

diets. Agriculture and food systems, therefore, play a key role to play in ensuring access to high-quality diets that provide levels of energy and micronutrients appropriate to age, sex, disease state and physical activity levels (Glopan, 2016).

1.2 Purpose and scope

Nutrition is at the centre of IFAD's Strategic Framework (2016–2025) (IFAD, 2016). IFAD has committed to improving the nutrition of 11 million people and to have 60% of its projects be nutrition sensitive by the end of 2024 (see Box 1). IFAD uses its Nutrition Action Plan (2019–2025) to guide its efforts to mainstream nutrition in a way that aligns with its mandate and relative advantage (IFAD, 2019). To achieve its ambitious targets, IFAD needs to apply a differentiated approach to address the challenges associated with the rise of overweight and obesity, tailored to IFAD's targeted populations and to the changing rural contexts. Addressing the overweight and obesity problem with a more comprehensive and new approach meets the purposes of IFAD's Strategic Framework (2016–2025) because it situates IFAD in relation to significant development challenges and articulates its contribution to the 2030 Agenda for Sustainable Development. It can also help IFAD to better orient and support the development of Country Strategic Opportunity Programmes and IFAD-supported investment projects, as well as global and regional grant-funded programmes, and new policies and strategies. Currently in the countries where IFAD is active, overweight and obesity are generally viewed from a public health perspective by the governments. However, the root causes of overweight and obesity are complex and go beyond the health sector. Addressing these issues, therefore, requires a multi-stakeholder approach with active involvement from multiple sectors, including agriculture and sectors along the value chains: this is where IFAD's potential role lies (IFAD, 2021).

Box 1 IFAD's current ambitions for nutrition (under IFAD12)

- At least 60% of new projects are nutrition-sensitive by design
- Eleven million people with improved nutrition (Minimum Diet Diversity for Women/MDD-W)
- Six million people provided with targeted support for their nutrition

Against this background, the scope of this assignment is to explore how IFAD can contribute to food system transformations and mitigate the rising incidence of overweight and obesity in low and middle-income countries (LMICs[2]) in the regions covered by IFAD (Latin America and the Caribbean, West and Central Africa, East and Southern Africa, Near East, North Africa and Europe, Asia and the Pacific), and how it can build the capacity of IFAD staff and other key relevant stakeholders.

The overall objective of the study is to deepen the knowledge on how agriculture and food value chains can contribute to addressing overweight and obesity within a food systems context, and how IFAD can apply these insights in its investments. Specific objectives are:

1. To comprehensively review the evidence that shows what strategies and interventions have worked and what have not (and how we know that) in dealing with overweight and obesity in rural and rural-urban transition ('rurban') areas in low and middle-income countries. This will include exploring the main drivers of overweight and obesity in rural areas (i.e. urbanisation, increased incomes, social and cultural factors, modern value chain induced problems, etc.) and document nutrition-sensitive interventions that have been implemented to address the problem within the context of agriculture and food systems investments.
2. To undertake a mapping and context-specific exercise to accompany the comprehensive review to narrow down the drivers and interventions that could inform the agriculture and food systems investments in selected countries. This will include a review of IFAD's programme of Loans and Grants (POLG) in these countries, alongside reviewing other relevant documentation and consulting key people. The aim is to document and identify potential entry points (i.e. nutrition-sensitive value chain development) and practical solutions (programmatic, policy, etc.).

[2] A note on the use of the term 'LMIC' can be found in Appendix 1.

3. Conduct one webinar for IFAD and project staff to share the study findings and build awareness on pathways, strategies, and IFAD's comparative advantage to tackle overweight and obesity in rural development projects.

This report addresses the first of these objectives.

1.3 Outline of the report

The current chapter (Chapter 1) provides an introduction to the background, purpose, scope and theoretical orientation of the planned research. Chapter 2 describes the methodology that was used to undertake the comprehensive literature review. Chapter 3 provides the results of the first component of the analysis, on the drivers of overweight and obesity in rural areas in LMICs. Chapter 4 dives into the second component of the study, on intervention strategies for overweight and obesity. As the concluding chapter, Chapter 5 provides answers to the research questions.

1.4 Theoretical orientation

There is a growing body of literature looking at the vast disparities in nutritional status, ranging from undernutrition and micronutrient deficiencies to overweight and obesity that exist between people, communities and countries from a systems perspective (Nisbett, 2019). Two interrelated and dominant conceptual sets of frameworks still guide most of the research and policy work on food and nutrition. Public health and international development specialists generally build on the conceptual framework for malnutrition developed by UNICEF (Black et al., 2013; Unicef, 1990). Within agricultural research and food and agriculture policy, nutritional outcomes are subsumed within a wider set of models focusing on food security, nutrition and healthier diets (HLPE, 2017, 2020; IFPRI, 2016).

Given IFAD's ambitions, this comprehensive review will build on the High-Level Panel of Experts (HLPE) 2017 and 2020 report and the Sustainable Food Systems framework, presented below (Figure 5). This is done to anchor the work, as it provides an excellent frame to analyse overweight and obesity issues across the food system from a rural development investments point of view. The report emphasises the following points.

1. There is an urgent need to strengthen and consolidate the conceptual thinking around Food Security and Nutrition (FSN), to prioritise the right to food, to widen our understanding of food security and to adopt an analytical food system and policy framework.
2. FSN outcomes in recent years show the extent to which the global community is falling short of the Agenda 2030 targets, especially SDG 2 (Zero Hunger). Food systems face a range of challenges and some opportunities linked to major trends in the drivers of food system change.
3. Policy approaches and actions for FSN, in light of the diverse challenges facing food systems, will require critical policy shifts and support for enabling conditions that uphold all dimensions of food security (HLPE, 2020).

The HLPE report also presents an evolving understanding of the concept of food and nutrition security over time. The current definition of food and nutrition security is as follows: "Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life[3]." This definition embraces four dimensions: availability, access, utilisation (referring to nutritional uptake) and stability (referring to the constancy of the other three dimensions). The HLPE, however, points to the necessity, based on the evidence generated over the past decades, to expand the food and nutrition security concept with two additional dimensions: 'agency' – what a person is free to do and achieve in pursuit of whatever goals or values they regard as important (Sen, 1985, p. 203) – and 'sustainability' – the long-term ability of food systems to provide food security and nutrition today in a way that does not compromise the environmental, economic or social bases that generate food security and nutrition for future generations.

[3] UN Standing Committee on Nutrition, 2013.

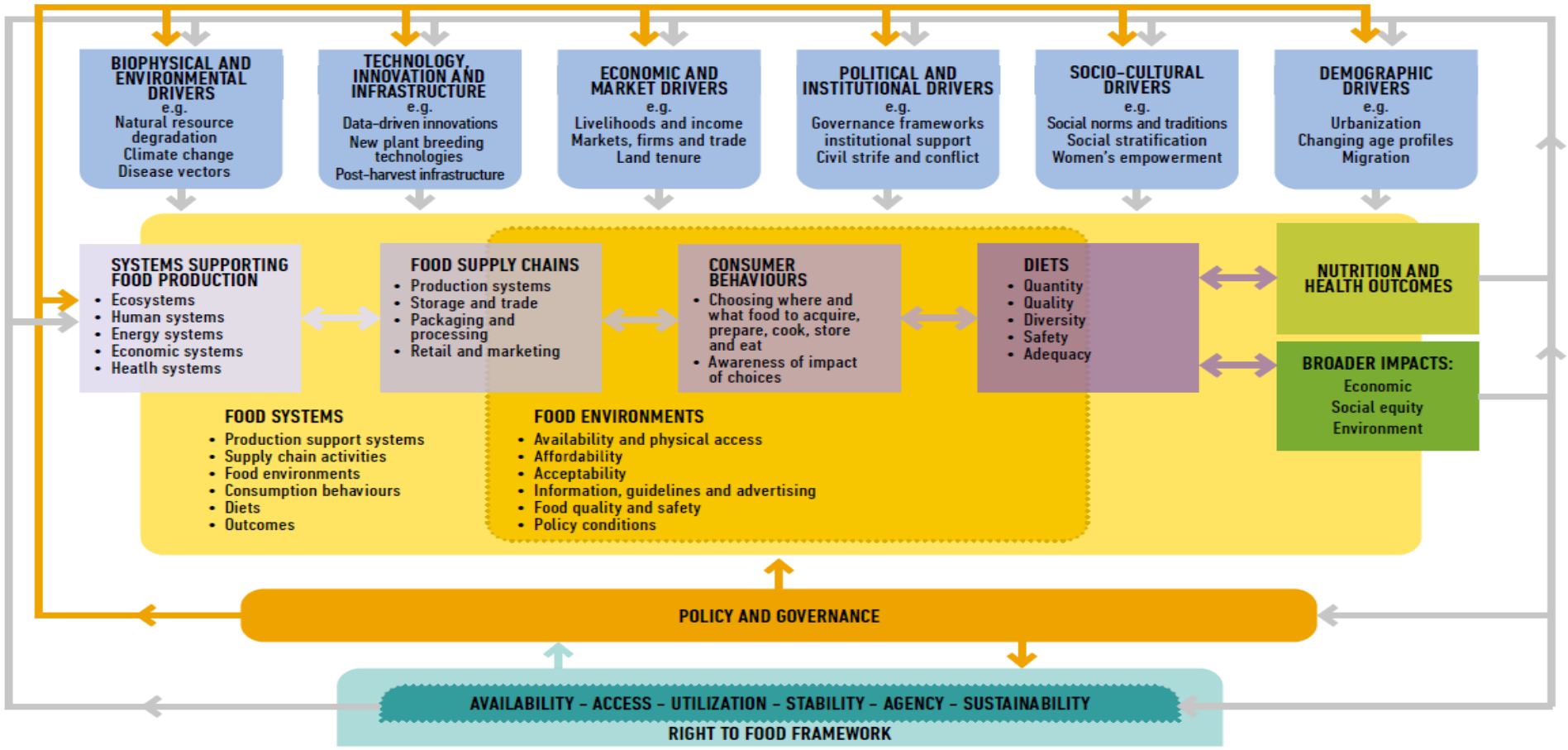

Figure 5 *Sustainable Food Systems Framework (adapted from HLPE framework 2017 (HLPE, 2017, 2020)*

At the core of the food systems approach is the food supply chain dimension. Food supply chains – or value chains, depending on which party is put at the centre of them – are at the centre of food systems in terms of delivering nutritious foods to consumers at affordable prices (Allen & De Brauw, 2018). However, they also influence the demand for nutritious foods. Value chain interventions have been recognised for their high potential to help reduce all three forms of malnutrition, including overweight and obesity (Allen & De Brauw, 2018). These interventions can create impact through three main channels: 1. Through improving the consumption of nutritious food, 2) through increasing incomes through value chain transactions, and 3) through adding value to nutrition in the chain transactions (Gelli et al., 2015). Food value chains have also been identified as one of the three fundamental elements of food systems that potentially determine an individual's diet, alongside consumer behaviour and the food environment (de Brauw et al., 2019; Mehta et al., 2014). The food environment is shaped by multiple value chains that consist of the actors necessary for the production, distribution and retailing of multiple products (de Brauw et al., 2019). Ericksen (2008) points out that it is essential to consider multiple food value chains and the food environment alongside consumer preferences and constraining factors, and the interactions between all these elements.

Recognising the practicality of the food value chain approach to navigate the complexity of food systems and identifying opportunities to shape food systems to be more nutrition-sensitive, IFAD has developed a framework for nutrition-sensitive value chains (NSVCs). Nutrition-sensitive approaches consider how the development of food value chains could contribute to improving nutrition. The NSVC framework focuses on the link between nutrition problems in target populations and the constraints in the supply and demand of specific foods (De la Peña & Garrett, 2018).

The concepts and frameworks described in this section are the basis for the methodology of this study, along with the definitions used and defined in Appendix 1. The HLPE Sustainable Food Systems Framework is used to map the findings of the various actions part of the comprehensive review, to highlight primary drivers and causal pathways as well as preferred or recurrent intervention strategies.

2 Methodology

This section provides a basic step-by-step methodology for the desk research. The methodology was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA): an evidence-based guideline for transparently reporting on reviews[4]. We split the literature review into two main components:

Component 1: Drivers of overweight and obesity in rural areas in LMICs
This component focused on the cause-effect relationships that underpin the prevalence of overweight and obesity in rural areas in LMICs. Research questions that relate to this component include:

1. What are the main drivers of overweight and obesity in rural areas?
2. What causal links have been identified by research between overweight/obesity and the food system along food value chains?
3. What are the gaps in terms of research and knowledge on the causes of overweight and obesity in rural areas in LMICs?
4. What are the inequity dimensions of overweight and obesity-related to IFAD's specific target groups (i.e. women, Indigenous Peoples (IPs), youth and people with a disability)?

Component 2: Intervention strategies for overweight and obesity
For this component, we observed parallels with the Lecoutere, Berg and Brauw (2021) definition of a food system innovation from a dietary perspective, which they define as follows:

> A policy or regulation, an institutional process, a change in knowledge, a technology, or [a] combination thereof that is either not used or not widely used within a food system, with the potential to change diets on a wider scale (e.g. Hekkert, Suurs, Negro, Kuhlmann, and Smits (2007)). Based on an analytical understanding of interactions within a food system, different types of innovations can be designed to potentially support healthier diets among individuals.

Research questions under this component are:

5. What is documented evidence of interventions with the potential to prevent and/or reduce overweight and obesity in the different areas of the food system?
6. What are existing good practices for interventions? What failures/lessons have been documented?
7. What are the constraints to intervention strategies for overweight and obesity?
8. What are the nutrition-sensitive interventions for IFAD target groups in the context of their food systems (i.e. women, Indigenous Peoples (IPs), youth, and people with a disability)?

