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Child-centered food systems: Reorienting food systems towards healthy diets for children

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ABSTRACT

Current food systems are failing to guide children towards healthy diets. This paper presents a tool to identify the actions needed to reorient food systems to become more child-centred from a nutrition perspective. To connect the dots between children's lives, their food environments and food supply systems, the tool takes a child-centred, food systems approach. Comprising six methodological steps, the tool starts by measuring and understanding children's realities and then working back up into the system to identify how food environments and supply systems could make relevant foods more or less available, affordable, appealing and aspirational in the contexts of children's lives. The paper spells out the mix of methods needed to make this assessment, gives examples of the data and studies already available and type of insights they provide, and discusses the methodological challenges and gaps. It presents a worked example that shows how following these steps in sequence enables the identification of a package of actions that can act coherently to reorient food systems in the way most likely to have impact on child malnutrition.

1. Introduction

Children are eating poor quality diets all over the world (Kupka et al., in this issue). Whether the focus is scarcity, undernutrition, dietary imbalance, obesity, or diet-related non-communicable diseases, poor diets affect children's ability to grow and eventually function as productive, engaged, and healthy citizens. It is increasingly understood that food systems have a key role to play in improving diets. Yet children and adolescents have been relatively neglected in the growing discourse about food systems and it is evident that in most contexts food systems are not guiding them towards healthy diets.

This paper presents a tool to identify the policies and interventions needed to orient food systems towards healthy diets for children in any particular context. Taking a novel, child-centered approach, it links the specific contexts in which children live their lives - and where malnutrition develops - with the more upstream elements of food systems. The paper starts by defining "child-centered food systems" from a nutrition perspective and sets out eight key principles underpinning what food systems guiding children towards healthier diets look like and how they can be created. It then sets out the six steps of assessment and analysis needed to identify the most effective package of actions (i.e. policies and other interventions) to reorient food systems towards healthy diets for children, and discusses and exemplifies the combination of methodologies needed to make this assessment.

2. Defining child-centered food systems

A food system can be defined as the interconnected system of everything and everybody that influences, and is influenced by, the activities involved in bringing food from farm to fork (Parsons et al., 2019). In the context of child nutrition, a child-centered food system is one that makes healthy diets available, affordable, appealing and aspirational (AAAA) for children (0–18 years) in the context of their lives. In short, a food system that guides children towards healthier diets.

Abbreviations: SECTION: AAAA, available, affordable, appealing and aspirational.

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Healthy diets optimize growth and development over the short- and long-term. They are characterized by being sufficient and balanced in quantity and quality, containing a diversity of nutrient-dense foods including vegetables, fruits, whole grain cereals, fish, legumes and nuts, modest amounts of animal-source foods, and limited in foods and drinks high in saturated and trans fats, added sugars and salt (WHO, 2015a). The constituents of a healthy diet vary between population groups and parts of the life-cycle; Hollis et al (in this special issue) set out the special dietary needs of children. Healthy diets are also free from contaminated foods that cause foodborne illness to which children are particularly susceptible (Sockett and Rodgers, 2001).

3. Principles behind child-centered food systems

The idea of creating food systems that guide children towards healthier diets is built on a series of foundational principles underpinning what such a system should look like and how it should be created. These principles embody established understandings of malnutrition and food systems and their determinants.

3.1. What does a food system that guides children towards healthier diets look like?

A food system that guides children towards healthier diets:

- *Reduces malnutrition in all its forms:*

A poor-quality diet is a common driver of all forms of malnutrition, albeit with differing degrees of importance in different contexts (Hawkes et al., 2020). Food systems that guide children towards healthier diets consider all aspects of the diet affecting different forms of malnutrition.

- *Supports children and their caregivers:*

Caregivers exert considerable influence over children, especially when young (Fox & Timmer, in this issue). As such they are implicitly part of child-centered food systems, albeit with variations over the life-cycle (with typically less influence during adolescence). A child-centered food system thus also makes it easier for parents and other caregivers to guide the children in their care towards healthier diets.

- *Incorporates all aspects of food systems*:

Food systems incorporate many elements and dimensions. They include children themselves as the "consumers" in the food system (and where relevant, their caregivers); food environments; and food supply systems (GLOPAN, 2016); plus the interconnected dimensions that influence and are influenced by the activities in this system (Parsons et al., 2019; de Brauw et al., 2019). A child-centered food system aligns all of these elements and dimensions towards healthier diets, with policies and interventions being mutually complementary - rather than incoherent - throughout the system.

- *Makes healthy diets AAAA in the context of children's lives:*

Food environments, as the interface between children and food supply systems, are critical spaces where children and their caregivers acquire, and receive information about food (Raza et al., this issue; HLPE, 2017). In addition to producing food that benefits children, child-centered food systems have food environments that make *healthy* diets AAAA in the context of children's lives (Box 1).

3.2. How should a food system that guides children towards healthy diets be created?

The process of reorienting food systems towards healthy diets for children:

- *Shifts the system coherently:*

Creating child-centered food systems involves shifting the "whole system," requiring either a mutually complementary set of actions in food supply systems, food environments and children/caregivers lives; or one or two actions at "leverage points" which have transformative ripple effects across the system. In both instances, the goal is to create coherence across the system towards healthier diets for children. Given the complexity and scale of the task, a practical starting point is to identify coherent actions across the system for specific foods or food groups likely to have the greatest impact (Gelli et al., 2020).

- *Builds on actions already in place:*

While there is huge amount of work to be done to create child-centered food systems from a nutritional perspective, in many contexts, existing policies and interventions are already contributing to food systems change (e.g. IFPRI, 2016; Ruel et al., 2018; Ridoutt et al., 2019; Breda et al., 2020; WCRF International, 2020). Where they do exist, recognising, building on and learning from these actions provides a base from which to work.

