Gaps and priorities in assessment of food environments for children and adolescents in low- and middle-income countries

Bianca Carducci^{1,2}, Christina Oh¹, Daniel E. Roth^{1,2,3,4,5}, Lynnette M. Neufeld⁶, Edward A. Frongillo⁷, Mary R. L'Abbe^{2,5}, Jessica Fanzo^{8,9,10}, Anna Herforth¹¹, Daniel W. Sellen^{1,2,5,12} and Zulfiqar A. Bhutta^{1,2,3,4,5,10,13} ✉

School-aged children and adolescents have complex interactions with their food environments—the point of engagement of individuals with the food system—and are influenced by a diversity of individual, household and organizational factors. Although a wide range of methods have been proposed to define, monitor and evaluate food environments, few are tailored to school-aged children and adolescents. Here, we interrogate published literature on food metrics and methodologies for the characterization of food environments for school-aged children and adolescents living in low- and middle-income countries. We identify key priority actions and potential indicators for better monitoring and evaluation to galvanize policymaking to improve the healthiness of these interactions, which are so crucial to future adult well-being.

Prior to the COVID-19 pandemic, globally one in three children under five years experienced poor growth and development due to multiple forms of malnutrition, including stunting (144 million), wasting (47 million) and overweight (38.3 million), and at least 340 million children suffered from 'hidden hunger' and micronutrient deficiencies^{1–4}. Over the past two decades, overweight and obesity have become more prevalent in children and adolescents, increasing the risk of non-communicable diseases (NCDs) in adulthood^{1,3}. The persistence of food insecurity and malnutrition worldwide is in part attributed to dramatic changes over the past 50 years within global food systems, and subsequently, food environments—the spaces within which individuals interact to procure and consume food^{5–7}. The aim of this Perspective is to identify priority actions and potential indicators for researchers and policymakers to monitor and evaluate food environments specific to school-aged children and adolescents in low- and middle-income countries (LMICs; Box 1).

Food environments and children and adolescents

Several frameworks and models have been proposed to conceptualize this interaction and to capture its complexity and diversity, but they are rarely tailored to include or consider children and adolescents^{8–14}. In 2019, the United Nations Children's Emergency Fund (UNICEF) and the Global Alliance for Improved Nutrition adapted the High Level Panel of Experts on Food Security and Nutrition food system framework⁹ and food environment framework¹¹, and introduced the Innocenti Framework on Food Systems for Children and Adolescents (Fig. 1)^{15,16}.

The Innocenti Framework conceptualizes and proposes the need to shape food systems as they relate specifically to children, adolescents and their caregivers. The framework depicts the dependency of agents, drivers and interactions within the food system that strongly influence and dictate how food moves from production to consumption, and how people interact with their surroundings to procure, prepare and consume food (external and personal food environments)^{14–16}. These external (for example, community, retail and schools) and personal (for example, individual, family and household) food environments are the two main points of interaction with the food system for children and adolescents^{9,11}. This framework also considers agency and one's capacity to make food choices, which may depend on age, autonomy and opportunities, and broader social influencers, such as power dynamics, gender norms, wealth gaps and governance structures^{17–19}.

An important caveat of this framework, however, is that food environments and their interactions are not static and uniform. Food environments, and more broadly the food systems and supply chains with which they are associated, are diverse and vary substantially in their typology (wild, cultivated, informal and formal)^{9,20,21}, often with multiple typologies coexisting within the same country or region (for example, in the island countries of the Caribbean²²) or differing environments (for example, urban, peri-urban or rural), which may substantially affect local actions to improve food environments³. This variability is more evident in LMICs where a large proportion of food is produced and sold through the informal sector⁹. Moreover, a lack of standardized metrics for food environments leads to unique challenges for assessment. For these