The drivers of overweight and obesity uncovered in this component provided a guideline to systematically search for and organise intervention strategies. It provided insights into which causal pathways have already been leveraged for intervention strategies (both successfully and not), and which drivers have potential for new, innovative approaches.

Box 2 Clearing up the terminology of causality

The terms 'cause' and 'driver' are used in the research questions. Especially the latter tends to be defined differently by different authors. In this box, we clarify our usage of the two terms. The term ***cause*** is only used if there is sufficient evidence to establish at least the causal effect or causal mechanism of a given phenomenon, or both. For other factors for which "some evidence of causal association with the outcome of interest is presented, but for which the evidence or knowledge is not sufficient to firmly establish the causal effects and explain the causal mechanisms of a specific phenomenon," the term ***driver*** is used instead following the definition suggested by Meyfroidt (2016).

[4] Systematic Reviews (OPEN ACCESS) Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Systematic Reviews 2021;10:89.

Step 1. Data collection on overweight and obesity (Component 1)
A combination of the keywords in Table 2 was applied, using Boolean operators 'AND' and 'OR', to find relevant records and reports. Scopus was used as search engine, making use of the Wageningen University & Research Library to gain access to the full documents behind the search results. A snowball approach was also used – i.e. the references of relevant materials were used to obtain further sources.

We aimed to first find meta-analyses and reviews, and only move to individual research papers if or when needed. If this did not yield sufficient information to answer the research questions, we broadened the scope to include both rural, peri-urban and urban areas in LMICs. If this still did not provide enough data, we again broadened the scope and considered studies that focus on high-income countries (HICs).

Table 1 *Search terms per research question*

Q#	1. Topic		2. Countries		3. Literature type
1, 2 and 4	overweight	AND	See list in Appendix 2	AND	"meta analysis"
	OR				OR
	obes*				"meta-analysis"
	OR				OR
	"body mass index"				"meta stud*"
	OR				OR
	BMI				"meta stud*"
	OR				OR
	"metabolic syndrome"				"meta synthesis"
	OR				OR
	"double burden of malnutrition				"meta-synthesis"
	OR				OR
	"triple burden of malnutrition"				"review"

The retrieved records and reports were listed in an Excel sheet along with the date they were found. Their abstracts were screened for eligibility by one of the team members. A list of eligibility criteria (inclusion and exclusion criteria) was used for this purpose. Each criterion was added as a column to the sheet and ticked if met.

Inclusion criteria
- Peer-reviewed journal articles (qualitative and quantitative)
- Covers rural populations
- Covers low and/or middle-income countries

Exclusion criteria
- Overweight or obesity is not mentioned in the abstract text
- Based on anecdotal or perception-based evidence
- Article only focuses on causes of overweight and obesity on molecular, cellular or physiological levels (e.g. evidence linking a specific genetic defect to overweight and obesity)
- Article only considers overweight and obesity as a driver to other topics (instead of looking into the causality of overweight and obesity itself – e.g. the role of overweight and obesity in the development of non-communicable disease)

Step 2. Analysis and description of causal pathways to overweight and obesity (Component 1)
Analysis was carried out using NVivo 12 qualitative analysis software. Relevant excerpts from the articles were coded according to a predefined coding list, which was based on the review questions. The code list can be found in Appendix 3. The coded passages were used to answer review questions 3, 4, 5 and 6. However, if any sections appeared relevant for the other review questions (e.g. for Component 2), they were coded as such. Codes to mark geographical context, flag bias and denote study quality concerns were also assigned.

The studies that identify drivers and causes that could answer questions 3 and 4 were assessed for the quality of evidence provided. We looked at whether a study was a primary study or meta-analysis, qualitative or quantitative, whether a counterfactual was used, and whether there were any critical limitations to internal and external validity. An overview of this quality assessment is available upon request. The identified drivers and causes were then grouped according to the components of the HLPE Sustainable Food Systems Framework.

Step 3. Data collection on intervention strategies for overweight and obesity (Component 2)
Data collection for Component 2 (focusing on intervention strategies rather than understanding the problem) was similar to Step 1. We first conducted a literature review on scientific publications using Scopus. The search terms are presented in Table 2. To avoid missing relevant non-scientific reports, we also looked for the non-scientific publication using the search engines of various prestigious organisations in the food domain (e.g. Agris (FAO), OAister) and the ones most relevant to IFAD.

Table 2 *The search terms for the interventions and innovations (combining the terms from each column into one search query)*

1. Topic		2. Intervention synonyms		3. Target groups		4. Countries
Overweight		"Interven*"		Rural		
OR		OR		OR		
Obesity		"Innovat*"		Periurban		
OR		OR		OR		
BMI		"Reduc*"		Farmer		
OR		OR		OR		
"Body mass index"		"Prevent*"		"Value chain"		
		OR		OR		
	AND	"Mitigat*"	AND	"Food environment"	AND	See the query in Appendix 2
				OR		
				"Postharvest"		
				OR		
				"Processing"		
				OR		
				"label*"		
				OR		
				"Pric*"		

Again, the retrieved records and reports were listed in an Excel sheet listing the date they were found. One of the team members screened them for eligibility. A list of eligibility criteria was used for this purpose. Each criterion was added as a column to the sheet and ticked if met.

Inclusion criteria
- Covers rural populations
- Covers low and middle-income countries
- Describes how the intervention strategy contributes to controlling and/or reducing overweight and obesity

Exclusion criteria
- Information is over ten years old (will be applied as a search filter)
- Covers only high-income segments of low-income countries

The analyses are not restricted to studies with experimental or quasi-experimental designs because their availability is limited. Reviews and qualitative analytical studies are also included.

Step 4. Analysis and description of intervention strategies for overweight and obesity (Component 2)

The intervention literature was first screened by the titles to exclude obviously irrelevant papers. The remaining papers were investigated further using the keywords and abstracts, and categorised by country type, target group and type of intervention. These categorisations were also guided by the HLPE Sustainable Food Systems Framework. Afterwards, the screened papers from the first two steps were subjected to an in-depth study. Only the papers with quantitative evidence or an explicit claim of the causal relationship between the interventions and mitigation of overweight and obesity are reported in this comprehensive literature review.

Chapter 3 provides the results of the first component of the analysis, on the drivers of overweight and obesity in rural areas in LMICs. Chapter 4 dives into the second component of the study, on intervention strategies for overweight and obesity.

3 Drivers of overweight and obesity in rural areas of LMICs

3.1 Drivers and causes of overweight and obesity integrated into the HLPE framework

This review identified a list of factors that are related to imbalances between calories consumed and calories expended (the 'energy equation'), which is the fundamental cause of overweight and obesity (World Health Organization, 2021d)[5]. For the majority of the identified factors, the available evidence cannot irrefutably pinpoint a causal relationship. The limitations of the retrieved evidence and the reasons behind them are described in more detail in Section 3.3. We choose not to disregard factors for which no direct causal link has been proven by scientific evidence when describing the issue of overweight and obesity, as this could lead to an incomplete picture of the pathways underpinning overweight and obesity, especially when focusing on rural areas in LMICs. A lack of evidence does not equal a lack of causality. Instead, we differentiate through terminology when describing the available evidence. The term ***cause*** is only used when there is sufficient evidence to establish at least the causal effect or causal mechanism of a given phenomenon, or both. For other factors for which "some evidence of causal association with the outcome of interest is presented, but for which the evidence or knowledge is not sufficient to firmly establish the causal effects and explain the causal mechanisms of a specific phenomenon", the term ***driver*** is used, following the definition suggested by Meyfroidt (2016). To gain insight into the pathways that connect causes and drivers of overweight and obesity, they are organised and described according to the HLPE 2020 framework (HLPE, 2020). As the HLPE framework only focuses on the consumption side of the energy equation, it was expanded with an 'Energy expenditure' box to make sure both fundamental drivers of overweight and obesity are covered. Furthermore, it should be clarified that the 'Nutrition and health outcomes' in the framework encompass the outcomes of the diet and energy expenditure boxes that are linked to it, while also presenting its own category of drivers to overweight and obesity. Finally, it should be noted that the framework element 'Systems supporting food production' is omitted from the analysis, as the current review focuses on food systems. It is evident, however, that some of the systems listed under that element of the framework (e.g. 'Health systems') are very relevant in light of drivers and causes of overweight and obesity.

[5] A full list of the retrieved literature can be found in Appendix 4.

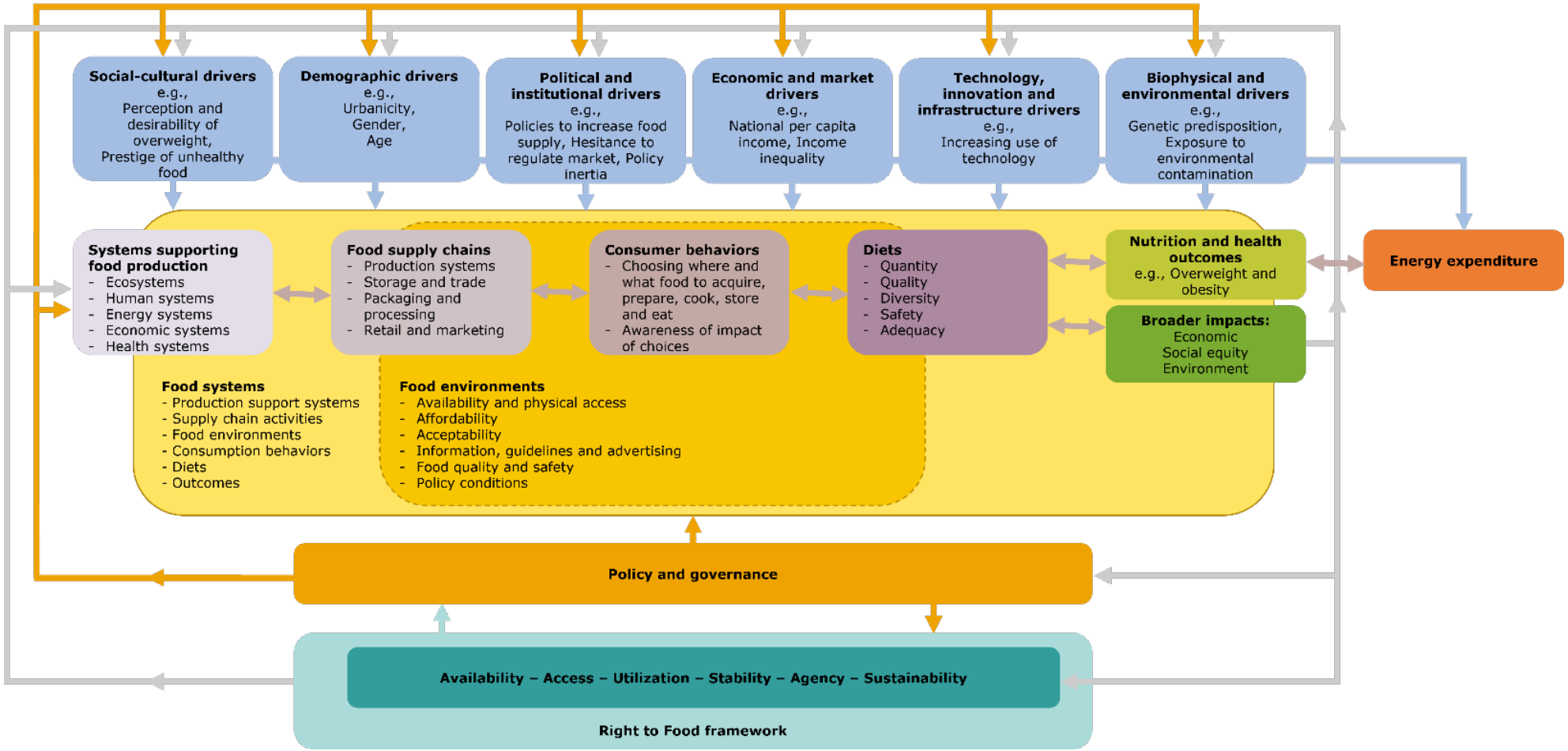

Figure 6 *The HLPE framework (HLPE, 2020), adapted to encompass energy expenditure and include the drivers yielded by this literature review*

Biophysical and environmental drivers

- **Environmental contamination.** Persistent Organic Pollutants (POPs) are a group of chemicals that accumulate and spread in the environment. They have significant negative effects on human health and the environment. Insecticide DDT is a famous example of this type of chemical. While many (high income) countries prohibit the use of POPs, there are also numerous regions in LMICs where it is still applied, for malaria control, in the case of DDT and pesticides too. Exposure to POPs seems to disrupt endocrine function[6] and thereby increase obesity risk. However, the exact mechanism by which exposure to obesogenic POPs leads to increased obesity risk remains unknown and needs further research (Ford et al., 2017; Grün & Blumberg, 2006).

Technology, innovation and infrastructure

- **Physical activity replaced by technology.** The amount of energy needed to conduct various daily activities is decreasing due to the increasing use of technology. This applies to the shift from active transportation, where walking and cycling are being replaced by motorised transport. It also includes domestic work where, for example, washing machines are being used to wash clothes instead of being done manually. This trend can also be observed in occupational labour, as more and more people have sedentary jobs (Ford et al., 2017; Hallal et al., 2012; Popkin, 2001). Farming is among these occupations, as the mechanisation of farming is being promoted with the objective of increasing land productivity, addressing labour shortages, decreasing environmental footprint and reducing poverty (Food and Agriculture Organization of the United Nations, n.d.). Finally, technology affects the way leisure time is spent, and television ownership is associated with increased prevalence of overweight and obesity, both because it is a sedentary activity that replaces more physical pastimes, and because it is associated with snacking (Goryakin & Suhrcke, 2014; Popkin, 2001). It may also be related to exposure to food and drink advertisements (Goris, Petersen, Stamatakis, & Veerman, 2010).