- *Considers trade-offs with other food system goals:*

While guiding children towards healthier diets should be a primary goal of a food system, policy makers, businesses and NGOs have other goals, such as generating economic growth, asserting geopolitical power, mitigating climate change, or creating gender equity. Since the food system is interconnected, actions to achieve these other goals will inevitably affect actions designed to improve diets, and vice versa, at times being complementary but often requiring trade-offs (Béné et al.,

Box 1
Definitions: available, affordable, appealing and aspirational (AAAA)

Available. The foods physically available to children in their daily lives, such as snacks being available at roadside vendor, or fruit not being available during certain seasons.
Affordable. A relative concept that reflects both price and income. For example, eggs become unaffordable if the price prevents low-income families from buying a sufficient quantity, or sugary drinks become affordable when placed in small packages.
Appealing. Attributes that make foods an (un)attractive proposition in the context of everyday life, practices and beliefs. For example, fast food becomes more appealing to parents when they are busy; indigenous fruit becomes less appealing if people believe they are an inferior food. How appealing a food is affects the degree to which it is valued and thus how much people are willing to pay for it.
Aspirational. If children aspire to eat the foods, such as the because they have seen them advertised or because they are consumed by children of higher socioeconomic status.

2019). These connections need to be recognized and accounted for and, where possible, co-benefits identified and trade-offs managed in what is typically a political process involving hard choices (Parsons and Hawkes, 2018).

- *Identifies needed actions through a child-centered assessment*:

Given what is at stake, a careful assessment should be conducted to identify the package of actions that have the greatest potential to shift the system for impact on children. As articulated by the assessment, analysis, and action cycle for nutrition proposed by UNICEF (1990), this needs to start with the realities of children's (and caregivers) lives and the foods they eat and then work backwards into the food system. This approach avoids the pitfalls of starting the assessment way upstream (e.g. agriculture), which carries the risk of identifying actions that would fail to translate into better diets because of other moderating factors in the supply chain and in households. It likewise avoids the limitations of remaining at the level of individuals and households without addressing the upstream elements of food systems. The paper sets out the steps needed for such an assessment, emphasising that all steps are needed in order to identify how to reorient the whole system towards healthy diets for children.

4. Steps to identify actions to create a child-centered food system

Drawing on these eight principles, here we propose a series of six methodological steps to identify the package of actions needed to reorient food systems to improve children's diets in any particular context (Table 1). The steps are designed to trace the flow of food through the system from children back upstream; this enables the identification of actions that act in *coherence* through the system to have impact on children's lives. The first three steps deal with children's realities – initially, what type of malnutrition a child is experiencing (Step 1) and then the aspects of their diets connected to these forms of malnutrition (Step 2). The third step explores how the realities of their lives influence what they are eating in the context of their interface with the food system – food environments (Step 3). This then leads onto measuring the aspects of food environments relevant to their lives (Step 4). The next step is to ask why food environments look the way they do, requiring an exploration of food supply systems and the incentives and disincentives within them (Step 5). The actions identified through this process are then brought together into a coherent package and analyzed for broader implementation challenges in a systems context (Step 6). We spell out the mix of methodologies needed to make this full assessment, give examples of the data and studies already available, the type of methods that can be used, and types of insights they can provide, and discuss the methodological challenges and gaps.

Table 1
Six steps to identify the package of actions to create a child-centered food system.

Assessment question	Methods
1. What is the prevalence of underweight, stunting, overweight, obesity and micronutrient deficiencies in the population of concern?	Use existing data or gather new data to assess the range of nutritional problems among children in a selected community, city or country.
2. Which foods should child-centered food systems make more AAAA to address the relevant forms of malnutrition, and which ones less so?	Assess from existing or new data the food groups children are eating (or not) and in what quantities, and how this differs from recommended diets.
3. Why are children eating, or not eating, these foods, and how does this relate to the food environments they are in?	Conduct household surveys and qualitative studies to assess the reasons why children are, or are not, eating these foods in the context of the food environments they are in.
4. Taking account of these contexts, which aspects of food environments should be changed to make these foods more or less AAAA in the short- and long-term?	Gather data on the measurable elements of food environments surrounding children and those who acquire food from them (e.g., caregivers), including where they acquire and obtain information about food, to assess what role food environments can play in changing what children eat.
5. What incentives and disincentives are needed in the food supply chain, and where, to create healthier food environments for children?	Use supply chain analyses to identify how interventions in food supply chains could create healthier food environments for children.
6. What is the package of mutually complementary actions and what are implementation opportunities and challenges?	Generate package of actions and analyze implementation issues in a broader systems context.

4.1. Step 1. Assess the range of nutritional problems among children in a selected community, city or country

The first step is to identify the prevalence of various forms of malnutrition in the population in question, and the extent to which they align (or not) to national nutrition targets. It is well-established that countries, cities and communities face a "new normal" of multiple burdens of malnutrition (IFPRI, 2014). At least 1 in 3 children under 5 is affected by stunting, wasting and/or overweight, and 1 in 2 have micronutrient deficiencies (UNICEF, 2019a). Although stunting is decreasing in most regions of the world, it still affects 21.9% of children under five globally and is increasing in Africa (UNICEF, 2019a). Overweight has also increased in all regions, and disproportionately among children and adolescents 5–19 years of age (UNICEF, 2019a). The multiple burdens of malnutrition often occur within the same individuals and households (Fernald and Neufeld, 2007; Dieffenbach and Stein, 2012).