¹Centre for Global Child Health, Peter Gilgan Centre for Research, Learning Hospital for Sick Children, Toronto, Ontario, Canada. ²Department of Nutritional Sciences, Temerty Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada. ³Department of Pediatrics, University of Toronto, Toronto, Ontario, Canada. ⁴Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada. ⁵Joannah and Brian Lawson Centre for Child Nutrition, University of Toronto, Toronto, Ontario, Canada. ⁶Global Alliance for Improved Nutrition, Genève, Switzerland. ⁷Department of Health Promotion, Education, and Behavior, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA. ⁸Berman Institute of Bioethics, Johns Hopkins University, Baltimore, MD, USA. ⁹Johns Hopkins Nitze School of Advanced International Studies, Johns Hopkins University, Washington DC, USA. ¹⁰Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA. ¹¹Department of Global Health and Population, Harvard TH Chan School of Public Health, Boston, MA, USA. ¹²Department of Anthropology, University of Toronto, Toronto, Ontario, Canada. ¹³Institute for Global Health and Development, Aga Khan University, Karachi, Pakistan. ✉e-mail: zulfiqar.bhutta@sickkids.ca

Box 1 | Priority actions and research foci in food environments in the context of school-aged children and adolescents in LMICs**Priority actions**

1. Prioritize research that aims to improve our understanding of the effects of food environments on the eating behaviours, diets, nutritional status and health outcomes of children and adolescents in LMICs.
2. Develop and test specific measures and indicators to monitor and evaluate food environments of children and adolescents in LMICs.
3. Encourage a food systems agenda and strengthen collaboration and accountability among all stakeholders within the food environment and the food system, including governments, private- and public-sector organizations, and consumers.

Research foci

- Greater representation of LMICs, including peri-urban and rural settings, and migrant, internally displaced, refugee, and urban slum child and adolescent populations.
- Greater focus on children and adolescents together, and separately, to compare differences across varying age sub-groups.

- Inclusion of micronutrient intake and status in assessing health outcomes given the characteristics of current global malnutrition.
- Consider other entry and interaction points with the food system (for example, social and sports clubs, religious institutions, workplaces, social media) to evaluate interventions and implementation programmes and policies pertaining to children and adolescents. For example, consider other settings apart from schools to capture those who do not or cannot attend school.
- More dietary data for children and adolescents (both boys and girls) and greater cohesion in how we measure dietary intake to better understand how food environments affect the diets of children and adolescents.
- Collection of ethnographic and other qualitative data that complement quantitative data, which can illuminate additional information about personal factors that affect behaviour and interactions with the food environment.
- Development of existing and new measures and indicators of external and personal food environments, and establishment of their validity and cross-context equivalence.

reasons, the need to develop specific measures and indicators to assess food environments in the context of school-aged children and adolescents is critical for policy and programmatic responses to improve them^{11,23,24}.

Evidence from LMICs on food environments for children and adolescents

So far, the majority of food environment research in school-aged children and adolescents has been conducted in high-income countries^{11,23–26}, while most studies from LMICs have been conducted in upper-middle-income countries such as Brazil^{27–30}, Chile^{31,32}, China³³, Guatemala^{34,35}, Indonesia³⁶, Mexico^{37,38} and South Africa^{39,40}. Very few studies are from lower-middle^{41–46} and low-income countries^{3,23,24}. The limited evidence on children and adolescents may be owing to a lack of financial and human resources. Most studies applied an observational design^{11,23,25,47,48}, with a limited number of intervention studies disaggregating data to isolate the effects of food environments on specific age groups^{47,49}. Most research targeting children and adolescents in LMICs is conducted within the school environment^{23,50,51} however, these studies do not account for the time spent outside school, and may miss a substantial proportion of those who do not or cannot attend school⁵². Furthermore, current research does not account for diverse community settings that may be important in LMICs, such as refugee settlements and urban slums. These unique settings may present different challenges in terms of food procurement and consumption, especially for migrant and internally displaced child and adolescent populations⁴. With regards to outcome indicators, most research has focused on anthropometric outcomes such as body mass index and weight status in response to the rising burden of obesity and overweight, and diet-related NCDs in this population^{3,11,23,50,53}. Research efforts should consider micronutrient deficiencies, as these may coexist with other forms of malnutrition in the same household and community, and even within the same individual across their life cycle^{23,54}.