Economic and market drivers

- **Economic development at the country and household levels.** There appears to be a positive correlation between national per capita income and obesity prevalence. The prevalence of overweight and obesity in a country is likely to rise as that country develops economically (Fruhstorfer, Mousoulis, Uthman, & Robertson, 2016; Goryakin & Suhrcke, 2014). Economic development also leads to decreasing physical activity levels and increasing prevalence of sedentary lifestyles (World Health Organization, 2020). As nations become wealthier, there is a shift in which population segments become more susceptible to becoming overweight or obese. A study by Monteiro, Conde, Lu and Popkin (2004) found that if a country's Gross National Product (GNP) was less than 2,500 USD, obesity prevalence was associated with a higher socio-economic status. In simpler terms, in the poorest countries, it is the richer segments of the population that are more likely to be obese. This effect shifts at the GNP 2,500 USD threshold: in richer countries (upper-middle income developing countries), it is the poor who are more likely to be obese.
- **Income inequality.** There is a link between overweight and obesity prevalence and income inequality, although the exact effect is unclear. There is evidence that high income inequality within a country is associated with a higher prevalence of obesity, regardless of how wealthy a country is. Another study finds that within the richest segment of LMICs, countries that have low income inequality (i.e. Armenia, Egypt, Indonesia, Jordan, Kazakhstan, Morocco and Turkey) see faster increases in overweight in women among lower socio-economic status (SES) groups compared to higher SES-groups. The opposite applies to countries with high income inequality (i.e. Bolivia, Colombia, Guatemala, Namibia and Peru). In these countries, the rise in overweight prevalence among lower-SES groups is slower when compared to higher-SES groups. These findings show that the effect of wealth on overweight prevalence is not universal, even between countries at the same level of economic development (Ford et al., 2017; Jones-Smith, Gordon-Larsen, Siddiqi, & Popkin, 2011).

Political and institutional drivers

- **Policies to increase food supply.** In the 1970s, the USA and other countries put policies in place to increase food supply. The resulting food supply is hypothesised to be so abundant that it started to push up population energy intake (B. A. Swinburn et al., 2011). The extent to which this hypothesis about the role of policies to increase food supply applies to LMICs is unknown.

[6] Endocrine function is the body's ability to communicate internally through hormones.

- **Hesitance to regulate the market.** A food value chain that contributes to overweight and obesity is a natural consequence of a market-based economy that favours economic growth and liberalised, less regulated global markets. Regulatory approaches to address overweight and obesity are more difficult to achieve in an environment where policymakers are reluctant to intervene in a liberalised market (B. A. Swinburn et al., 2011).
- **Policy inertia.** While UN Sustainable Development Goal 2 refers to ending all forms of malnutrition (i.e. both undernutrition and overnutrition), many LMICs have not yet reoriented their nutrition funding, development aid, professional capacity, institutions and mindsets to include overnutrition. To explain the lack of uptake of existing evidence-based policy recommendations to halt the rising prevalence of overweight, regardless of income level, B. A. Swinburn et al. (2019) coined the term 'policy inertia', meaning "a collective term for the combined effects of inadequate political leadership and governance to enact policies […], strong opposition to those policies by powerful commercial interests, and a lack of demand for policy action by the public."

Socio-cultural drivers

- **Perception of the ideal body shape and inability to recognise overweight.** In some LMICs, fatness in children is desirable as it is considered a sign of health and wealth (Fruhstorfer et al., 2016). Similarly, large body size in adults is considered a positive attribute in some cultures (e.g. Tonga) (Kanter & Caballero, 2012; B. A. Swinburn et al., 2011), especially for women. Furthermore, studies show an inability to accurately perceive one's weight as being overweight in some cultures, possibly having a negative effect on the effectiveness of overweight prevention programmes (Jaacks, Kavle, Perry, & Nyaku, 2017).
- **Social acceptability of physical activity.** It is not universally socially acceptable or desirable for people, or women in particular, to be physically active. There are also cultures where physical inactivity is associated with high social status (Kanter & Caballero, 2012).
- **Prestige of unhealthy foods.** Jaacks et al. (2017) report a case in Nigeria where the consumption of processed foods was associated with higher social standing.

Demographic drivers

- **Urbanicity.** There is a clear positive association between urbanicity and obesity in LMICs. However, the difference between urban and rural populations is shrinking due to increases in overweight among rural populations. While the prevalence of overweight continues to increase in both rural and urban areas, the rate of increase is higher in many rural populations (Ford et al., 2017; Goryakin & Suhrcke, 2014). There are various underlying drivers (mentioned elsewhere in this chapter) that could cause the correlation between urbanicity and obesity. Urban environments differ from rural ones in terms of the need for physical activity (different infrastructure, methods of transport, employment types, etc.), income levels, socio-economic status and food access (higher availability of calorie-dense cheap foods) (Ford et al., 2017). Evidence from China between 1991 and 2004 suggests that as a country develops economically, the aspects of urbanicity that lie at the root of overweight prevalence spread into rural areas, and the distinction between urban and rural areas in terms of overweight prevalence becomes less pronounced (Van de Poel, O'Donnell, & Van Doorslaer, 2009).
- **Gender and age.** These factors are described in Section 3.2.2 ('Women') and 3.2.3 ('Youth').
- **Genetic predisposition.** The heritability of BMI is estimated to be between 40% to 70% (Allison et al., 1996; Herrera, Keildson & Lindgren, 2011). A person with a genetic predisposition does not necessarily develop overweight or obesity over the course of their life, as genes are not always expressed. Gene expression depends on many factors, such as environmental and behavioural factors. More research is needed to understand the epigenetic influences on overweight and obesity (Ford et al., 2017).

Food supply chains

- Globalisation and modernisation of food supplies. The globalisation of food supplies, facilitated by trade liberalisation, has influenced food systems in LMICs (Kennedy, Nantel, & Shetty, 2004). It has led to more food import[7], more direct investment in food production and processing, and the growth of transnational food companies. This, in turn, has effects on food availability and pricing – also that of processed and fast foods. Ultimately, this has contributed to increased consumption of snacks and fast food (Ford et al., 2017). Globalisation is one part of an observed transformation to modern food supply chains. Gómez and

[7] The top five crops most imported into the least developed countries in 2019 were wheat, rice, sugar, palm oil and maize (Food and Agriculture Organization of the United Nations, 2019).

Ricketts (2013) conducted a review of how transforming value chains influence the triple malnutrition burden and developed a value chain typology. Four types of value chains are distinguished: traditional, modern, modern-to-traditional and traditional-to-modern – each with different participants, implications for food access, and hypothesised nutritional impacts (predictions based on literature). The typology is shown in Table 3. The modern and modern-to-traditional chains are hypothesised to drive overweight prevalence by expanding the reach of cheap, high-calorie processed/packaged foods, mainly in urban areas.

- **Increased food energy supply**. There is evidence that suggests that increases in food energy supply (expressed in kJ/day of supply per citizen) are sufficient to explain increases in average population body weight, especially in high-income countries (Vandevijvere, Chow, Hall, Umali, & Swinburn, 2015). The role of an increased food energy supply in LMICs is less evident, which could be explained by poorer data availability and higher reliance on subsistence farming (which is not tracked by FAO food supply data). According to World Bank (2017), the Green Revolution (in the 1960s and 1970s) increased the production of staple foods in developing countries (e.g. rice, wheat and maize), and led to a shift in prices that made staples more affordable relative to other food groups, like legumes, vegetables and fruits. This trend continues today. A review into drivers of overweight and obesity by B. A. Swinburn et al. (2011) names the increased availability of cheap, tasty and highly promoted obesogenic foods as the main driver of the global obesity epidemic – though they note that this hypothesis is mainly based on data from the United States of America and would need to be validated in other countries.
- **Use of added sugars, especially in beverages.** Caloric sweeteners, such as added sugars, contribute to overweight and obesity. A study on ultra-processed foods[8] by Phillip Baker et al. (2020) concludes that the rising supply of caloric sweeteners is cause for concern. This is especially true when caloric sweeteners are consumed in beverages (soft drinks, juices, alcoholic drinks and when added to tea or coffee), as liquid calories are less satiating than solid foods so likely to be consumed in excess. Evidence shows that BMI increase reduces over time when the consumption of sugar-sweetened beverages is reduced, indirectly showing that consumption of sugar-sweetened beverages can in fact cause weight gain (Malik & Hu, 2022). Sugar-sweetened beverage consumption is on the rise in LMICs (Ford et al., 2017; Malik & Hu, 2022). While drinking water would be a healthier alternative (Malik & Hu, 2022), potable water is not universally accessible in LMICs. Globally, 2 billion people do not have access to safely managed drinking water services (World Health Organization, 2022). Anecdotal cases of replacing water consumption with soft drink consumption have been reported, e.g. by Lopez and Jacobs (2018). However, the scale of this behaviour is unknown.
- **Use of vegetable oils in processed foods.** The global availability of edible plant oils has risen sharply, as well as its affordability. The use of edible plant oils in processed foods has contributed to changing food consumption behaviours, like snacking and the consumption of processed foods, ultra-processed foods[8] and fast foods (Drewnowski & Popkin, 1997; Ford et al., 2017).

[8] Ultra-processed foods are produced using lots of types of additives. The processes and the ingredients used in the manufacture of ultra-processed foods make them convenient (ready-to-consume, almost imperishable) and attractive (hyperpalatable) for consumers and profitable (low-cost ingredients, long shelf-life) for their manufacturers. However, these processes and ingredients also make ultra-processed foods typically nutritionally unbalanced and liable to be over-consumed (Monteiro, Cannon, Lawrence, Costa Louzada, & Pereira Machado, 2019).

Table 3 *Food value chain (FVC) typologies and their hypothesised influences on nutrition (reproduced from Gómez and Ricketts (2013)*

Type	Participants	Implications for food access	Hypothesised nutritional impacts
Traditional	Traditional traders buy primarily from smallholder farmers, and sell to consumers and traders in wet, mostly local, markets	Affordability: A local 'clearing-house' for products, with flexible prices, product volumes, and quality standards Availability: Food 'hub' for consumers and local 'mom and pop' stores to access directly from traders and smallholder farmers; market offerings are highly dependent on production seasonality	• Traditional FVCs help reduce micronutrient deficiencies and undernourishment by offering low-priced fruits, vegetables, livestock products, and staples, particularly in rural areas and in poor neighbourhoods of urban areas • Production seasonality, combined with lack of post-harvest and distribution infrastructure, increase FVC intermediation costs and limit the ability of traditional FVCs to reduce micronutrient deficiencies and undernourishment
Modern	Domestic and multinational food manufacturers procure primarily from commercial farms and sell through modern supermarket outlets	Affordability: Economies of scale enable the production, marketing, and distribution of packaged/processed foods at low per-unit prices Availability: Modern supermarkets provide year-round, wide product assortment, primarily in urban areas; supermarkets are successfully expanding the market for processed and packaged foods	• Modern FVCs may contribute to alleviate micronutrient deficiencies by offering a wide assortment of products year-round; but supermarket's physical location and quality standards may imply higher retail prices, missing the poor • Modern FVCs may contribute to obesity/overweight malnutrition by expanding the reach of inexpensive, calorie-dense processed/packaged foods, primarily in urban areas
Modern-to-traditional	Domestic and multinational food manufacturers sell through the network of traditional traders and retailers (e.g., 'mom and pop' stores)	Affordability: Food manufacturers benefit from economies of scale to connect with traditional distributors and retailers, offering low-priced processed foods to reach low-income consumers Availability: By linking with traditional retailers, food manufacturers develop intense distribution strategies in urban areas and in rural, isolated markets	• Expansion of processed/packaged foods into isolated, rural regions may alleviate undernourishment; but it can result in over-nutrition among urban consumers • Food fortification initiatives focusing on modern-to-traditional FVCs may contribute to reduce micronutrient malnutrition
Traditional-to-modern	Supermarkets and food manufacturers source food from smallholder farmers and traders	Affordability: Increased income opportunities in high value crop and livestock production for smallholder farmers and traders can expand food budgets because most are net-food buyers Availability: Increased production and crop diversification may increase food available for local consumption	• Traditional-to-modern FVCs may reduce micronutrient deficiencies and undernourishment of smallholder farmers through and traders through higher incomes leading to diet diversification • Opportunities for smallholder farmers and traders to benefit directly from participation appear limited and may miss asset-poor farmers; substantial benefits happen through off-farm employment opportunities

Box 3 The role of trans-fat

Trans fats, officially named trans-fatty acids (TFAs), are a type of fatty acid. They occur naturally in some animal-source products but can also be naturally produced by converting vegetable oil into a solid form. This can be useful for specific food products, and it prolongs product shelf life. According to the WHO, approximately 540,000 deaths each year can be attributed to the intake of industrially produced TFAs (World Health Organization, 2018). While most HICs have placed limits on TFA content in foods, this is not the case in LMICs. For example, in Africa, only South Africa has a functional TFA policy in place, although several other countries have committed to eliminating TFAs in the future (World Health Organization, 2021a). While we did not find evidence that TFAs drive overweight prevalence more than other sources of energy, they are a driver to the same type of adverse health consequences, such as coronary heart disease (World Health Organization, 2018).