Stratifying the prevalence of malnutrition by population characteristics such as age group, socioeconomic status, gender, and location, can uncover inequalities and identify specific populations that could most benefit from interventions across the food system. For instance, Partnership and Opportunities to Strengthen and Harmonize Actions for Nutrition (POSHAN), led by the International Food Policy Research Institute, used data from the National Family Health Survey (NFHS)-4 to promote evidence-informed actions in India (POSHAN, 2020). The NFHS-4 provides district-level information on nutritional status of children. Through an analysis of these national surveys, POSHAN tracked variation in prevalence of wasting and stunting among children under five (Menon et al., 2018), anemia among children and women of reproductive age (Nguyen et al., 2018), and overweight and obesity among adolescents and women (Young et al., 2020) at district and state-levels between 2006 and 2016. These analyses informed where progress was made or not, and characteristics of the populations that explained variation between districts; these informed next steps for recommended nutrition policy actions in each district (POSHAN, 2020b).

There are challenges in obtaining these data. Existing data may be outdated and/or unavailable, particularly at community- and district-level (Development Initiatives, 2018). This makes location-specific assessment difficult. Gathering primary data of height, weight, and micronutrient status data requires trained personnel, calibrated devices, and analytical expertise to compare measures to international growth standards and cut-offs (WHO Multicentre Growth Reference Study Group and De Onis, 2006). Data from local programmes, which might be used to stratify by age group, gender, and location, are often targeted to certain populations (e.g., infants and young children, adolescent girls), and, thus, may not include data on certain groups (e.g., school-age children, adolescent boys).

However, in the absence of "ideal" data there are sources of data that exist to provide insights into the likely malnutrition burden. Country-level data can provide an overview of the national range of nutritional problems that impact children and adolescents. Examples include: the Demographic and Health Survey (DHS) (DHS, 2019); Multiple Indicator

Cluster Survey (MICS) (UNICEF, 2019b); Standardized Monitoring and Assessment of Relief and Transitions survey (SMART, 2019); Vitamin and Mineral Nutrition Information System (WHO, 2015b); data compiled by UNICEF, WHO, and World Bank joint child malnutrition estimates (UNICEF et al., 2019); the Global Nutrition Report (Development Initiatives, 2018); NCD Risk Factor Collaboration (NCD-RisC, 2017); and the Global Burden of Disease (IHME, 2015). Although national-level data frequently masks inequalities, stratifying this data by population characteristics can prove useful in assessing populations of concern. Subnational data can also provide insight into the geospatial distribution and heterogeneity within countries and regions (Menon et al., 2018; Osgood-Zimmerman et al., 2018).

4.2. Step 2. Assess what children are eating

The goal of this step is to identify the elements of child and adolescent diets that could be contributing to the identified forms of malnutrition. The purpose is to prioritise the food groups child-centered food systems should be making more AAAA to children/caregivers, and which should be made less so.

Data from 24-h recalls about the diets of infants and young children are available from national dietary surveys, such as the DHS (DHS, 2019) and MICS (UNICEF, 2019b), and are compiled regionally in UNICEF's global database for Infant and Young Child Feeding (UNICEF, 2018). These data sources largely focus on infants and young children 0–23 months of age, and provide information on breastfeeding practices, the introduction of complementary foods, infant feeding patterns, dietary diversity and dietary adequacy of young children (Kupka et al., in this issue). For older children and adolescents, data from 24-h recalls and food frequency questionnaires can be obtained from national dietary surveys, the Global School-based Student Health Surveys (CDC and WHO, 2018), Health Behavior in School-Age Children (WHO Regional Office for Europe, 2016), the WHO European Childhood Obesity Surveillance Initiative (WHO Regional Office for Europe, 2019), and the Women's Dietary Diversity Score (Martin-Prevel et al., 2017).

Challenges of dietary assessments for children and adolescents are well-established. Dietary assessments often do not capture what individuals consume. This could be due to misreporting (Micha et al., 2018; Walker et al., 2018), but also due to lack of standardized measures to capture what people eat. Certain food categories, such as oils and fats, savory and fried snacks, sweets, and sugar-sweetened beverages, are often not included or are optional food categories in many dietary questionnaires (FAO and FHI 360, 2016; FAO, 2018). Measures such as minimum acceptable diet (MAD) are commonly used to assess dietary adequacy, but are not designed to capture excessive intake or to capture foods and food groups which are damaging when consumed in excess (WHO, 2008; GLOPAN, 2016). Many of these measures to capture excess consumption of foods are also not standardized. For example, the lack of standardized indicators for the consumption of sugar-sweetened beverages and snacks among children limits systematic measurement of these dietary practices. Efforts to standardize dietary measures would allow for comparisons across populations and over time (Walker et al., 2018).

Population-specific dietary information can help to address some of these limitations. Collection of 24-h dietary recalls, including quality-control procedures such as random repeat measures, multiple-pass formats, and triangulation of dietary outcomes (Walker et al., 2018), and of dietary patterns (e.g., servings per week of food groups and sub-groups) can help to assess what children and adolescents are eating. For example, researchers from Wageningen University and the Global Alliance for Improved Nutrition (GAIN) collected dietary data and market information in Ghana using Optifoods, a software program that supports dietary analysis, to identify gaps in current diets among children 6–23 months old (Brouwer et al., 2017; GAIN, 2017). They found that additional interventions were needed to support consumption of nutrient-dense foods that were rich in micronutrients (e.g., iron), in order to meet nutrient requirements. Local measures of dietary patterns among populations provide the opportunity for researchers and practitioners to collect consumption data on specific food groups and subgroups that are well-known to affect children's diets, such as sugar-sweetened beverages, fruits and vegetables, and fortified staple foods.