Research limitations and recommendations. Based on this evidence, current designs, tools and indicators do not provide a complete picture of the food environment. Alternative study designs should be pursued to assess food environments that generate actionable results and support plausible causal inference by capturing repeated measures such as natural experiments, interrupted

time series and longitudinal studies^{11,23,25,47,48,55}. Qualitative methods, including ethnographic studies (for example, photovoice and intergenerational interviewing), which remain underutilized in this field, may provide additional insights into children's, adolescents' and their caregivers' lived experiences of and perspectives about the food environment. This includes their views of food safety in their neighbourhood shops or the top priorities they consider when purchasing and consuming food, and the factors that underlie those priorities^{11,47,56}. Mixed, integrated qualitative and quantitative methods and the triangulation of multiple data sources may provide a more comprehensive picture of children's and adolescents' perspectives and interactions with the food environment^{11,23,47,56}.

In high-income settings, geographic information systems (GIS), global positioning systems (GPS) and shop audits are widely used to assess spatial indicators of food environments^{57–60}. Food procurement by individuals, especially those in LMICs, however, may not be limited to geographic boundaries designated by GIS and GPS coordinates⁴⁷. For example, shifts in daily activities (for example, commutes to and from school) contribute to the spatial and temporal uncertainty in identifying the relevant geographic area that exerts behavioural influence and exposure to various food environments. This has been raised as a major challenge in developing food environment metrics⁶¹. In some LMIC contexts, the informal nature of markets and mobile street stalls further complicates the accurate characterization of the food environment^{24,62}. In addition, food choice behaviours of school-aged children and adolescents are influenced by objective features of the food environment, their perspectives about the food environment and purchasing decisions made by their caregivers. Proxy measures at the interface between personal and external food environment are contingent on consumer behaviour and relate to household affordability, including purchasing patterns (for example, frequency of fast-food/take-out purchases per month), purchasing power (for example, amount of pocket money given to children and adolescents to purchase food at school), spending patterns (for example, household income and budget share spent on fruits and vegetables) and perceived affordability.

There is also a widely recognized need for improved measurement and collection of dietary intake and diet quality data for children and adolescents in LMICs^{3,4}. Available evidence linking diets to the food environment is inconsistent because few intervention

Fig. 1 | The Innocenti Framework on Food Systems for Children and Adolescents. The Innocenti Framework illustrates the influence of food system drivers (structural factors including demographic change, political and economic environment, technological advances, natural resource management and social and cultural norms), determinants (processes and conditions including food supply chains and food environments), influencers (individual factors including behaviours) and interactions (dynamic feedback loops) on the diets of children and adolescents. Figure reproduced with permission from ref. ¹⁶.

studies measure dietary intake and quality, reported food choices and behaviours, and nutritional knowledge^{23,49,53}. Especially in this age group, food choice and behaviour, and subsequently dietary intake, are influenced not only by objective features and personal perspectives of the food environment, but also by the purchasing decisions made by caregivers. The involvement and influence of caregivers in a child's or adolescent's food choice should be considered in the measurement dietary intake and behaviours. In addition, collection and interpretation of dietary intake data are inherently challenging due to a lack of standardization of methods, compositional data and metrics^{49,63,64}. Furthermore, given that personal food environments are spaces that are rooted in and promote culture, norms and beliefs in food preparation and feeding practices, dietary intake data should sufficiently capture dietary patterns and the diversity and complexity of cultural, wild and traditional, and home-prepared foods^{49,63,64}. To date, there exists no single, validated composite index or tool to effectively measure diet quality². With a variety of rapid and inexpensive dietary assessment tools available, there is a strong tendency to use food frequency indicators as proxies for diet quality, in terms of dietary diversity and adequate nutrient content^{14,24,49}.