Consumer behaviour

- **Individual-based motives of food choice.** While the food environment shapes food choice, it also has an individual component. A systemic review by Karanja, Ickowitz, Stadlmayr and McMullin (2022) identified seven clusters of such individual-based motives for LMICs. These include psychological factors, sociocultural factors, sensory appeal, nutrition and health perceptions, ethical concerns, social interactions and socio-demographic variables. Only one of the drivers they identified pertained to motives regarding body weight: "weight consciousness in pursuit of an ideal body size" (under the cluster 'Nutrition and health perceptions'). This driver was only identified in four studies (in Brazil, China, Iran and Malaysia). The review by Karanja et al. (2022) concluded that the body of evidence on individual-based motives of food choice is fragmented, and there is a dearth of studies in rural areas. Only 15% of the studies they identified focused on rural areas. These focused mostly on food taboos with no apparent relation to overweight and obesity, such as the prohibition of certain foods or food types during pregnancy, lactation or menstruation.
- **Tobacco smoking.** While tobacco smoking is not technically part of the food system, engaging in it does have consequences that fall within its scope. A systematic review by Chiolero, Faeh, Paccaud and Cornuz (2008) shows that, in general, smokers tend to have lower body weight than non-smokers. This could be due to the increased energy expenditure and appetite reduction that are associated with nicotine, which would also explain why smoking cessation is often associated with weight gain. However, these findings do not apply to heavy smokers, who usually have a higher body weight than light smokers or non-smokers. This could be indicative of a tendency to cluster unhealthy behaviours, like combining heavy smoking with low physical activity and poor diet. However, the extent to which these conclusions apply to LMICs is not clear.
- **Poor quality sleep and chronic psychosocial stress.** There is an association between sleep deprivation (i.e. less than five hours of sleep), poor food choices and the risk of obesity. Sleep deprivation may increase hunger and heighten the preference and hedonistic reward for consuming fatty and sweet foods. The effect could also be mediated by the impact of stress on sleep quality (Ford et al., 2017; Wu, Zhai, & Zhang, 2014). The hormonal response to chronic stress affects the body's regulatory system. It is also associated with increased appetite, a more dangerous type of fat deposition that occurs around abdominal organs, and the propensity for weight gain. Stress can also promote overweight through emotional eating (Ford et al., 2017; Hirotsu, Tufik, & Andersen, 2015; McEwen, 1998).

Food environment

- **Food deserts and food swamps.** Food deserts are characterised by a relative lack of nutritious food options. They are relatively rare in low-income countries due to the presence of informal markets (which can exist due to a lack of land-use zoning regulations) but are widespread in middle-income countries, like Brazil. Food swamps, meanwhile, are inundated by the availability of unhealthy food and were identified in Mexico. There are indications from the United States of America that obesity is more prevalent in areas that have more fast food outlets and small grocery stores (B. A. Swinburn et al., 2019; Turner et al., 2020).
- **Convenience of junk food.** Junk food (pre-prepared or packaged food with low nutritional value) tends to be convenient. If there is limited time to prepare food at the household level, this could drive the consumption of unhealthy foods (Jaacks et al., 2017). Processed foods may also have a longer shelf life. The trend that more and more women are entering the workforce could be relevant to this driver, although the impact of this on weight status requires further research.

- **Affordability of high-caloric foods.** Studies have linked the relative affordability of different food groups to the likelihood of being overweight. This evidence suggests (although cannot prove irrefutably) that the relative cheapness of unhealthy calories is an important explanation of the obesity epidemic. Most of this evidence comes from HICs but, as Table 4 shows below, unhealthy foods are also relatively inexpensive in low-income countries. The table provides an overview of food groups and their relative prices per calorie[9] across different national income levels. It demonstrates that healthy foods are relatively more expensive in poorer countries than in richer ones (Headey, 2019).
- **Promotion.** Experimental studies show that advertising for food and drink that targets children can cause an increase in energy intake (Goris et al., 2010; Sadeghirad, Duhaney, Motaghipisheh, Campbell, & Johnston, 2016). This can contribute to the prevalence of overweight. However, these studies took place in HICs. The estimated contribution to overweight prevalence differs considerably by country (Goris et al., 2010), which means these findings are hard to generalise to LMICs. As far as we could establish, there are no reviews conducted on the general impact of advertising (including television, radio, magazines, social media and at point-of-sale) on overweight and obesity in LMICs. A quick search indicated that exposing children to snack food advertising is a widely used strategy in some LMICs, like Guatemala, Mongolia and the Philippines (Chacon, Letona, Villamor, & Barnoya, 2015; Kelly et al., 2015).

Table 4 *Relative caloric prices across food groups and national income levels (adapted from Headey and Alderman (2019))*

	All countries (N=176)	High income (N=64)	Upper middle (N=44)	Lower middle (N=41)	Low income (N=27)
Fats & oils	0.67	0.66	0.49	0.75	1.05
Sugar	0.83	0.36	0.57	1.06	2.07
Soft drinks	5.26	3.30	3.55	6.72	11.45
Juice	12.62	3.16	11.59	18.23	11.78
Sugary snacks	2.16	1.43	2.09	2.44	2.92
Salty snacks	2.54	1.81	2.24	2.54	6.88
Milk	3.84	1.93	2.72	4.55	10.45
Other dairy	6.93	2.46	6.25	9.40	8.53
Eggs	5.54	2.60	4.46	6.65	11.66
White meat	5.42	3.91	3.54	6.98	9.97
Red meat, unproc.	3.07	3.07	2.68	3.30	3.72
Red meat, proc.	11.51	7.50	9.34	14.89	15.26
Fish & seafood	6.00	5.65	4.31	6.90	10.20

Diets

- **High-energy diets.** Diets that are too high in energy (relative to energy expenditure) are the main driver of weight gain (World Health Organization, 2021d). Sources of energy are fat (e.g. vegetable oils, as described in the section on value chains), carbohydrates (e.g. sugar, see the section on the value chain), protein and alcohol. A review by Kwok, Dordevic, Paton, Page and Truby (2019) looked into the effect of alcohol consumption on energy balance. It demonstrated that adults do not compensate for the extra calories they consume through alcohol intake by deriving fewer calories from other food. In fact, a modest dose of alcohol may lead to an increase in consumption of other foods. Figure 7 provides an overview of alcohol consumption worldwide, showing a general increase of alcohol consumption in LMICs since 2005, although there are also countries that report decreases (e.g. Brazil, Nigeria). The WHO also reports a general trend towards greater availability of alcohol around the clock in LMICs, as well as a shift towards commercialised European-style alcoholic beverages rather than those produced by local communities and indigenous groups (World Health Organization, 2019).
- **Diet quality.** The quality of the diet is also relevant to the prevalence of overweight, but it likely also influences weight gain by affecting energy balance. The exact physiological mechanisms by which dietary quality exerts its influence are complex and have not been fully unravelled, but are hypothesised to involve hormonal and neurological pathways that influence satiety (Romieu et al., 2017).

[9] Relative caloric prices (RCPs) are defined as "The ratio of the price of 1 calorie of a given food to the price of 1 calorie of a representative basket of starchy staple food in each country. These RCPs have a simple interpretation: an RCP of 5 for eggs implies that it is 5 times as expensive to obtain a calorie from eggs as it is to obtain a calorie from starchy staples." (Headey, 2019).

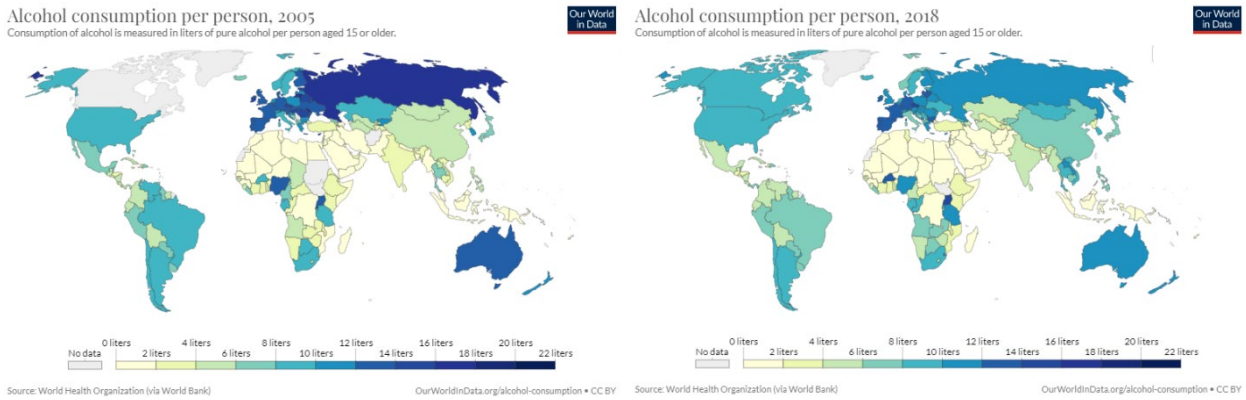

Figure 7 *Global alcohol consumption (in litres of pure alcohol per person) per person in 2005 and 2018.*

Energy expenditure

- **Low energy expenditure**. As stated under 'Diets', a positive energy balance drives weight gain. In low-income countries, 12% of men and 24% of women are insufficiently physically active to meet WHO guidelines, compared to 26% of men and 35% of women in high-income countries (World Health Organization, 2020). While physical activity is beneficial in its own right, its role in the rising prevalence of overweight and obesity is likely limited compared to the role of high-energy diets (B. A. Swinburn et al., 2011).

Nutrition and health drivers/outcomes

- **Maternal BMI and diet.** A mother's BMI and diet can predict or influence her child's chances of becoming overweight or obese over the course of their life in multiple ways. The first way is by being obese themselves, which is associated with a higher likelihood of her child becoming obese in middle and high-income countries. More research is needed to establish the causality of this association (Castillo-Laura, Santos, Quadros, & Matijasevich, 2015; Ford et al., 2017). The second way is through insufficient intake of energy, protein and micronutrients by the mother during the first half of their pregnancy, which is shown to be related to increased adiposity in their female offspring. (Jaacks et al., 2017; Yang & Huffman, 2013). Interestingly, the opposite effect occurs when women face famine during the final trimester of their pregnancy and after birth: their offspring had a lower risk of obesity (Yang & Huffman, 2013). A hypothesis that explains the pathway behind sub-optimal nourishment in early life and overweight later on is the "developmental origins theory" (Wadhwa, Buss, Entringer, & Swanson, 2009). It posits that undernutrition in utero causes the foetus to adapt its development – which could be to preserve brain and vital organ development. These adaptations could predispose an individual to a higher BMI in later life. Appropriate birth weight, as an indicator of foetal growth, may be protective against overweight and obesity as it builds adult lean body mass Jaacks et al. (2017). Finally, the third way that a mother's BMI and diet influence their child's propensity to overweight is through excess weight gain during pregnancy. This is associated with increased adiposity in offspring.
- **Weight gain during pregnancy.** Not only do pregnancy-related factors influence the potential for overweight and obesity in offspring, but they can also be a driver of overweight for the mother themselves. A few studies suggest that women are not always aware of the concept and importance of appropriate gestational weight gain (Jaacks et al., 2017).
- **Exclusive breastfeeding and rate of infant weight gain.** Being breastfed exclusively is associated with a slower rate of weight gain, and possibly a decreased risk of overweight in childhood and adolescence. However, the studies that demonstrate this effect were based in HICs, and often had a control group that was formula-fed. The higher protein content of formula could therefore be a factor in this effect, as excessive protein intake and rapid weight gain in infants are associated with an increased risk of obesity later in life (Yang & Huffman, 2013).
- **Gut microbiome.** The gut microbiome is the collection of microorganisms (bacteria and archaea) that live inside the digestive tract. Through interaction with genetic and lifestyle factors, it could play a role in the pathophysiology of obesity, although the evidence on this topic is limited. Evidence from animal studies suggests that a change from a traditional diet towards a Western diet causes changes in the composition of their microbiome, increasing the uptake of calories from the diet and altering energy metabolism (Ford et al., 2017; Turnbaugh, Backhed, Fulton, & Gordon, 2008).

3.2 Dimensions of overweight and obesity to specific target groups

3.2.1 Rural populations

As urbanisation is one of the major trends that drive overweight and obesity prevalence, it would seem that rural populations are less susceptible. However, as mentioned in Section 3.1, the difference between urban and rural populations is shrinking. While overweight prevalence continues to increase in both rural and urban areas, the rate of increase is higher in many rural populations. In some LMICs, this has led to a closing or even a reversal of the gap between urban and rural BMI (Bixby et al., 2019; Ford et al., 2017; Goryakin & Suhrcke, 2014). It is hypothesised that the causes of overweight and obesity in urban areas are permeating rural areas as countries develop economically. Drivers like changing infrastructure, transportation, employment, income, food access and physical activity are becoming more prevalent in rural areas too (Ford et al., 2017). Meanwhile, undernutrition remains more prevalent in rural areas (Micha et al., 2020); this may put rural areas at an especially high risk of the double burden of malnutrition[10]. There is evidence from Colombia and Mexico that the double burden of malnutrition is more prevalent in rural areas than in urban ones (Mahmudiono, Segalita, & Rosenkranz, 2019). However, the authors note that this evidence could be biased by large indigenous populations in rural areas, who are prone to experiencing the double burden of malnutrition.

While the current study focuses on rural populations, it became clear early in the search stage that there is a paucity of evidence on the drivers of overweight and obesity that are specific to rural areas in the context of LMICs. Many of the drivers and causes listed in Section 3.1 are general, and the extent to which they apply to rural contexts s uncertain, although inferences can be made for a few. Table 5 lists all identified drivers and describes an inferred relevance for rural contexts in particular. These are mostly hypotheses and would need to be backed up by more specific evidence. The table highlights that urbanisation is a key driver that is related to many of the other drivers.