Food group adequacy can be determined by comparing the results of dietary assessments to global and national recommendations, such as recommendations for feeding practices, meal frequency and dietary reference standards (WHO, 2008; Daelmans et al., 2009; WHO, 2010; Ochola and Masibo, 2014). An analysis of national surveys in South Asia, for example, showed that only 21% of children 6–23 months were fed minimally acceptable diets and only 33% of children received minimally diverse diets – 33% of children consumed fruits and vegetables rich in vitamin A, 17% consumed meat, fish, poultry, and/or egg, and only 11% consumed dairy (Aguayo, 2017). This indicates that actions taken to make food systems more child-centered from a nutritional perspective should focus on making more of these foods available to the caregivers of these young children. In Mexico, national surveys similarly showed low consumption of micronutrient-rich foods, and high consumption of energy-dense foods (such as sugar-sweetened beverages) (Rodríguez-Ramírez et al., 2016). Both are not aligned with dietary recommendations from the Government of Mexico (SEGOB, 2013), indicating they need to be the focus of action in food systems. Dietary data can thus provide an indication of the specific foods, or food groups, that child-centered food systems need to be making more AAAA to children and their caregivers, and which less so.

4.3. Step 3. Assess the reasons why children are, or are not, eating these foods in the context of their lives and food environments

The next question concerns why children are eating, or not eating, these foods and how this relates to the AAAA of these foods in the environments in which they live their lives. There are many aspects of children's lives that influence how they engage and interact with food environments and why, with important implications for what actions will be most impactful.

Household surveys are an important method to collect data on what is happening in children's homes that affects how they live and eat. Although such surveys are limited by their reliance on respondents providing information, they are useful to gather information on an individual's context. For example, in a study conducted in Bangladesh into the risk factors of cardiovascular disease, key socioeconomic variables included access to electricity and ownership of particular items, including a refrigerator (Khanam et al., 2019). This information provided important insight into the contexts in which children and adolescents consume food, in this case, their lack of access to the assets needed to store and prepare nutritious foods. Household surveys, such as the DHS surveys used to collect data on child nutritional status and diets, also provide data on household characteristics known to be associated with children's dietary practices, such as the education and wealth level of parents (Di Cesare et al., 2015; Khanal et al., 2013; Ramírez-Luzuriaga et al., 2019; Boah et al., 2019). Many surveys focus on household food insecurity and include measures like access to food, household expenditures, intra-household gender relationships, coping mechanisms, and family eating practices.

Understanding the context of children's lives also requires qualitative methods, which include: in-depth, semi-structured interviews; focus group discussions; visual methods (e.g. PhotoVoice or photo elicitation); 'go-along' interviews and transect walks; participatory and community observations and mapping of the food environment; cognitive mapping (e.g. pile-sorting or listing); group model building and co-designing or co-creating policy and interventions with participants. Qualitative methods aim to delve into an individual's context and elicit a range of perspectives and accounts of the world, thereby providing insights into *why* children adopt certain dietary practices. The open-ended nature of these methods allows the role of AAAA to be explored *together* as a set of

interweaving factors influencing how children engage with their food environments. They also allow identification of the points of interaction between children and their food system - where they are provided with food, for example, or where they shop (see Step 4). Thus, the insights gained from such methods can highlight how the food environment influences children in their individual contexts.

While the research literature in this area is limited, especially in LMICs, a range of studies show the insights into the role of AAAA that qualitative methods can provide. These studies have typically been undertaken in communities affected by poverty, and mainly involve caregivers of children, although some studies focus explicitly on adolescents. Caregivers often report on 'availability' and 'affordability' (Box 1) as interrelated factors when asked about how they feed their children. For example, in a study in rural Kenya, mothers of young children said that their children ate cheaper, less nourishing foods (such as maize gruel), and ate less frequently, when they had less money to buy food, notably during the dry season when food availability and income were lower (Pelto and Armar-Klemesu, 2015). 'Milk tea' for infants would be made with very little milk and fresh fruits and vegetables cut from children's diets. In a study in Niger, pregnant women indicated that they had limited diets due to the limited range of foods available in the village market in comparison to those available in urban settings, and reported that they could not afford the diet they perceived as ideal for their unborn children (Rosen et al., 2018).

Availability and affordability are also particularly relevant to adolescents with agency to buy snacks for themselves on the way to and from school. For instance, adolescent girls in Indonesia explained during in-depth interviews how the wide availability of affordable and 'tasty' snacks made them appealing (Blum et al., 2019). Focus group discussions and interviews with 8–11-year-olds in Kenya indicated excess consumption of fast foods and sweetened beverages was due to the availability of cheap snacks in the environment surrounding the school (Kigaru et al., 2015).

Qualitative methods have also highlighted the role of 'appeal' (Box 1), particularly in studies involving mothers. The "listening posts" established by Scott-Villiers et al. (2016) in ten countries helped explain why 'junk' food became so much more appealing after the food price crisis - because women took on multiple jobs, making them short on time, thus making the convenient, packaged foods high in fats, sugars and salt more appealing. Likewise, semi-structured interviews with Australian mothers revealed the interaction between gender inequity and food provisioning, with women speaking about the stress of food preparation when short on time driving them towards the appeal of convenience and takeaway foods (Mehta et al., 2019) A PhotoVoice study in the United States also showed mothers bought these foods in order to limit conflict with their children (Colón-Ramos et al., 2017).

'Aspiration' (Box 1) emerges as critical from these studies. In Niger, for example, pregnant women said they aspired to a modern urban diet, idealizing spaghetti as a nutritious food, associating it with the better diet and health outcomes of urban women (Rosen et al., 2018). Recent immigrants from Latin America into the United States reported that their children aspired to eating the foods from the new country rather than 'traditional' foods (Colón-Ramos et al., 2017). The post-2008 food crisis study also found that industrially-manufactured foods were seen as a "sign of status and wealth" in many places and children aspired to eat the foods they had seen advertised (Scott-Villiers et al., 2016, p36.) Similarly, adolescents from poorer economic backgrounds in Guatemala discussed in participatory workshops their aspiration to purchase soft drinks revealing it was because they were a sign that a family has middle- or upper-class status (World Food Programme, 2018).