Future research should also consider how this group makes food choice decisions and procures food in a variety of settings, such as the household, community, workplace and market environments. In the home environment, younger children's food choice and behaviour may be strongly influenced by their caregivers, who make the primary decisions regarding food procurement³. As they transition into adolescence, children have greater freedom of choice and exposure to influences in food purchasing and consumption outside the home^{15,16,48}. The role of personal factors (for example, nutrition lit-

eracy, appetite, preference and desirability) and the potential influences of conventional and digital advertisements (for example, social media and Internet marketing)⁶⁵ to which this age group is exposed should be considered. This transition is influenced by greater autonomy, more independent travel, availability of pocket money and greater influence of peers^{15,48}. The precise patterns of independence and agency will probably vary—perhaps substantially by child age, gender, culture and religion, social and economic status, and across geographic, political and built environmental contexts.

Given the current array of measures, indicators and assessment tools, a global food environment research agenda should aim to test and implement standardized methods, measures and indicators that accurately and reliably reflect the effects of the food environment on children and adolescents in LMICs^{11,14,23,24,48,50,56}.

Standardized metrics and indicators

Food environment measures and indicators relevant to school-aged children and adolescents in LMICs should: (1) be specific, measurable, achievable, relevant and timely; (2) be applicable, valid and cross-context equivalent across diverse geographies to enable accurate comparisons across countries; (3) be translatable to drive policy action and implementation; and (4) help reveal gaps in current knowledge or practice relevant to public health priorities⁶⁶. Examples of food environment measures and indicators, available tools, and suggested data collection methods in the context of school-aged children and adolescents in LMICs by domain, construct and survey type are presented in Table 1.

There are several methodological considerations in the development of food environment measures and indicators. First, agreement on standardized parameters for geographic range (proximity

Table 1 | Measures, indicators, tools and data collection methods of personal and external food environments specific to school-aged children and adolescents in LMICs

Domain	Construct	Examples of measures and indicators specific to school-aged children and adolescents	Examples of available tools	Suggested data collection methods
Physical and temporal access	Presence	Presence of different types of food outlet within and near schools	INFORMAS food retail module	Routine surveys
	Time	Time and energy used to forage, acquire and prepare food Perceived time used to forage, acquire and prepare food	Household water insecurity experiences scale Accelerometers and pedometers GIS and GPS	Market surveys Primary research Direct observation and mapping
	Daily mobility	Mode of transportation to school Time to school by varying modes of transportation		
	Proximity	Distance travelled to procure food		
	Density	Number of food outlets near schools per specified geographic area		
Financial access	Food prices and affordability	Cost of food products Perceptions of food cost and affordability	Cost of a healthy diet Cost of the diet software INFORMAS food price module	Routine surveys Market surveys Consumer surveys Primary research
	Assets and purchasing power	Income or wages per household or per individual Ownership of land usable for agriculture Proportion of household expenditure on food Money or allowance spent on school purchases	Living standards measurement survey (World Bank)	Routine surveys Primary research
Food availability	Procurement and preparation	Proportion of food grown at the household, purchased in markets, bartered or received as a gift Presence of proper food storage	INFORMAS food retail module INFORMAS food provision module Healthy eating index	Routine surveys Market surveys Primary research
	Food availability	Free listing/inventory of items available at the household, at a food outlet or at school Presence of school meal/food programme Perceptions of food availability Diversity of fruits and vegetables available at food outlet	Nutritional environment measurement survey Nutritional environment measurement survey—perceived Environmental profile of a community's health tool (adapted)	
Promotion and marketing	Presence, proximity or density	Number of child-targeted advertisements within a broadcast period or observed within a geographic area Frequency of advertisements observed within a specific radius	INFORMAS food promotion module	Market surveys Consumer surveys Primary research Direct observations and mapping
	Type of promotion	Number of advertisements that use popular characters, celebrities or themes and appeals (for example, good taste or 'being cool')		
	Content of advertisements	Number of advertisements promoting different types of food item		
	Airtime	Total duration of child-targeted advertisements aired Number of child-targeted television or radio advertisements		
	Medium	Number of child-targeted advertisements per media type (for example, television, online, radio, social media)		
	Location and size	Number of advertisements near or within school Size of advertisements per specified geographic area		
	Main marketer and sponsorship	Number of advertisements promoting different brands or companies Proportion of sponsored resources/materials in schools Type of sponsored food items in schools or at child-specific events/programmes		
	Shelf space and placement	Types of food positioning strategy to market foods (for example, at check-out, shop entrance, floor display) Ratio of shelf space for healthy versus unhealthy food		
Vendor and product properties	Vendor properties	Opening and closing hours of food outlets Number of days per week of operation for food outlets		Market surveys Primary research