Table 5 *Drivers of overweight and obesity and their hypothesised applicability to rural areas*

Driver	Inferred relevance for rural contexts in particular
Biophysical and environmental drivers	
Environmental contamination	Farmers may be exposed to POPs when applying pesticides. Rural inhabitants may suffer environmental exposure in addition to dietary exposure
Technology, innovation and infrastructure	
Physical activity replaced by technology	Partially a general driver, although uptake of technology may be slower in underserved rural areas. Applicable to rural contexts where technology replaces agricultural labour
Poor facilities for physical activity	May be less relevant to rural contexts as open space is generally available
Economic and market drivers	
Economic development at the country and household level	General driver, although there may be differences between economic development in urban and rural areas
Income inequality	General driver, although income inequality can exist between urban and rural areas
Political and institutional drivers	
Policies to increase food supply	General driver, although possibly less relevant if food is sourced from wild/cultivated environments or informal markets (i.e. without government regulation)
Hesitance to regulate the market	General driver, although possibly less relevant if food is sourced from wild/cultivated environments or informal markets (i.e. without government regulation)
Policy inertia	General driver, although possibly less relevant if food is sourced from wild/cultivated environments or informal markets (i.e. without government regulation)

[10] This refers to the coexistence of undernutrition (underweight and/or micronutrient deficiencies) along with overweight and obesity, or diet-related noncommunicable diseases, within individuals, households and populations, and across the life course (World Health Organization, 2021b).

Driver	Inferred relevance for rural contexts in particular
Socio-cultural drivers	
Perception of the ideal body shape and inability to recognise overweight	General driver, although context specific
Social acceptability of physical activity	General driver, although context specific
Prestige of unhealthy foods	General driver, although context specific
Demographic drivers	
Urbanisation	Key driver as rural areas may become more similar to urban ones as countries develop economically. Urbanisation likely combines the susceptibility to various other drivers to overweight, e.g. food supply chain drivers
Gender, age	General driver
Genetic predisposition	General driver
Food supply chains	
Globalisation and modernisation of food supplies	Linked to urbanisation; rural areas in LMICs may be less affected as they rely less on modern value chains and more on traditional ones
Increased food energy supply	Linked to globalisation and modernisation of value chains; rural areas in LMICs could be less affected
Use of added sugars, especially in beverages	Linked to globalisation and modernisation of value chains; rural areas in LMICs could be less affected
Use of vegetable oils in processed foods	Linked to globalisation and modernisation of value chains; rural areas in LMICs could be less affected
Consumer behaviour	
Individual-based motives of food choice	General driver, although context specific
Tobacco-smoking	General driver. In some LMIC contexts, smoking is less prevalent in rural areas (Gupta, Yadav, & Anand, 2010; Ho et al., 2010), while the reverse applies in others (Gupta et al., 2010)
Poor quality sleep	General driver; urban/rural influence unknown
Chronic psychosocial stress	General driver; urban/rural influence unknown
Food environment	
Food deserts and food swamps	Food deserts in rural areas are likely to have different causes (e.g. remoteness) than those in urban areas (e.g. land-use zoning regulations). Remoteness may protect rural areas from becoming food swamps
Convenience of junk food	Junk food outlets could be less convenient in rural areas if more distance needs to be covered to reach them. At the same time, long shelf lives of junk food products could increase their appeal
Affordability of high-caloric food	Rural consumers can also be food producers and may consume their own produce. This would make market prices only indirectly relevant to their consumption decisions. On the other hand, high market prices may also be an encouragement to sell high-value foods to generate income. This would still make high prices result in low consumption (Headey, 2019)
Advertisements	General driver, though levels of exposure may vary
Diets	
High-energy diets	Likely less prevalent in rural areas as prevalence rates of overweight are lower
Diet quality	No inferences made as underlying mechanism is unknown
Energy expenditure	
Low energy expenditure	Likely less prevalent in rural areas as prevalence rates of overweight are lower
Nutrition and health drivers/outcomes	
Maternal BMI and diet	Maternal undernourishment
Pregnancy	General driver, though fertility rates may differ between rural and urban areas
Birth weight	General driver, though average birth weight may differ between rural and urban areas
Exclusive breastfeeding and rate of infant weight gain	General driver, though breastfeeding practices may differ between rural and urban areas
Gut microbiome	May be less relevant to rural contexts if traditional diets are predominant

Part of the reason for this lack of specific evidence likely lies in the fact that overweight and obesity are less prevalent in rural areas, which could make it less of a priority for research. However, we would argue the inverse of this reasoning: the current lower prevalence of overweight and obesity provides a unique opportunity for preventative action, and therefore it should be a high priority for research.

3.2.2 Women

Women are more prone to overweight and obesity than men in nearly all LMICs. Ford et al. (2017) provide various possible explanations for this: differing physiological responses to early-life nutrition, differing hormonal responses to energy expenditure, weight gain associated with (a high number of) pregnancies, lower physical activity levels, depression, economic circumstances over the lifespan and differences in sociocultural factors – like ideal body size and acceptability of physical activity. Jaspers Faijer-Westerink, Kengne, Meeks and Agyemang (2020) demonstrate that women's higher life expectancy (which has been hypothesised as why overweight and obesity get more prevalent as the population ages) does not explain the difference between the sexes.

Ford et al. (2017) highlight the important position of women in the increasing obesity prevalence due to the influence that maternal obesity has on childhood obesity. Another reason why women are key in the prevalence of overweight and obesity relates to their role in food preparation. Jaacks et al. (2017) hypothesise that the increase of women entering the workforce leads to limited time to prepare food, which may cause households to turn to unhealthy fast foods. More research is needed to assess this theory.

3.2.3 Youth

The United Nations defines youth as people between 15 and 24 years of age. The literature found did not follow these specific cut-off points. It did demonstrate a general pattern across the lifespan, where a higher prevalence of overweight and obesity is found among older individuals as compared to younger groups (e.g. youth). It seems that the period of adolescence and youth entails the onset of higher obesity prevalence among females as compared to men. Before this period (i.e. during childhood), the prevalence of overweight is similar between boys and girls (Ford et al., 2017).

3.2.4 Indigenous peoples

As described in Section 3.2.1, there is evidence that Latin Americans (from Mexico and Guatemala) from Indigenous populations have a higher risk of being affected by the double burden of malnutrition. The differences are hypothesised to originate from variations in body fat storage, race or ethnicity (Mahmudiono et al., 2019). Indigenous peoples can also be affected by a lack of evidence relating to the association between fat tissue and BMI, and BMI and health risks. This affects several non-Caucasian groups. It may require alternative cut-off points to determine which parts of the BMI spectrum should be considered problematic (Ford et al., 2017).

3.2.5 People with a disability

None of the literature retrieved addressed specifically this target group.

3.3 What gaps are there in terms of research and knowledge on the causes of overweight and obesity in rural areas in LMICs?

It is not difficult to find gaps in terms of research and knowledge on the causes of overweight and obesity in rural areas in LMICs. The main issue lies in the search for causes of overweight and obesity that are demonstrated by a robust body of scientific evidence. The possibilities for experimental studies that include a control group are limited due to practical constraints. Causal pathways that connect a driver to an impact on BMI can be long and difficult to control in a scientific experiment (e.g. the effect of urbanisation on BMI). Furthermore, it is unlikely that two food systems are completely separate yet simultaneously similar enough for one to serve as a control to the other. For example, using Lagos as a control for an Abuja-based intervention would be an imperfect comparison because there are more differences between the two cities than the ones the intervention accounts for. While the causal relationships between 'diets' and 'nutrition and health outcomes' allow for some robust evidence, the further one moves away from the bodily system and into the food system, the more difficult it is to find or create robust scientific evidence. Ethical constraints also exist: studies are limited to the extent to which and circumstances under which they may deliberately expose participants to health risks. Another reason for the observed research gaps can be found in the fact

that overweight and obesity are more prevalent in high-income countries than in middle and low-income countries. It is perhaps, therefore, unsurprising that the specificities of overweight and obesity in low-income countries have not received the same amount of attention yet. This applies even more when focusing on rural populations. Many of the drivers and causes identified are general, and the extent to which they apply to rural contexts is uncertain.

A large amount of the reviewed literature provided specific suggestions for topics for future research. This section highlights a few of the topics that are currently being researched:

- Population-specific BMI cut-off points to establish overweight or obesity (Ford et al., 2017; B. A. Swinburn et al., 2011). Most studies on overweight and obesity were conducted among Caucasians. It is uncertain whether other populations have the same association between BMI and the amount of fat tissue or between high BMIs and adverse health consequences. This may mean that the cut-off points to establish overweight or obesity should perhaps be lower or higher for different populations. Filling this evidence gap would be facilitated by more insight into national-level overweight and obesity statistics in both genders and at all ages, related to prevalence data on adverse health outcomes of overweight and obesity (e.g. diabetes, cardiovascular disease, hypertension, sleep apnoea and osteoarthritis)(Ford et al., 2017).
- Food environment and food choice research in LMICs, including the full spectrum of diets, nutritional status and health outcomes (Turner et al., 2020). This means paying attention to how a transitioning food environment contributes to undernutrition as well as overnutrition (and nutrition-related non-communicable disease). B. A. Swinburn et al. (2011) note that a better understanding of the powerful sociocultural determinants of food choices, physical activity and body-size perception can help identify opportunities to make environments less obesogenic. In their systematic scoping review of food environment research in LMICs, Turner et al. (2020) provide specific recommendations for future research on the topic. These are listed in Box 4. Studies into individual-based motives of food choice in rural areas of LMICs are also lacking (Karanja et al., 2022) – preferably looking beyond food taboos. Finally, substitution effects among processed/packaged foods, staples, fruits and vegetables and livestock products warrant further research (Gómez & Ricketts, 2013), which would also address a prevalent but implicit hypothesis that a larger availability of nutritious options will cause consumers to make healthier choices.
- A quantification of and insight into the specific characteristics of urban environments that explain the link between urbanicity and obesity (Angkurawaranon, Jiraporncharoen, Chenthanakij, Doyle, & Nitsch, 2014). This would be helpful in understanding the differences between overweight and obesity prevalence in urban versus rural areas and possibly help with designing strategies to protect rural areas.
- The epigenetic influences on overweight and obesity to better understand what causes a person with a genetic predisposition to develop or not develop overweight or obesity over the course of their life. This includes the mechanisms by which exposure to obesogenic Persistent Organic Pollutants (POPs) leads to increased obesity risk (Ford et al., 2017; Grün & Blumberg, 2006), and the influence of changes in the gut microbiome (Ford et al., 2017; Vandevijvere et al., 2015).
- The exact physiological mechanisms by which dietary quality exerts its influence on overweight and obesity. Studies are needed to validate the hypothesis that they involve hormonal and neurological pathways that influence satiety (Romieu et al., 2017).
- As demonstrated in the previous section on the dimensions of overweight and obesity for the specific target groups, there is a paucity of evidence on the extent to which general drivers and causes of overweight apply to specific groups like rural populations, Indigenous peoples and people with a disability.

Box 4 Recommendations for future research on food environments in LMICs (Turner et al., 2020)

1. Research should seek to harmonise theoretical concepts with empirical research.
2. Low-income countries and lower-middle-income countries should be considered a priority given the current paucity of studies from these settings and the pressing public health nutrition challenges at hand.
3. Research should address the double burden of malnutrition, including undernutrition, overweight, obesity and nutrition-related chronic disease.
4. The development, testing and validation of standardised instruments and metrics to profile food environments should be prioritised to track transitioning diets across diverse settings in LMICs.
5. Rigorous mixed-methods designs should be implemented to provide comprehensive assessments of external and personal food environment domains and dimensions.
6. Research should apply robust longitudinal and experimental designs at multiple scales to assess the impact of interventions on diets, nutrition status, and health outcomes in LMICs.

4 Intervention strategies for overweight and obesity

Several types of interventions were identified as being effective or potentially effective in the literature review. An overview of the retrieved literature can be found in Appendix 4. They have been categorised into 'food supply chains', 'policy & governance', 'food environments' and 'consumer behaviours interventions', following the HLPE framework. It is necessary to point out that this categorisation is not strict because some interventions can be classified into multiple categories. To avoid unnecessary repetition, these interventions are only mentioned once under the most relevant category.

4.1 Food supply chains

Focus on food items. There are studies that focus on finding specific food items that can act as interventions to reduce obesity. Siva et al. (2017) claim that lentils, a cool season legume, can be used as a whole-food solution to combat global obesity. This is because lentils contain rich low-digestible carbohydrates that can stimulate the growth and activity of hindgut bacteria, which can lead to reduced obesity. An Icelandic study by Arnarson et al. (2011) indicates that salt and fat-reduced meat products are well accepted by potential consumers and can be successfully used in weight loss programmes. Mvitu Muaka, Longo-Mbenza, Tulomba Mona, and Nge Okwe (2010) show that cassava leaves and dried red bean intake, rich in antioxidants, can help to reduce the risk of metabolic syndrome and hence contribute to obesity prevention.

Food package labelling. Food package labelling emerged as a potentially effective food system intervention to reduce the prevalence of overweight and obesity. A study (Bhattacharya, Saleem, & Bera, 2022) focusing on India showed that effective food labelling, which provides visible and understandable information as an unhealthy food warning, can reduce childhood obesity. It also showed that consumer knowledge/information, commonly found on food labels, plays a crucial role in food purchasing. Basto-Abreu et al. (2020) estimated the potential impacts of warning labels on beverages and snacks in Mexico on obesity prevalence and obesity-related costs. They found a positive relationship between the adoption of warning labels (if the food exceeds a threshold for calories, added sugars, fats, etc.) and the reduction of obesity and obesity-related costs. A more recent study (Pérez-Escamilla et al., 2021) presented similar findings for Chile. Owing to Front-of-Food Pack warning labelling, consumers' food perceptions and knowledge are improved, and purchases of unhealthy beverages and foods decrease. Compared to labelling that focuses on the negative impacts of unhealthy foods, nutrition labelling that provides general nutrition information on foods and menus is considered less effective (Storcksdieck genannt Bonsmann & Wills, 2012). Storcksdieck genannt Bonsmann and Wills (2012) claim that no real-life evidence exists linking nutrition label use with measured changes in body weight for European consumers. Similarly, an American study by Chaufan, Fox, and Hong (2011) found little empirical evidence to support the assumption that menu labelling providing nutritional information affects food consumed at restaurants or purchased for home consumption. Combining these studies' insights, it seems that food labelling that focuses on conveying negative or warning messages is more effective than nutrient labelling to provide nutrient information. However, this finding is not definitive. A general review study (Lobstein, Neveux, & Landon, 2020) claims that front-of-pack nutritional labelling is likely to be highly cost-effective from an economic perspective.