These insights provide a picture of the context and dynamics in which nutrition decisions are made for and by children. Qualitative methods, along with household surveys, provide essential insights into what actions are needed to address the factors underpinning why children eat what they do, as well asidentifying the aspects of the food environment that need to be tackled. For example, the post-2008 food crisis study showed the importance of womens' time in influencing what they were feeding their children, suggesting that providing school meals to allow a reallocation of domestic work would be helpful. The findings also indicated that reducing unhealthy advertising to children would reduce the 'aspirational' pressure on women to provide children with 'junk food' (Scott-Villiers et al., 2016).

4.4. Step 4: Measure the food environments surrounding children and adolescents and those who acquire food for them

The next step is to measure the aspects of food environments identified in the previous step as being particularly relevant for children such as the (low) availability and (high) cost of nutritious foods, the widespread availability and advertising of cheap snacks, and the degree of convenient access to unhealthy versus unhealthy ready-to-eat foods. Food environments are vast and varied, presenting a challenge for measurement. Measurable aspects include the availability of food in specific communities and what it costs, the prevalence of specific types of food outlet and food prices in those outlets, and the advertising and promotional landscape within outlets and more broadly (Turner et al., 2017). Carducci et al. (2018), for example, identified 60 studies in LMICs with substantial heterogeneity in outcomes and metrics assessed. Studies also varied with regard to the specific food environment measured (e.g. homes, streets, schools, community retail, stores) and had substantial heterogeneity in methodology. Turner et al. (2017) grouped available methods into four: geographical information systems (GIS) based (e.g. distance between peoples' homes and stores); market based (e.g. audits and food baskets); global positioning systems (GPS) based (e.g. to track people's movements); and consumer based (e.g. qualitative discussions).

A large number of studies in high-income country settings have focused on the *availability* of food at the community-retail level, using GIS, inventory/audit measures, and on-site observations or mapping (Briefel et al., 2009). GIS is the most common technique to capture the relationship between peoples' homes, schools etc and the presence, counts, density and distance to the nearest food outlet (Engler Stringer et al., 2014). Studies then calculate the ratio of 'unhealthy' to 'healthy' stores close to people's homes and/or the degree of clustering of outlets e.g. clustering of fast-food restaurants around schools (Austin et al., 2005). Measurements may also be based on *perceptions* of these measures (Engler Stringer et al., 2014; Williams et al., 2014). An increasing number of studies also audit the foods available in stores. For example, Cameron (2018) and Horacek et al. (2018) audited stores in Australia and the US to estimate how "healthy" there were.

To enable the linkages to be made between people, food environments and supply systems, it is critical that measures of food outlets also identify where children (if they have the agency to do so) and their caregivers actually acquire food and otherwise interact with their food system (also see Step 3). Yet most studies to date are limited because they do not start from the perspective of where children or their caregivers actually spend time, i.e. the food environment actually navigated (Williams et al., 2014; Wilkins et al., 2019). Home-store distance measures have found, for example, that people do not necessarily shop in their closest store (Drewnowski et al., 2012). "People-centric" methodologies, such as the go-alongs referred to in Step 3, thus attempt to measure environments in the spaces people actually navigate. For example, Burgoine and Monsivais (2013) characterized food environment exposure at home, at work, and commuting journeys in the UK, showing that what was included in the exposure measure significantly changed the nature of exposure. A comparison between area-based and person-centered metrics by Maguire et al. (2017) found the two approaches yield differing results.

There are a range of methods used to measure food prices (Lewis and Lee, 2016). Price data can be collected in local stores as individual items (e.g. Nykänen et al., 2018) or may involve measuring the prices in a basket of goods available in stores used by local households. For

example, Kirk et al. (2019) conducted market basket surveys to identify and compare the prices of fruits and in seven cities around the world. Studies have also used this data to assess 'affordability' by households by comparing with household incomes (Lee et al., 2016), as well as comparing different items. For example, Dizon and Herforth (2018) examined the cost of food in four South Asian countries – Sri Lanka, Pakistan, Afghanistan, and India – using government collected market data. The prices of the nutrient-dense foods were higher and more variable, with seasonal fluctuations. This higher price and inflation was mainly due to vegetables and in some country cases, dairy. The most energy-dense, low-micronutrient foods, such as cereals and oils, had more stable prices, and less regional variation (except Afghanistan). In Sri Lanka, the cost of a nutritious diet was 38% higher as compared to a basic diet that meets baseline caloric needs.

Another critical food environment measure is food marketing. Most studies to date have focused on TV advertising. For example, a global overview of children's television advertising in 22 countries showed there were four times the amount of 'unhealthy' food advertisements than 'healthy' advertisements during peak viewing times for children (Kelly et al., 2019). Given the growth of advertisements beyond television, more studies are now focusing on capturing advertising elsewhere. For example, an inventory of advertising in and around Mexican schools of posters, banners, stickers, billboards, showed the number of advertisements was higher around public schools than around private schools for sugar-sweetened beverages, candy and sweet breads (Barquera et al., 2018). A study by UNICEF in Latin America measured point-of-sale marketing strategies used by retailers and the food industry through field work, store audits and interviews with management personnel, finding that most of it was for 'unhealthy' foods (UNICEF Regional Office for Latin America, 2019).