Continued

Table 1 | Measures, indicators, tools and data collection methods of personal and external food environments specific to school-aged children and adolescents in LMICs (continued)

Domain	Construct	Examples of measures and indicators specific to school-aged children and adolescents	Examples of available tools	Suggested data collection methods
Policy	Governmental and institutional	Laws on marketing unhealthy food products to children Laws on point-of-sale tax on unhealthy food items Regulations on marketing of unhealthy foods in schools	INFORMAS food labelling module INFORMAS food provision module INFORMAS food environment policy index	Primary research
	Compliance	Compliance with national regulations of available food items in school Number of food items with regulated nutrition labelling		
Safety	Analysis	Analysis of toxins, bacteria and contaminants of foods available or sold in schools		Primary research
	Compliance	Food safety ratings of food outlets Level of compliance of food safety regulations in schools		
Quality	Quantitative and qualitative analysis of composition	Analysis of food quality in child-care centres, school cafeterias, tuck shops, canteens and food outlets or mobile vendors outside schools	INFORMAS food provision module	Primary research

Examples from the existing literature; primary research refers to both quantitative and qualitative methods. Routine surveys include: the Multiple Indicator Cluster Survey, the Demographic and Health Survey, the Global School-Based Student Health Survey, Health Behaviour in School-Age Children, and Young Lives and Gender and Adolescence Global Evidence. See Supplementary Information for more details and the complete table.

and density measures) is needed. Synthesizing food accessibility, availability and promotion using density measures depends on the definition of consistent reference points and buffer radial ranges (for example, 250, 500 or 750 m radius around a school). Second, while nutrient profiling models exist to dichotomize healthy versus unhealthy foods, especially for marketing to children, this classification system is not established for food retailers⁶⁷. Criteria to distinguish foods, and to discriminate and categorize between healthy and unhealthy food access points (for example, retailers), would be useful. It may be necessary to determine whether such a dichotomy is appropriate or if a gradient in healthfulness is more effective. The classification of healthy versus unhealthy foods and retailers influences the inferences made about accessibility and availability, and may lead to spurious conclusions about causal relations of health outcomes with the food environment. Third, frequency measures that are applicable to food availability (for example, number of items available for sale) and food promotion (for example, television and Internet advertisement viewings) need to be standardized in terms of sampling frames, measurement units (timing) and other contextual information (channel type)^{68,69}. At present, the International Network for Food and Obesity/Non-Communicable Diseases Research, Monitoring and Action Support (INFORMAS) has developed protocols for food retail, provision and promotion, but these are not specific to school-aged children and adolescents^{67–69}.

Routine and market survey data. Routine national and sub-national surveys, such as the Multiple Indicator Cluster Survey, the Demographic and Health Survey, the Global School-Based Student Health Survey and Health Behaviour in School-Age Children, and large longitudinal studies such as Young Lives and Gender and Adolescence Global Evidence, may provide opportunities to assess representative populations and to extract information about personal and external food environments of school-aged children and adolescents^{14,70}. For example, in areas where local infrastructure (for example, electricity, refrigeration and transportation) is inadequately developed, assessment of food acquisition (for example, proportion of food grown or purchased) and food preparation (proportion of food prepared or purchased ready-made) at the household level may explain the relative influence of personal versus external food environments¹³. In many LMICs, this interface

becomes increasingly complex within modernized food environments, whereby the time burden of household food preparation competes with the cost and convenience of shop-bought prepared foods¹³.