Advertisements. Restrictions on advertisements for unhealthy food can play a role in tackling obesity among children (Campbell, 2020). In a Peruvian study, Aquino-Vivanco et al. (2013) point out that restricting advertising of unhealthy foods has great potential to impact overweight prevalence. Lobstein et al. (2020) mention that restrictions on child-directed advertising appeared to be highly cost-effective in the longer term to reduce childhood obesity.

4.2 Food environment

Food environment. The food environment can be defined as "The physical, economic, political and socio-cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food" (HLPE, 2017). Achieving a healthier food environment is considered effective to mitigate the problem of overweight and obesity. Pineda, Bascunan and Sassi (2021) show that a healthier school food environment can help to improve children's dietary behaviour and BMI. To realise successful school food environment interventions and prevent childhood obesity, obesogenic food environments around school must be changed. This requires involvement from governments through enforcement and continuous supervision of regulation implementation. Tao, Zhao, Glauben and Ren (2020), based on the data from 8,500 Chinese rural primary students, found that higher dietary diversity can mitigate the risk of overweight and obesity among primary school children. This can be achieved presumably through more frequent food intake throughout the day and developing a more diverse dietary profile. Gittelsohn and Kumar (2007) questioned the effectiveness of school-focused food environment interventions in the United States and Europe, and they suggested that developing healthy eating zones around schools could be an effective tool to reduce childhood obesity. Perepezko et al. (2018) claim that interventions targeting takeaways from restaurants provide new methods for changing the food environment (e.g. employing social media) to address child obesity problems. Hu, Nguyen, Langheier and Shurney (2020) find that digital apps that provide personalised nutrition recommendations and changes to the food purchasing environment could lead to meaningful weight reduction among individuals with obesity. Haire-Joshu and Nanney (2002) show that early intervention with parents of young children by altering the food environment is essential to reduce obesity prevalence.

4.3 Policy and governance

The taxation of unhealthy food products is another common food system-related intervention that was widely adopted. Cabrera Escobar, Veerman, Tollman, Bertram and Hofman (2013) conclude that taxing sugar-sweetened beverages (SSBs) may reduce obesity. Pfinder et al. (2020) confirm that the effectiveness of taxing foods exceeding a sugar threshold value leads to a reduction in the consumption of sugar-added food, which can prevent obesity or other adverse health outcomes. Lobstein et al. (2020) also find that beverage taxes are likely to be a highly cost-effective intervention. Similar findings are presented by Itria, Borges, Rinaldi, Nucci and Enes (2021), indicating that a high sugar-sweetened beverage (SSB) tax could be an effective fiscal policy to reduce overweight/obesity prevalence: it would lead to reduced SSB purchase and consumption, especially if the tax is specific for beverage volume. The study of Nakhimovsky et al. (2016) focusing on the SSBs in MICs, however, shows a more complex picture. While their research indicates that a tax on SSBs may be a promising policy for MICs to prevent the further growth of overweight (if it raises prices by at least 20%), they also find taxation alone will likely not be big enough to assure permanent reductions in population weight. A study focusing on the Pacific Islands (Snowdon & Thow, 2013) indicated that taxation of SSBs has minimal impact on obesity prevalence. This finding is supported by Pfinder et al. (2020), which demonstrates the uncertainty surrounding the effectiveness of taxing unprocessed sugar or sugar-added foods in reducing their consumption and preventing obesity. A study by Bell et al. (2020) showed that the reduction of import duties on fruits and vegetables may have brought benefits to overweight prevention in Fiji because it contributed to increases in the volumes of fruits and vegetables. However, it did not provide evidence of any increase in consumption. Similar to the effect of taxation, restrictions on price promotion for unhealthy foods are considered necessary to ensure low-energy food intake and address the obesity issue (Looi et al., 2021). On the contrary, reducing the prices of healthy foods has a positive effect on their purchase and consumption (Adam & Jensen, 2016).
Pehlke, Letona, Ramirez-Zea and Gittelsohn (2016) suggest that price manipulation and promotions could increase intakes of healthier options (e.g. fruits and vegetables). It has been found that higher prices for fast foods and lower prices for vegetables and fruits lead to lower body weight in some groups, specifically, adolescents and lower-income adults and children (Ries, 2013). Noormohamed et al. (2012) suggest that lowering prices and adding photographs of healthy items to takeaway menus could encourage healthier ordering practices in takeaway restaurants and therefore contribute to obesity prevention. However, Noormohamed et al. (2012) also pointed out that, although price reduction strategies could be very effective to induce healthy food consumption at the consumer end in theory, they may have limited feasibility when concerning private businesses because profitability needs to be considered.

Shaping a healthy food environment is a challenging task, which is beyond the capacities of the individual and the private sector. It requires the engagement of the governments to make adequate food environment-related regulations and policies. B. Swinburn (2009) indicate that market failure has led to an increasingly obesogenic food environment, signalling the need for government interventions with policies. Seidell and Halberstadt (2020) point out that government regulation is necessary to ensure a healthy food environment for children and their families, and this requires intersectional action. A synergistic mix of population-level interventions is required for effective obesity prevention, including a strong role for government and regulation of the marketing, labelling, content and pricing of energy-dense foods and beverages (P. Baker, Gill, Friel, Carey, & Kay, 2017). Gittelsohn et al. (2017) indicate that interventions at the environmental and policy levels are promising due to their wide reach. It is recommended that future research activities involve policy-makers, store owners and communities throughout the entire research process. Similar ideas are put forward in other studies (e.g. Calancie et al., 2015; Phulkerd et al., 2016; Sacks, Swinburn, & Lawrence, 2008).

4.4 Consumer behaviour

Behaviour change strategies. Nutrition education and awareness raising for behaviour changes in dietary choice and physical activities are the most mentioned interventions. Many of these interventions are school-based, and most were based in high-income countries. Greening, Harrell, Low and Fielder (2011) looked into a healthy lifestyle school-based obesity intervention, which shows statistically significant improvement in the percentage of body fat. Gezmen-Karadağ, Yildiran, Köksal and Ertaş Öztürk (2019) demonstrated the importance of designing educational programmes about nutrition policies that target school teachers. They claim that school teachers' knowledge about nutrition policies can affect children's dietary habits, and these effects can last into adulthood. Hadi et al. (2019) prove that the effects of peer nutrition education in schools change children's nutritional behaviour, and this can be used for childhood obesity prevention. Evans, Albar, Vargas-Garcia and Xu (2015) state that school-based interventions are very cost-effective for reducing obesity risk in children because large numbers of children can be targeted with a single school programme. Game-based education can be employed to increase knowledge and motivation (Evans et al., 2015). Addressing people across different sectors is advocated. Norman, Nyberg, Elinder and Berlin (2016) recommend cooperating with parents for school-based nutrition education programmes so change can be effected in the home environment. School-based interventions with the engagement of families and communities are more likely to succeed at improving children's long-term health, according to Evans et al. (2015). Lee et al. (2022) studied a preschool-based behavioural intervention programme to improve children's knowledge and practices of healthy energy balance-related behaviours. They found that interactions between teachers and parents are crucial in facilitating behavioural change in children. Varagiannis et al. (2021) investigated three types of family-based interventions: group-based (with a group of experts), individual-based (with a dietitian) and a website approach (receiving training online). These interventions targeted parents and school-aged overweight or obese children. They found that personalised, family-based interventions are effective to improve children's eating behaviour and therefore contribute to obesity reduction. In an American study, Eldridge et al. (2016) researched the effectiveness of ten face-to-face educational sessions for parents, compared to the minimal (control) intervention group, who received similar information via email. They declare that this intervention can mitigate the obesity problem among rural preteens. Education of first-time mothers is important to prevent obesity (Uesugi, Dattilo, Black & Saavedra, 2016). Leroy, Habicht, de Cossío and Ruel (2014) prove that the negative effects of household wealth on the prevalence of double-burden households in rural Mexico can be effectively mitigated by maternal schooling. To improve the overall effectiveness of intervention programmes, school and family-based approaches should be extended to include community-based interventions (Filbert, Chesser, Hawley, & St. Romain, 2009). Koletzko et al. (2020) point out that effective obesity interventions should include multiple integrated components that involve a variety of stakeholders. Redmond et al. (2021) studied multi-level, multi-component (MLMC) interventions within five culturally diverse tribal communities; the interventions included "working with store owners to stock healthy beverages, display and dispersal of educational materials, support of policies that discouraged unhealthy beverage consumption at worksites and schools and taste tests". Their work showed that large, community-based MLMC interventions can help Native American adults reduce their intake of regular, sugar-sweetened sodas. Robinson et al. (2021) studied another community-based multi-level, multi-setting, multi-component intervention that looked into including home environment changes and behavioural counselling, community after-school team sports and reports made to primary health-care providers. They show that the children in the intervention group outperformed the ones in traditional health education (control group) in terms of gaining less BMI over one year.

5 Conclusion

This chapter provides answers to the research questions.

1. **What are the main drivers of overweight and obesity in rural areas?**
2. **What causal links have been identified by research between overweight and obesity and the food system along food value chains?**

Overweight and obesity are products of an obesogenic food system. This review shows just how systemic an issue overweight and obesity is, with drivers being present in nearly every component of the food system. This helps to explain why addressing overweight and obesity at an individual level is so difficult, and why there are so few interventions that have proven effective thus far.

Rural areas in LMICs seem to be protected against overweight and obesity owing to their differences from urban environments. However, the differences are diminishing. As rural areas continue to urbanise, they will likely increasingly be exposed to a cluster of drivers of overweight and obesity. Connection to global value chains could transform food environments, and rural consumers could increase their intake of added sugars, sugar-sweetened beverages and vegetable-oil-rich processed foods, leading to a higher total energy intake. At the same time, an urban lifestyle may mean that the need and opportunity to be physically active decreases.

The direct cause of overweight and obesity is energy imbalance: more energy is consumed than is expended. Physical activity, through which energy is expended, is becoming less of a requirement for daily life, partly thanks to technological innovations, ranging from motorised transport to television. Meanwhile, and likely more importantly, diets are delivering too many calories and can be of poor quality. These diets are the result of modern, global food supply chains, which favour processed and ultra-processed foods, energy-dense staples, the use of caloric sweeteners in foods (especially in beverages) and the use of vegetable oil. Food environments, where consumers interact with the food supply chain, can drive the consumption of energy-dense foods if they make these foods available, affordable, acceptable, promoted and safe. Energy-dense foods tend to be cheaper than their more nutritious counterparts. Convenience can also be a factor that tips the balance towards energy-dense choices. The individual aspect of food choice is somewhat under-researched, but it includes weight consciousness in pursuit of ideal body size. Other individual behaviours that can affect the propensity of becoming overweight or obese are tobacco smoking, poor quality sleep and chronic psychosocial stress. One special category of factors is nutrition and health outcomes in themselves, which are also drivers for overweight that can affect offspring. These are as follows: maternal BMI and diet, weight gain during pregnancy, birth weight, exclusive breastfeeding, rate of infant weight gain and the gut microbiome. This framework is completed at the meta-level, where each of the HLPE-defined categories plays a role in creating or sustaining an obesogenic food system.

When it comes to the specificities of overweight and obesity in rural contexts in LMICs, research is scarce. What is known is that it is not only urban people who are exposed to its drivers. Rural BMI is on the rise, even more so than in urban populations. In some LMICs, this has led to a closing or even a reversal of the gap between urban and rural BMI (Bixby et al., 2019). It is hypothesised that the causes of overweight and obesity in urban areas permeate rural areas as countries develop economically. Historically urban drivers, like changing infrastructure, transportation, employment, income, food access and physical activity, are becoming more prevalent in rural areas too.

The systemic nature of the issue makes it difficult to assess causes, as opposed to drivers. The possibilities for experimental studies that include a counterfactual are limited due to practical constraints. Causal pathways that connect a driver to an impact on BMI can be long and difficult to control in a scientific experiment (e.g. the effect of urbanisation on BMI). It is also unlikely that two food systems are separate yet similar enough for one to be used as a control for another. Generally, the causal relationships between 'diets'

and 'nutrition and health outcomes' allow for the most robust evidence. However, the further one moves away from the bodily system and into the food system, the more difficult it is to find or create robust scientific evidence. Ethical constraints are also present: studies are limited in the extent to and circumstances under which they can deliberately expose participants to health risks.

3. What gaps are there in terms of research and knowledge on the causes of overweight and obesity in rural areas in LMICs?

It is not difficult to find gaps in terms of research and knowledge on the causes of overweight and obesity in rural areas in LMICs. Not all the gaps can be filled by rigorous scientific evidence, as demonstrated in the previous sections. However, there are also issues that would be feasible for future research. These include:

- Population-specific BMI cut-off points to establish overweight and obesity. It is uncertain whether all populations have the same association between BMI and amount of fat tissue, or between high BMI and adverse health consequences. Filling this gap in evidence could be facilitated by more insight into national overweight and obesity statistics for all genders and ages, related to prevalence data on adverse health outcomes of overweight and obesity (e.g. diabetes, cardiovascular disease, hypertension, sleep apnoea and osteoarthritis).
- Food environment and food choice research in LMICs, including the full spectrum of diets, nutritional status and health outcomes. A better understanding of the sociocultural determinants of food choices, physical activity and body-size perception could help identify opportunities to make environments less obesogenic.
- A quantification of and insight into the specific characteristics of urban environments that explain the link between urbanicity and obesity.
- The epigenetic influences on overweight and obesity to better understand what causes a person with a genetic predisposition to develop or not develop overweight or obesity over the course of their life.
- The physiological mechanisms by which dietary quality influences overweight and obesity.
- The specific dimensions of overweight and obesity among rural populations (as opposed to more urban populations) are not yet well understood. It is hypothesised that the causes of overweight and obesity in urban areas are permeating rural areas as countries develop economically. Drivers like changing infrastructure, transportation, employment, income, food access and physical activity are becoming more prevalent in rural areas too. This is a hypothesis that needs validation. Additionally, there may be drivers that are specific to rural areas, like exposure to environmental contaminants through agriculture and the likelihood of areas becoming food deserts due to remoteness.
- Many of the target groups listed in the next section remain underrepresented in overweight and obesity research.