Such research also exemplifies how these studies can be used to identify interventions needed to guide children towards healthier diets while also reorienting food systems. In a study measuring the extent and nature of front-of-pack marketing in Chilean supermarkets, Mediano Stoltze et al. (2019) identified that characters popular with children were used commonly on high-sugar products. Chile now has a law stipulating that marketing using characters and child-like figures, animations and cartoons that pique the interest of children under 14 years of age (including on food packages) can no longer be used on such foods (Corvalan et al., 2013), leading to dramatic declines in their usage. Food companies also reformulated their products after the implementation of the law (Reyes et al., 2020).

Most of these studies focus on just one aspect of the food environment. In an attempt to bring the different aspects together, the International Network for Food and Obesity/non-communicable diseases (NCDs) Research, Monitoring and Action Support (INFORMAS) has innovated multiple modules to assess food composition, labelling and promotion on food packages; food prices, shelf space and placement of foods in vender outlets; food provision in schools; density of and proximity to food vendors in communities; and food promotion to children on television, magazines, sport club sponsorships, and internet and social media (Vandevijvere et al., 2014).

Overall, children tend to be neglected in these studies (Ravensbergen et al., 2016). Recent exceptions include research in New Zealand using GPS and wearable cameras to measure children's space-time exposures to unhealthy food advertising in public outdoor spaces and Google street view to identify the types of advertising across the built environment (Liu et al., 2019; Egli et al., 2019); and in Beirut and Tunis, testing out wearable cameras as a measure of exposure to obesogenic environments (Semaan et al., 2020). An earlier study in Canada used activity-travel log approach to identify children's "activity spaces" beginning and ultimately ending at home in relation to fast food outlet exposure (Ravensbergen et al., 2016). It is also notable that food environment studies have been used far less overall in situations to identify actions to address child undernutrition, with the exceptions largely relating to price (Dizon and Herforth, 2018). In the future, food environment studies are needed in all settings that take a more child-centered approach, including measures of where they and their caregivers acquire food and receive information about it.

4.5. Step 5. Identify how interventions in food supply chains could create healthier food environments for children

The next step is to identify how food supply systems influence food environments and where interventions in these systems can make the most difference (HLPE, 2017). This involves methods designed to explore what lies behind the visible food environment to the more hidden series of processes involved in the production, processing, storage, distribution, retail and marketing of foods that people subsequently have access to within their food environments (Hawkes, 2009). Food supply chain analysis has been conducted by the private sector and economists for several decades, but has only recently been adopted by the nutrition community to examine the dynamics of the food supply through a nutrition lens (Morgan et al., 2019). There are several overarching, inter-related methodological approaches to conducting analyses of the food supply system, including: value/supply chain analysis, political economy analysis, consumption-oriented food supply chain analysis (Table 2). Collectively these approaches use a combination of different qualitative and quantitative methods, including semi-structured interviews with key stakeholders, document analysis; and market, food purchasing and household surveys, among others (Table 2). The most recent contribution, the SCAN (supply chain analysis for nutrition) approach developed by GAIN (2020), provides a unique example of combining several different methods and tools with the end view of identifying supply chain bottlenecks and potential points for intervening to improve nutrition.

The utility of value chain analysis to identify interventions is illustrated by Morgan (2014), who employed a case study approach to examine amaranthus, papaya and tomato value chains in Fiji. Focus groups with urban consumers found that price and quality were valued by consumers, and workshops, semi-structured interviews and observations of value chain actors that main bottlenecks to improving price and quality were access to inputs by farmers, as well as limited transportation and market infrastructure. Recommended supply chain interventions included strengthening relationships between actors combined with downstream interventions to promote the qualities that consumers value. Brouwer and Tedesco (2019) found through a commodity chain analysis that inadequate availability of biofortified, vitamin A-rich sweet potato varieties in Mozambique's main market emerged from the lack of distinction with the white-fleshed sweet potato supply chains and absence of financial stimuli, leading to the conclusion that the most critical intervention was having biofortified varieties that can compete successfully with the conventional ones at the farm-level. Padulosi et al. (2014) conducted a comprehensive value chain analysis that examined neglected and underutilized species of Andean grains in Bolivia and Peru. Through documenting the diversity of crops produced, evaluation trials of different cultivars and stakeholder meetings to identify opportunities for value addition, they identified the development of new processing technologies for home consumption and market purposes, documentation and publication of traditional recipes, production of novel food items, and strengthening of linkages between farmers and private sector, as key potential interventions.

Such methods have been criticized for focusing on single foods (Gelli et al., 2015; Morgan et al., 2019.) Although the schema presented in this paper validates the approach of focusing on specific food groups (i.e. identified in Step 2 and then further refined in Steps 3–4), more than one food group is inevitably necessary to improve the total diet. Gelli et al. (2015) developed a methodological framework to simultaneously examine value chains of several key foods. The mixed-method, multisectoral diagnostic includes diagnosing and contextualizing dietary problems in the target population using household surveys, prioritising nutritious foods based on their potential contribution to the diet and

Table 2
An overview of the different methodological approaches for analyzing food supply systems.

Overarching methodological framework	Goal of approach	Methods	Examples
Value chain analysis	● To identify entry and exit points throughout the food supply chain to create value addition. ● Value chain analysis can include nutrition-oriented value chain analysis, strategic management value chain, and global value chain approaches.	● On-farm surveys and assessments ● Semi-structured interviews ● Document analysis ● Market surveys ● Consumer surveys ● Household surveys	Anim-Somuah et al. (2013); Brouwer and Tedesco (2019); Downs and Fanzo (2016); Gelli et al. (2015), 2020; Morgan et al. (2019); Temu et al. (2014); Robinson et al. (2014)
SCAN	● To understand how the steps in the supply chain contribute to food accessibility, desirability and quality ● To identify weaknesses or bottlenecks in supply chains and suggest potential points for interventions to improve nutrition	● Intake surveys and consultations ● Interviews ● Stakeholder analysis/ mapping ● Price mark-up maps ● SWOT analysis of supply chain actors ● Supply chain heat mapping ● Challenge and opportunity matrices ● Traffic light models	GAIN, 2020
Consumption-oriented food supply chain analysis	● To understand the incentives and disincentives influencing chain participants' behavior and how the incentives and disincentives could be leveraged to better align the supply chain with healthy diets.	● Semi-structured interviews ● Document analysis ● Market surveys ● Consumer surveys ● Household surveys	Hawkes (2009), Hawkes et al. (2013)
Political Economy Analysis (PEA)	● To examine the roles of power, incentives, institutions, and ideas that shape nutrition policy processes in reality.	● In-depth PEA ●Interviews ● Stakeholder analysis ● Rapid assessment PEA ● Questionnaire	Reich & Balarajan, 2012; Reich & Balarajan 2014