Market and consumer surveys and tools⁷¹ developed both by the public (including the United Nations and non-governmental organizations) and private sectors are important to better understand the external food environment. These types of surveys have been widely used by the private sector to create industry benchmarks for sales and marketing, but these data are often proprietary or very expensive to purchase and use. Greater collaboration between the public and private sectors may enable researchers and policymakers to leverage available data sources to generate measures and indicators appropriate to school-aged children and adolescents in order to monitor the external food environment.

Collaboration with the private sector

Renewed efforts are needed to build an equity-sensitive, rights-based food systems agenda that promotes the basic human right to healthy, nutritious, affordable, safe and accessible food, and ultimately diets, with specific considerations to protect and promote the unique needs of children and adolescents^{14,64}. Private sector and industry partners should be incentivized to produce and market healthier, safe and more sustainable food and beverage products, as well as to comply with international and national codes of conduct regarding production, packaging and labelling, and marketing and promotion to children and adolescents^{72,73}. The private sector may help drive investments in technological innovation and advancement in agriculture and food manufacturing. For example, reformulation efforts to reduce levels of sodium and sugars, eliminate trans-fats, strengthen large-scale food fortification and increase availability of specially formulated foods for children and adolescents³.

Investing in evidence-based research and policy actions

Numerous global research institutions and non-governmental organizations have made strides in developing collaborative tools and platforms to monitor food environments globally, such as the Healthy Food Environment Policy Index by INFORMAS⁷⁴, the Measurement, Evaluation, Accountability, and Leadership Support for NCDs⁷⁵, the NCD Risk Factor Collaboration⁷⁶ and, recently, the

Food Systems Dashboard⁷⁷. These concerted efforts by stakeholders are vital in streamlining and tracking progress of health goals, interventions and policy implementation in real time. However, systemic barriers within food systems will continue to hinder progress if left unaddressed. Societal inequities related to race, gender and socioeconomic status permeate food systems, exacerbate dietary inadequacies and result in intergenerational malnutrition¹⁵. Food consumption is affected by power imbalances that are influenced by the priorities and agendas of governments at all levels, the agricultural industry, transnational food and beverage corporations, international development policymakers, and donors⁷⁸.

Governments, funding agencies and donors should seek to increase research spending to address evidence gaps regarding food environments of children and adolescents. Funding should be allocated towards strengthening capacity to identify innovative and cost-effective interventions and solutions to target health and nutrition in this population, with the consideration of local culture and practices³. Governments have the capacity to enact proactive interventions that target food environments and delivery platforms directed at school-aged children and adolescents to minimize inequities, support agency, and promote safe, affordable and healthy food. These may include taxes on unhealthy foods and beverages⁷⁹, subsidy programmes, behavioural change and nutrition education programmes, and food environment interventions³. In addition, stronger governance is necessary to ensure that policies in food, agriculture and trade align with public health and nutrition targets, and do not compromise the cost and affordability of food consumed by children and adolescents. This may be achieved with robust legal and regulatory frameworks that can effectively monitor adherence and compliance among both public and private sector partners^{3,17}.

Way forward

Beyond providing access to healthy, nutritious, affordable and safe food, food systems—including food environments—promote food culture, traditions and practices, and support the incomes and livelihoods of 1 billion people globally⁸⁰. However, the rapidly changing landscape of food systems, including food environments, has also had negative consequences, including rising NCD rates, the climbing costs of food, food waste and unsafe food, that threaten global food security, nutrition and diets. In the current context of increased urbanization, climate change, ongoing humanitarian conflicts and disruptions due to the COVID-19 pandemic, food systems are at a crossroads^{2,17,81}.

Global discourse around transforming food systems and a united agenda to create a resilient food system that prioritizes nutrition and diets particularly for the world's children has intensified^{4,82}. For this reason, we propose three mutually reinforcing priority actions and research efforts required to develop and test standardized food environment measures and indicators that directly inform policies and programming, and allow monitoring of progress of school-aged children and adolescents in LMICs (Box 1). Global public mobilization and actionable commitments from all stakeholders to invest in diverse ways to make food systems inclusive, climate-smart, resilient and supportive of sustainable peace is needed⁸². Furthermore, stronger collaboration among stakeholders will be vital to enable policy action and investments to promote food security and nutrition for future generations. Finally, policies and context-specific strategies must be developed and promoted in a manner that embraces the interdependence between the food system and other societal subsystems (health, environment and climate, social protection, education and water, and sanitation and hygiene), as well as democratizing food systems to restore food-related freedom of choice and sovereignty.