4. What dimensions of overweight and obesity are there that are related to IFAD's specific target groups (i.e. women, indigenous peoples (IPs), youth, and with people with a disability)?

Women are more prone to overweight and obesity than men in nearly all LMICs. There are various possible explanations; both physiological (sex) and socio-cultural (gender). Explanations could include differing physiological responses to early-life nutrition, differing hormonal responses to energy expenditure, weight gain associated with pregnancies, lower physical activity levels, depression, economic circumstances over the lifespan and differences in sociocultural factors – like ideal body size and acceptability of physical activity. The higher prevalence among women is not the only reason women deserve special attention in overweight and obesity interventions. Maternal obesity influences the risk of childhood obesity, as do maternal undernutrition and breastfeeding practices. Women also tend to play a key role in food preparation.

Finding evidence on the inequity dimensions for **youth** was complicated by the fact that different countries and institutions maintain different definitions of the term. Literature demonstrated a general pattern across the lifespan where a higher prevalence of overweight and obesity is found among older individuals as compared to younger groups. This means youths are typically less vulnerable to overweight and obesity. However, it seems that the period of adolescence and youth roughly leads to the onset of higher obesity prevalence among females as compared to men. Before this period (i.e. childhood), the prevalence of overweight is similar between boys and girls.

The inequity dimensions of overweight and obesity for **people with a disability** and **indigenous peoples** can be considered a research gap. For the former, no specific evidence was found in LMIC contexts. For the latter, we found examples where Ips were more affected by overweight and obesity (in Mexico and Guatemala). Indigenous peoples can also be affected by the aforementioned lack of evidence on the association between fat tissue and BMI, and between BMI and health risks, which applies to several non-Caucasian groups.

5. What is documented evidence of interventions with the potential to prevent and/or reduce overweight and obesity in the different areas of the food system?

We aimed to provide an overview of the overweight and obesity intervention strategies that have been proven to be potentially effective in mitigating the overweight and obesity problems in LMICs. Due to the limited number of papers that specifically address LMICs, we also included some literature on HICs.

The results show that food system-related interventions still apply traditional approaches, such as food package labelling, price manipulation and changing the food environment. There is a gap in food value chain approaches to address the problem of overweight and obesity from a postharvest management perspective (e.g. postharvest handling, storage, transportation). This makes it difficult to unpack how the value chain impacts on overweight and obesity. This may be because the logic behind postharvest management and overweight mitigation is implicit. For example, we know that good postharvest practices can extend the shelf-life of fruit and vegetables and improve their availability throughout the year. Improved availability should (hopefully) lead to more fruit and vegetable consumption, which may thus contribute to overweight reduction. The long (and potentially hidden) logic chain means evidence-based research on this topic is rare in the literature.

For traditional food-system interventions, food package labelling to convey negative impact information seems to be effective in reducing overweight and obesity. Price manipulation or taxation is expected to have some effects on overweight prevention. However, it is likely unable to solve the problem by itself. Advertisement restrictions on unhealthy foods are considered highly effective in mitigating childhood obesity. Achieving a healthier food environment is crucial for overweight reduction. It requires governments and policymakers to be engaged, as well as intersectional collaboration.

For food environment interventions, behaviour change strategies – such as nutrition education – and awareness play a key role in combating overweight. It requires an integrated multi-level, multi-component approach with school, family, and community-based programmes because none of the individual interventions can solve the problem by itself.

Looking at the links between the drivers and the interventions identified in the literature review, some are quite aligned (directly or indirectly) with each other and some are not. There are identified intervention strategies that are directly connected to a specific driver. For example, taxation is a widely used measure to reduce the use of added sugars, especially in sugar-sweetened beverages, identified as a driver in this research. The same applies to advertisement restrictions targeting the driver 'promotion of unhealthy foods'. There are also interventions targeting multiple drivers. For example, school-based nutrition education and awareness programmes aim to improve the knowledge of teachers, students and parents in order to change their behaviour with regard to dietary choice and physical activities, which are affected by multiple socio-cultural, dietary and consumer behaviour drivers.

The links between some drivers and interventions are somewhat weak because of the following reasons:
1. Unintervenable drivers (e.g. income growth, technology advancement, urbanisation).
2. Unclearness about the causality and correlations (e.g. income equality and overweight prevalence).
3. Trade-offs between contradictory policy goals (e.g. market development and overweight prevention).

6. What are existing good practices for interventions? What failures/lessons have been documented?

Overweight and obesity reduction are complex issues that cannot be tackled by any individual intervention. The responsibility is not isolated to individuals, businesses or the government, but to society as a whole. Therefore, it requires an integrated approach with cross-sectoral collaboration and engagement from policymakers. Successful interventions that deliver long-term impact are often multi-level, multi-setting and multi-component arrangements, which aim at both individual behaviour change and food environment improvement, backed up by effective policies and regulations.

The barrier that hampers the success of interventions is the lack of incentives for stakeholders. For example, policymakers may feel reluctant to intervene in the market with regulations because of the belief in the free-market principles or potential violation of World Trade Organisation rules. Businesses could also be hesitant to introduce overweight interventions due to economic considerations. For individuals, nutrition knowledge alone may not lead to strong motivation or lead to changes in habitual practices. If the food environment is unfavourable, they may easily fall back into old habits. Furthermore, there is no clear ownership of the problem for the stakeholders. Overweight tends to be considered an individual problem, with responsibility for addressing it being at the individual level too.

7. What are the constraints to intervention strategies for overweight and obesity?

There are constraints that can limit the applicability of intervention strategies.

Policy constraints: Policymakers have limited tools to address multiple and conflicting targets. When designing overweight and obesity interventions, they must consider negative impacts on other targets (e.g. economic growth, market environment, food security). Moreover, policy interventions must be carried out within national and international legal frameworks, which further restricts action space for policymakers.

Resource constraints: Systemic interventions with multi-level, multi-component, multi-setting approaches need a lot of resources, which could be a significant constraint for LMICs.

Socio-cultural constraints: Socio-cultural factors can heavily affect people's perception of unhealthy food and physical activity, which imposes another contextual constraint for the effectiveness of overweight and obesity interventions.

8. What are the nutrition-sensitive interventions for IFAD target groups in the context of their food systems (i.e. women, Indigenous Peoples (IPs), youth, and people with a disability)?

The relevance of considering overweight and obesity as a food system outcome in interventions was underlined by this review. As Bixby et al. (2019) put it:

> There is an urgent need for an integrated approach to rural nutrition that enhances financial and physical access to healthy foods, to avoid replacing the rural undernutrition disadvantage in poor countries with a more general malnutrition disadvantage that entails excessive consumption of low-quality calories.

Many interventions from the literature consider children, as childhood obesity prevention is considered to have a life-long impact. The literature emphasises the importance of the environmental influence on youth's dietary choices and lifestyle. It recommends interventions, such as changing the food environment around the school, as well as school and home-based nutrition education. The value chain or policy interventions are also observed with respect to food labelling and advertising to children. Role model impacts have also been discussed and may be a leverage point to be targeted.

Studies that specifically focus on interventions to address overweight and obesity among the other target groups (women, IPs and people with a disability) are rarely observed in the literature. A few studies look into IPs, but the interventions were also applicable to the general population, so no IP-specific insights on the interventions could be derived from them.

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Appendix 1 Glossary

Term	Definition used
Malnutrition and related concepts	
Malnutrition	Deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients (World Health Organization, 2021b).
Adult overweight and obesity	Refers to an adult who is too heavy for their height. In adults, overweight is defined as having a BMI of 25 or more, whereas obesity is a BMI of 30 or more (World Health Organization, 2021b).
Childhood overweight	Refers to a child who is too heavy for their height. It is clinically assessed if a child's weight (kg) for height (cm) exceeds +2 SD of the WHO Child Growth Standards median (UNICEF et al., 2021).
Double burden of malnutrition	The coexistence of undernutrition (underweight and/or micronutrient deficiencies) along with overweight and obesity or diet-related noncommunicable diseases, within individuals, households and populations, and across the life course (World Health Organization, 2021b).
Triple burden of malnutrition	The coexistence of underweight, hidden hunger (where children suffer from a deficiency in micronutrients) and overweight. These three burdens often co-exist in the same country, and can even occur in the same family. (UNICEF, 2019)
Undernutrition (wasting, stunting, underweight, micronutrient deficiencies)	"There are four broad sub-forms of undernutrition: wasting, stunting, underweight, and deficiencies in vitamins and minerals. Undernutrition makes children in particular much more vulnerable to disease and death" (World Health Organization, (2021b). Wasting: "Low weight-for-height is known as wasting. It usually indicates recent and severe weight loss, because a person has not had enough food to eat and/or because they have had an infectious disease, such as diarrhoea, which has caused them to lose weight. A young child who is moderately or severely wasted has an increased risk of death, but treatment is possible" (World Health Organization, 2021b). Stunting: "Low height-for-age is known as stunting. It is the result of chronic or recurrent undernutrition, usually associated with poor socioeconomic conditions, poor maternal health and nutrition, frequent illness, and/or inappropriate infant and young child feeding and care in early life. Stunting holds children back from reaching their physical and cognitive potential." (World Health Organization, 2021b). Underweight: "Children with low weight-for-age are known as underweight. A child who is underweight may be stunted, wasted, or both" (World Health Organization, 2021b). Among adults, underweight refers to a person whose weight is too low for their height. It is defined as a BMI of 18.5 or less (World Health Organization). Micronutrient deficiencies: A lack of important vitamins and minerals (World Health Organization, 2021b).
Food security and related concepts	
Food security	Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996).
Agency (as a pillar to food security)	What a person is free to do and achieve in pursuit of whatever goals or values they regard as important (Sen, 1985, p. 203). This is an additional pillar to the concept of food security put forward by HLPE (HLPE, 2020).
Sustainability (as a pillar to food security)	The long-term ability of food systems to provide food security and nutrition today in such a way that does not compromise the environmental, economic and social bases that generate food security and nutrition for future generations. This is an additional pillar to the concept of food security put forward by the HLPE (HLPE, 2020).

Term	Definition used
Food system and related concepts	
Food system	"That which gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation, consumption and disposal of food, and the outcomes of these activities, including nutritional, food security but also socio-economic and environmental outcomes" (Agriculture for Nutrition and Health, 2020).
Consumer behaviour	"Considering the entire process from acquisition to consumption of food as reflective of all the choices and decisions made by consumers, at the individual, household or collective levels, on what food to acquire, store, prepare, cook and eat – and how to dispose [of] the waste – and on the allocation of food within the household (including gender repartition and feeding of children (HLPE, 2017). Food choices are determined by personal attitudes and motives, such as familiarity with the foods, taste preferences, convenience, perceived safety of foods, nutritional and health-related motives and desirability, as well as societal norms regarding the symbolic, cultural, and economic values of food. Nutrition knowledge, as well as skills and availability of time for food preparation can have an impact on consumer food choices and can lead people to opt for healthier foods" (Agriculture for Nutrition and Health, 2020).
Food environment	The physical, economic, political and socio-cultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food (HLPE, 2017). It includes food availability and physical access (proximity); economic access (affordability); promotion, advertising, and information; convenience and time savings, and food quality and safety (Herforth & Ahmed, 2015).
Ultra-processed food	Ultra-processed foods are produced using many types of additives. The processes and the ingredients used in the manufacture of ultra-processed foods make them convenient (ready-to-consume, almost imperishable) and attractive (hyperpalatable) for consumers, and profitable (low cost ingredients, long shelf-life) for their manufacturers. However, these processes and ingredients also make ultra-processed foods typically nutritionally unbalanced and liable to be over-consumed (Monteiro et al., 2019).
Value chain	"The full range of activities which are required to bring a product or service from conception, through different phases of production to final consumers, and final disposal after use. In reality, VCs are a complex network of activities and linkages among different actors, and therefore the idea of "chain" should be considered as a metaphor for connectedness among them. The term "value" refers to the "value" that is generated along the chain as the commodity goes through the different phases, referring to both the value added to the product at each stage of the chain and the value captured by the different actors involved" (Agriculture for Nutrition and Health, 2020).
Miscellaneous relevant concepts	
Body Mass Index (BMI)	The ratio of weight-to-height commonly used to classify the nutritional status of adults. It is calculated as body weight in kilograms divided by the square of the body height in metres (kg/m^2) (World Health Organization).
Healthy diet	"A diet that is human health promoting and disease preventing and safeguarding of planetary health by providing adequacy without excess, of nutrients from foods that are nutritious and healthy, and by avoiding the introduction of health-harming substances, through all stages of the value chain. Healthy diets must be affordable, culturally acceptable. They must progressively change towards originating from sustainable production and processing systems that do not adversely affect local and regional ecologies" (Neufeld, Hendriks, & Hugas, 2021).
Low and Middle Income Countries (LMIC) and High Income Countries (HIC)	The term 'LMIC' is applied to combine the World Bank categories of low-income economies, lower-middle-income economies and upper-middle-income economies. However, this is one among multiple categorisations. Sources referenced may have used different definitions for these terms. Furthermore, categorisation of countries can change over time as economies grow or decline.