subsequently assessing constraints and intervention opportunities along those value chains, using market surveys and in-depth interviews with household members (International Food Policy Research Institute, 2018). The methodological approach has been applied to Malawi, identifying factors like on-farm constraints for expanded production and limited capacity of markets to supply safe and nutritious foods as bottlenecks in the supply chains of nutritious foods (Gelli et al., 2020).

While these examples indicate where action in the food supply system could make a difference to food environments, there are very few studies of longer supply chains of 'eat less' foods despite the lengthening of supply chains that, in many cases, cross multiple countries. These longer supply chains are more difficult to analyze in comparison to the short supply chains of specific commodities. In this context, consumption-oriented food supply chain analysis has been used to examine fat (Downs et al., 2014, 2015a, 2015b), sugary drinks (Hawkes, 2009) and sugar (Hawkes and Watson, 2017) supply chains. For example, Downs et al. (2014, 2015a, 2015b) interviewed 18 key stakeholders across the fat supply chain in India to identify bottlenecks that influence the availability, affordability and appeal of healthier oils. Existing secondary data sources related to oil availability, imports and exports, as well as information related to market share, were used to triangulate the interview findings. Overall, key bottlenecks identified were: the low production of healthier oils in the country; the low availability and use of healthier oils for product reformulation; wastage due to inefficiencies in the supply chain; use of unhealthy fats by street vendors; lack of consumer awareness regarding trans and saturated fat and the promotion of foods containing unhealthy fats (Downs and Fanzo, 2016).

4.6. Step 6. Generate the priority package of actions and assess implementation opportunities and challenges

The final step is to pull together the priority mix of actions that, if implemented, would be most effective in coherently shifting food systems towards making the identified food groups more (or less) AAAA. This involves bringing together the information collected in Steps 1-5 and analysing it to identify the targets, places and forms of actions that would have coherent impact in different parts of the system. By way of illustration, Box 2 and Table 3 draw on a range of published studies from Ghana to show how using all six steps enables the identification of actions in a coherent, connected way. The example indicates the insights that can be obtained from each different step to inform what is most likely to have impact in the context of children's lives. For example, the qualitative component in Step 3 indicated that education and campaigns to raise awareness of the importance of nutritious foods would not be impactful in this rural context because, for the most part, mothers already find these foods appealing and aspirational. However, empowering them with increased income combined with supply chain development to make nutritious foods they value more affordable would, in theory, be a more effective way to coherently shift the system. In urban areas, in contrast, conducting campaigns to increase aspiration of water and reduce the appeal of sugary drinks could be impactful if appropriately designed.

The example also shows the limitation of excluding one or more steps. For instance, if kindergarten pupils had not been surveyed about where they acquired sugary drinks, and food environment measures not taken about where sugary drinks are sold, restricting sale through vending machines and informal vendors would have likely emerged as the only priorities, with the critical need to target parents through supermarket interventions likely missed.

Once this package has been defined, a series of related processes are required to identify opportunities and challenges for implementation. Although detailing these processes in detail is beyond the scope of this paper, they are an important part of operationalising the principles of child-centered food systems (Section 3). They include identifying the policies and interventions that already exist in the specific context to

Box 2
Worked example: identifying the right mix of actions to guide food systems towards less child stunting and obesity in Ghana