Received: 13 December 2020; Accepted: 6 May 2021;
Published online: 18 June 2021

References

1. *The State of Food Security and Nutrition in the World 2018: Building Climate Resilience for Food Security and Nutrition* (FAO, IFAD, UNICEF, WFP, WHO, 2018).
2. *The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Healthy Diets* (FAO, IFAD, UNICEF, WFP, WHO, 2020).
3. *2020 Global Nutrition Report: Action on Equity to End Malnutrition* (Development Initiatives, 2020).
4. *State of the World's Children 2019: Children, Food and Nutrition: Growing Well in a Changing World* (UNICEF, 2019).
5. Afshin, A. et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **393**, 1958–1972 (2019).
6. Baker, P. & Friel, S. Food systems transformations, ultra-processed food markets and the nutrition transition in Asia. *Glob. Health* **12**, 80 (2016).
7. Popkin, B. M. & Reardon, T. Obesity and the food system transformation in Latin America. *Obes. Rev.* **19**, 1028–1064 (2018).
8. Swinburn, B. et al. INFORMAS (International Network for Food and Obesity/Non-Communicable Diseases Research, Monitoring and Action Support): overview and key principles. *Obes. Rev.* **14**, 1–12 (2013).
9. *Nutrition and Food Systems: A Report by the High Level Panel of Experts on Food Security & Nutrition of the Committee on World Food Security* (HLPE CFS, 2017).
10. Glanz, K., Sallis, J. F., Saelens, B. E. & Frank, L. D. Healthy nutrition environments: concepts and measures. *Am. J. Health Promot.* **19**, 330–333 (2005).
11. Turner, C. et al. Concepts and critical perspectives for food environment research: a global framework with implications for action in low- and middle-income countries. *Glob. Food Secur.* **18**, 93–101 (2018).
12. *Global Nutrition Report 2017: Nourishing the SDGs* (Development Initiatives, 2017).
13. Herforth, A. & Ahmed, S. The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. *Food Secur.* **7**, 505–520 (2015).
14. Hawkes, C., Fox, E., Downs, S. M., Fanzo, J. & Neve, K. Child-centered food systems: reorienting food systems towards healthy diets for children. *Glob. Food Secur.* **27**, 100414 (2020).
15. *Food Systems for Children and Adolescents: Working Together to Secure Nutritious Diets* (UNICEF Innocenti, 2018).
16. Raza, A. et al. Conceptual framework of food systems for children and adolescents. *Glob. Food Secur.* **27**, 100436 (2020).
17. *Food Security and Nutrition: Building a Global Narrative Towards 2030* (HLPE CFS, 2020).
18. Peter, F. Gender and the foundations of social choice: the role of situated agency. *Fem. Econ.* **9**, 13–32 (2003).
19. Engler-Stringer, R., Le, H., Gerrard, A. & Muhajarine, N. The community and consumer food environment and children's diet: a systematic review. *BMC Public Health* **14**, 522 (2014).
20. Downs, S. M., Ahmed, S., Fanzo, J. & Herforth, A. Food environment typology: advancing an expanded definition, framework, and methodological approach for improved characterization of wild, cultivated, and built food environments toward sustainable diets. *Foods* <https://doi.org/10.3390/foods9040532> (2020).
21. Fanzo, J. Healthy and sustainable diets and food systems: the key to achieving Sustainable Development Goal 2? *Food Ethics* **4**, 159–174 (2019).
22. Haynes, E. et al. Food sources and dietary quality in small island developing states: development of methods and policy relevant novel survey data from the Pacific and Caribbean. *Nutrients* <https://doi.org/10.3390/nu12113350> (2020).
23. Carducci, B., Oh, C., Keats, E. C., Roth, D. E. & Bhutta, Z. A. Effect of food environment interventions on anthropometric outcomes in school-aged children and adolescents in low- and middle-income countries: a systematic review and meta-analysis. *Curr. Dev. Nutr.* **4**, nzaa098 (2020).
24. Turner et al. Food environment research in low- and middle-income countries: a systematic scoping review. *Adv. Nutr.* **11**, 387–397 (2020).
25. Pineda, E., Swinburn, B. & Sassi, F. Effective school food environment interventions for the prevention of childhood obesity: systematic review and meta-analysis. *Lancet* [https://doi.org/10.1016/s0140-6736\(19\)32874-0](https://doi.org/10.1016/s0140-6736(19)32874-0) (2019).
26. Downs, S. & Demmler, K. M. Food environment interventions targeting children and adolescents: a scoping review. *Glob. Food Secur.* <https://doi.org/10.1016/j.gfs.2020.100403> (2020).
27. Correa, E. N., Rossi, C. E., das Neves, J., Silva, D. A. S. & de Vasconcelos, F. A. G. Utilization and environmental availability of food outlets and overweight/obesity among schoolchildren in a city in the south of Brazil. *J. Public Health* **40**, 106–113 (2018).
28. de Assuncao Bezerra, M. K. et al. Health promotion initiatives at school related to overweight, insulin resistance, hypertension and dyslipidemia in adolescents: a cross-sectional study in Recife, Brazil. *BMC Public Health* **18**, 223 (2018).