Appendix 2 Elaborated search terms

These are the search terms that will be used to refine the literature search to LMICs.

"Developing Countries" OR "developing countr*" OR "developing nation*" OR "developing population*" OR "developing econom*" OR "undeveloped countr*" OR "undeveloped nation*" OR "undeveloped economy" OR "undeveloped economies" OR "least developed countr*" OR "least developed nation*" OR "least developed economy" OR "least developed economies" OR "less-developed countr*" OR "less-developed nation*" OR "less-developed population" OR "less-developed populations" OR "less-developed econom*" OR "lesser developed countr*" OR "lesser developed nation*" OR "lesser developed population" OR "lesser developed populations" OR "lesser developed economy" OR "lesser developed economies" OR "under-developed countr*" OR "under-developed nation*" OR "underdeveloped countr*" OR "underdeveloped nation*" OR "underdeveloped population*" OR "underdeveloped econom*" OR "low income countr*" OR "middle income countr*" OR "low income nation*" OR "middle income nation*" OR "low income population*" OR "middle income population*" OR "low income econom*" OR "middle income econom*" OR "lower income countr*" OR "lower income nation*" OR "lower income population*" OR "lower income economy" OR "lower income economies" OR "resource limited" OR "low resource countr*" OR "lower resource countr*" OR "low resource nation*" OR "low resource population*" OR "low resource economy" OR "low resource economies" OR "underserved countr*" OR "underserved nation*" OR "underserved population*" OR "underserved economy" OR "underserved economies" OR "under-served country" OR "under-served countries" OR "under-served nation" OR "under-served nations" OR "under-served population" OR "under-served populations" OR "underserved economy" OR "underserved economies" OR "deprived countr*" OR "deprived nation" OR "deprived nations" OR "deprived population*" OR "deprived economy" OR "deprived economies" OR "poor countr*" OR "poor nation*" OR "poor population*" OR "poor econom*" OR "poorer countr*" OR "poorer nation*" OR "poorer population*" OR "poorer econom*" OR "lmic" OR "lmics" OR "lami" OR "transitional countr*" OR "transitional nation" OR "transitional nations" OR "transitional econom*" OR "transition countr*" OR "transition nation*" OR "transition econom*" OR "low resource setting*" OR "lower resource setting*" OR "middle resource setting*" OR "Third World*" OR "south east asia*" OR "middle east*" OR "Afghan*" OR "Angola*" OR "Angolese*" OR "Angolian*" OR "Armenia*" OR "Bangladesh*" OR "Benin*" OR "Bhutan*" OR "Birma*" OR "Burma*" OR "Birmese* " OR "Burmese*" OR "Boliv*" OR "Botswan*" OR "burkina Faso*" OR "Burundi*" OR "Cabo Verde*" OR "Cambod*" OR "Cameroon*" OR "Cape Verd*" OR "Central Africa*" OR "Chad" OR "Comoro*" OR "Congo*" OR "Cote d'Ivoire*" OR "Djibouti*" OR "East Africa*" OR "Eastern Africa*" OR "Egypt*" OR "El Salvador*" OR "Equatorial Guinea*" OR "Eritre*" OR "Ethiopia*" OR "Gabon*" OR "Gambia*" OR "Gaza*" OR "Georgia (Republic)" OR "Ghan*" OR "Guatemal*" OR "Guinea" OR "Haiti*" OR "Hondur*" OR "India*" OR "Indones*" OR "Ivory Coast*" OR "Kenya*" OR "Kiribati*" OR "Kosovo*" OR "Kyrgyz*" OR "Lao PDR*" OR "Laos*" OR "Lesotho*" OR "Liberia*" OR "Madagascar*" OR "Malaw*" OR "Mali" OR "Mauritan*" OR "Mauriti*" OR "Micronesi*" OR "Mocambiqu*" OR "Moldov*" OR "Mongolia*" OR "Morocc*" OR "Mozambiqu*" OR "Myanmar*" OR "Namibia*" OR "Nepal*" OR "Nicaragua*" OR "Niger*" OR "North Korea*" OR "Northern Korea*" OR "Democratic People's Republic of Korea" OR "Pakistan*" OR "Papua New Guinea*" OR "Philippine*" OR "Principe" OR "Rhodesia*" OR "Rwanda*" OR "Samoa*" OR "Sao Tome*" OR "Senegal*" OR "Sierra Leone*" OR "Solomon Islands*" OR "Somalia*" OR "South Africa*" OR "South Sudan*" OR "Southern Africa*" OR "Sri Lanka*" OR "Sub Saharan Africa*" OR "Subsaharan Africa*" OR "Sudan*" OR "Swaziland*" OR "Syria*" OR "Tajikist*" OR "Tanzan*" OR "Timor*" OR "Togo*" OR "Tonga*" OR "Tunis*" OR "Ugand*" OR "Ukrain*" OR "Uzbekistan*" OR "Vanuatu*" OR "Vietnam*" OR "West Africa*" OR "West Bank*" OR "Western Africa*" OR "Yemen*" OR "Zaire*" OR "Zambia*" OR "Zimbabw*"

Appendix 3 Coding list

Bias and quality concerns	Concerns on the validity of the findings reported in a study
Context	
APR	Asia and Pacific Region
Indonesia	
India	
Etc.	Countries to be added as they come up in literature.
ESA	East and Southern Africa
Mozambique	
Ethiopia	
Etc.	Countries to be added as they come up in literature.
LAC	Latin America and the Caribbean
Argentina	
Belize	
Etc.	Countries to be added as they come up in literature.
NENA	Near East, North Africa, Europe and Central Asia
Egypt	
Uzbekistan	
Etc.	Countries to be added as they come up in literature.
WCA	West and Central Africa
DRC	
Mali	
Etc.	Countries to be added as they come up in literature.
Q1 Interventions	What is documented evidence of interventions with the potential to control and/or reduce overweight and obesity in the different areas of the food system? (Q1)
Q2 Good practices	What are existing good practices? What failures/lessons have been documented? (Q2)
Q3 Drivers	What are the main drivers of overweight and obesity in rural areas, particularly among smallholder farmers in developing countries? (Q3)
Q4 Link VC and FS	What causal links have been identified by research between overweight/obesity and food system along food value chains? (Q4)
Q5 Gaps	What are the gaps in terms of research and knowledge, and what are technical, economic and institutional constraints? (Q5)
Constraints	Technical, economic and institutional constraints
Research and knowledge gaps	
Q6 Target groups	What are dimensions of overweight and obesity to specific target groups? (Q6)
Gender	
Indigenous peoples	
People with a disability	
Youth	
Potential reference	Reference to an article that seems useful (snowball approach)

Appendix 4 Search results

A. Drivers of overweight and obesity in rural areas of LMICs
The search strategy described in Chapter 2 yielded 253 results. The first selection was carried out based on the articles' titles.

1. Article had a geographical focus that was restricted to HICs.
Despite the search terms focusing on LMICs, there were still six articles focused exclusively on HICs. Examples include "Obesity prevention within the early childhood education and care setting: A systematic review of dietary behavior and physical activity policies and guidelines in high income countries" and "The impact of childhood obesity on human capital in high-income countries: A systematic review".

2. Article focuses only on causes on molecular, cellular or physiological level (e.g. genetic defects).
This applied to 28 articles. Examples of the type of articles excluded are "Further evidence supporting a potential role for ADH1B in obesity" and "Intragastric Balloon Versus Endoscopic Sleeve Gastroplasty for the Treatment of Obesity: a Systematic Review and Meta-analysis".

3. Article only considers overweight and obesity as drivers to other topics instead of looking into the causality of overweight and obesity itself.
This applied to 20 articles. Examples of the type of articles excluded are "Prevalence and determinants of metabolic syndrome in patients with schizophrenia: A systematic review and meta-analysis of Indian studies" and "Anesthetic implications of morbid obesity during pregnancy; a literature-based review".

4. Article did not include 'RURAL' or 'FARM*' in the title, key words or abstract.
This applied to 135 articles, which were excluded from analysis. A handful of these articles were re-included later as a result of the snowball method, which is described below.

Finally, another eight articles were excluded because they could not be accessed or downloaded. This meant that the number of articles that met our initially assessed criteria was 58. For these articles, the abstracts were read to establish relevance to the research questions.

We read the abstracts of the remaining articles. After this, it became clear that a large share of the articles only provided a cursory overview of drivers into overweight and obesity; they did not offer much depth as the actual topic of the article was something else (e.g. describing prevalence trends – 13 cases). For example, one article mentioned 'urbanization' as a driver without providing more detail. It was decided to start with the most promising articles, and to use the reference lists of these articles as an entry point to find more relevant literature. In the end, this meant seven priority articles were studied in detail. Based on their reference lists, 35 additional studies were added.

B. Intervention strategies for overweight and obesity
1. Literature screening.
Using the keywords proposed in Chapter 2, we obtained a total of 236 articles concerning overweight and obesity interventions. After this, we filtered out the irrelevant articles by article title. Articles were excluded for the following reasons:

1. *The title clearly indicates the content of the article is irrelevant.*

Take the following title as an example:
"An enhanced participant information leaflet and multimedia intervention to improve the quality of informed consent to a randomised clinical trial enrolling people living with HIV and obesity: a protocol for a Study Within A Trial (SWAT)".

Even though the words 'intervention' and 'obesity' are in the title, it is clearly not about preventing or reducing overweight and obesity but improving the quality of informed consent.

2. *The title shows that the article is about exploring the effect of biomolecules and macromolecules on overweight and obesity prevention/reduction.*

The examples include:
"Soybean β-Conglycinin: Structure Characteristic, Allergenicity, Plasma Lipid-Controlling, Prevention of Obesity and Non-alcoholic Fatty Liver Disease".

3. *Cannot find the PDF of the article to download it.*

After title filtering, we performed abstract filtering by looking into the abstracts of the articles to confirm correctness of the exclusions.

2. General overview of the relevant articles

In the end, there a total of 167 relevant scientific articles were found for further in-depth investigations. The distribution of the publications across the years is presented in Figure 8:

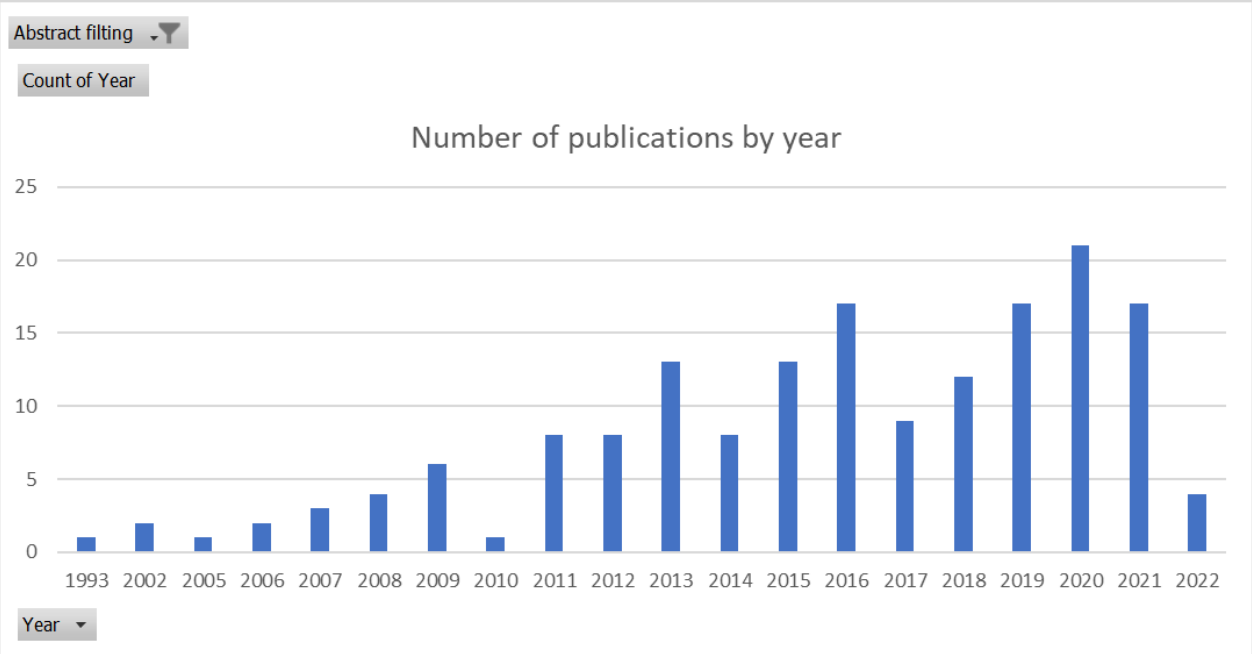

Figure 8 *Number of relevant overweight and obesity intervention publications across the years*

Generally, there is an increasing trend in the number of publications in this field over the last 20 years.

There are only 38 articles that provide information related to LMICs. A further 40 articles provide general information and did not clearly specify the countries' contexts. There are 60 studies targeting the United States, followed by Australia, which had eight publications. There are 43 studies that did not mention specific countries or regions. Mexico is the LMIC with the highest number of the publications (five papers).

About half of the studies concern childhood/adolescent overweight and obesity preventions and interventions. The remaining articles are about adult obesity and general obesity issues. There are 25 articles specifically targeting the rural communities, of which only four are about LMICs.

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Wageningen Centre for Development Innovation supports value creation by strengthening capacities for sustainable development. As the international expertise and capacity building institute of Wageningen University & Research we bring knowledge into action, with the aim to explore the potential of nature to improve the quality of life. With approximately 30 locations, 7,200 members (6,400 fte) of staff and 13,200 students, Wageningen University & Research is a world leader in its domain. An integral way of working, and cooperation between the exact sciences and the technological and social disciplines are key to its approach.

To explore the potential of nature to improve the quality of life

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The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,200 employees (6,400 fte) and 13,200 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.