Step 1. Country-level DHS surveys show that 18.4% of Ghanian children under the age of 5 are stunted (Boah et al., 2019). The study did not report on overweight/obesity, but 34% of mothers were overweight, and in another, location-specific study in metropolitan Ghana, 46.9% of children aged 5–16 were affected by overweight or obesity (Ganle et al., 2019).
Step 2. Ganle et al. (2019) conducted a questionnaire on food and drink consumption, identifying that children who drank sugar-sweetened drinks on most days were 2.84 times more likely to be affected by obesity compared to children who hardly or never consumed them. The second stage of the DHS survey reported by Boah et al. (2019) showed that stunting was associated with low levels of dietary diversity but did not identify the degree of inadequacy of specific food groups. GAIN (2017) used 24-hr recalls to measure food intake in two areas of rural Ghana, revealing that a high proportion of children aged 6–23 months ate fish, eggs, vegetables, groundnuts and legumes daily, but far fewer ate dairy products or fruits daily; most significantly, portion sizes were extremely small, helping to explain the high levels of stunting (GAIN, 2017). Over 50% of infants also ate sugar daily (1.5–4 tsp per day). A previous study estimated 27% of infants (6–23 m) consume sugary snacks in rural Ghana (Huffman et al., 2014), but these were not reported by GAIN (2017).
Step 3. The GAIN (2017) study conducted interviews with mothers, finding that nutritious foods were understood to be important for health and nutrition and thus aspirational (Armar-Klemesu et al., 2018). They appealed to mothers because they aligned with their desire to have peace of mind for their children and their role in feeding them. However, buying nutritious foods in greater quantities was viewed as unaffordable. During the dry season nutritious foods were less available from own production and too expensive in markets. Adding milk, beans and groundnuts to infant porridges was desired by mothers but done sparingly because these products were too costly, meaning most infants were fed porridges made only with flour, water, and sugar. With regard to sugary drinks in metropolitan areas, studies have found associations between sugary drink consumption among children and adolescents and higher wealth and paternal education (Ganle et al., 2019; Lopes et al., 2018; Abizari and Ali, 2019). A study of older children found that some children associated these drinks with healthiness and others with ill health (Frederick and Obed, 2017). Focus groups about water-drinking among urban youth (15–34) found public sources unappealing due to perceived lack of cleanliness and it not being cold (Doegah and Amoateng, 2018). This led to increased aspiration for branded bottled water which signified "economic standing" but at the same time limited drinking water due to cost. In contrast, the widespread availability of sugary drinks made them an appealing alternative to water.
Step 4. Kroll et al. (2019) found in urban Ghana that supermarkets were the largest source of sugary drinks (around 55%) with informal vendors also being a major source (around 38%) (Kroll et al., 2019). Bragg et al. (2017) found that billboard advertising in Accra for sugary drinks was adult directed. Lopes et al. (2018) found that sugary drinks were available from school-authorized vendors through kindergartens in Accra, but that the 43.1% of children who drank them brought them in from home, suggesting supermarkets were the largest supply source. GAIN (2017) found that caregivers purchase food from various sources including district markets, vendors within their communities, but did not measure availability or prices. Nykänen et al. (2018) measured food prices in 11 urban markets and supermarkets (266 items) and in 8 rural markets (141 items) and gathered information on the availability of wild foods (e.g. moringa leaves). They estimated the affordability of low-income households of a nutritionally adequate (and culturally-acceptable) food basket, optimised to consider malnutrition in all its forms (e.g. no sugar). They concluded that nutritionally adequate food baskets could be afforded in urban settings if households increased groundnuts, vegetables and cereals at the expense of fruit and tubers. Nutritionally adequate diets were less affordable in rural areas and could only be afforded in sufficient quantities if wild foods were included.
Step 5. None of the above studies explored food supply systems. Analysis of groundnut value chains in Ghana indicate considerable potential for enhancing availability and reducing price through improving transportation, transparency and safety and leveraging power relations and the role of women distributors and vendors (Angelucci and Bazzucchi, 2013; Anim-Somuah et al., 2013; Owusu-Adjei et al., 2017). Sugar is more affordable than groundnut paste (despite groundnuts being locally produced) as part of the highly organised but complex global sugar system. Sugary drinks are produced in Ghana as a result of international investments by leading companies.

Collectively, these disparate studies indicate the potential for a package of policies and interventions (Table 3). The final part of the process is to assess implementation opportunities and challenges in a systems context. This is beyond the scope of this worked example, but there are indications of challenges. For example, Ghana has very low implementation of food environment policies (Laar et al., 2020) and a recent study showed there is low community readiness to accept them (Pradeilles et al., 2019). A study by Hartley and Arndt (2018) indicates that the groundnut value chain has high potential to improve diets, but would generate relatively little economic growth compared to other foods..

build on (or deprioritise) (e.g. WCRF International, 2020), identifying who needs to be involved (e.g. GAIN, 2020), assessing coherence with other food system goals important to decision-makers in that context to identify potential economic and political conflicts, as well as potential for co-benefits (e.g. Parsons and Hawkes, 2019); engagement with children themselves to provide opportunities for ownership and buy-in (e.g. Norwegian Institute for Public Health, 2020); and developing methods to monitor and evaluate the package of actions (e.g. Rawat et al., 2013).

5. Conclusion

Child-centered food systems that make healthy diets AAAA for children is a vision for the future. The steps outlined here provide a process of assessment and analysis to identify how to shift towards such systems. It combines methods old and new to set out a rigorous process to identify the package of priority actions needed in the context of children's lives and the food system more broadly.

The proposed series of methods have all been tried and tested individually, but have to date, rarely been connected to each other. As done by Gelli et al. (2020), these methods now need to be combined in new ways to connect the dots between eaters and their food systems, and, in so doing illuminate how to reorient the food system towards healthy diets for children and adolescents. This requires collecting data on overlapping nutritional burdens at the community and district level, dietary assessment to identify both the 'eat more' and 'eat less' foods, qualitative methods to understand context, people-centered food environment measures that include where children and their caregivers acquire food, and analysis of local and/or global food supply systems. The tool created from this unique combination of methods now needs to be tested in the field to assess if it is feasible and fit for purpose in practice in identifying the most effective actions to reorient food systems towards healthy diets for children.

Table 3
Hypothetical actions to shift food systems towards healthier diets for children in Ghana.*

Elements of action package	Actions for child stunting	Actions for child obesity
Step 1: Malnutrition target	Child stunting among low income infants and young children	Obesity among higher income and educated children and adolescents
Step 2: Food group targets	Groundnuts, milk, fruit	Sugary drinks
Step 3: Actions targeting children and/or caregivers	Social safety nets, better wages or value allocation to self-employed women to increase income	Campaigns to increase aspiration for water and reduce the 'economic status' appeal of sugary drinks
Step 4: Actions in food environments	Considering the potential for wild foods	Reducing sugary drink advertising targeting caregivers; supermarket-based interventions to make surgery drinks less appealing; taxation to make more expensive than water
Step 5: Actions in food supply systems	Supply chain development of groundnuts and milk to enhance affordability	Imposing conditionalities on private-sector investment in sugary drinks
Step 6: Bring together the package and assess implementation opportunities & challenges	Development of groundnut chain not the most aligned with economic/poverty reduction goals	Low current readiness to implement policies suggests low political commitment.

*Based on information in Box 2.

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