29. Motter, A. F., Vasconcelos Fde, A., Correa, E. N. & Andrade, D. F. Retail food outlets and the association with overweight/obesity in schoolchildren from Florianópolis, Santa Catarina State, Brazil. *Cad. Saude Publica* **31**, 620–632 (2015).
30. Rossi, C. E., Patricia de Fragas, H., Correa, E. N., das Neves, J. & de Vasconcelos, F. A. G. Association between food, physical activity, and social assistance environments and the body mass index of schoolchildren from different socioeconomic strata. *J. Public Health* **41**, e25–e34 (2019).
31. Dillman Carpentier, F. R., Correa, T., Reyes, M. & Taillie, L. S. Evaluating the impact of Chile's marketing regulation of unhealthy foods and beverages: pre-school and adolescent children's changes in exposure to food advertising on television. *Public Health Nutr.* **23**, 747–755 (2020).
32. Rebolledo, N., Reyes, M., Corvalan, C., Popkin, B. M. & Smith Taillie, L. Dietary intake by food source and eating location in low- and middle-income Chilean preschool children and adolescents from southeast Santiago. *Nutrients* <https://doi.org/10.3390/nu1071695> (2019).
33. An, R., He, L. & Shen, M. J. Impact of neighbourhood food environment on diet and obesity in China: a systematic review. *Public Health Nutr.* **23**, 457–473 (2020).
34. Pehlke, E. L., Letona, P., Hurley, K. & Gittelsohn, J. Guatemalan school food environment: impact on schoolchildren's risk of both undernutrition and overweight/obesity. *Health Promot. Int.* **31**, 542–550 (2016).
35. Chacon, V., Letona, P., Villamor, E. & Barnoya, J. Snack food advertising in stores around public schools in Guatemala. *Crit. Public Health* **25**, 291–298 (2015).
36. Umberger, W. J., He, X., Minot, N. & Toiba, H. Examining the relationship between the use of supermarkets and over-nutrition in Indonesia. *Am. J. Agric. Econ.* **97**, 510–525 (2015).
37. Barrera, L. H., Rothenberg, S. J., Barquera, S. & Cifuentes, E. The toxic food environment around elementary schools and childhood obesity in Mexican cities. *Am. J. Prev. Med.* **51**, 264–270 (2016).
38. Soltero, E. G. et al. Characterization of the school neighborhood food environment in three Mexican cities. *Ecol. Food Nutr.* **56**, 139–151 (2017).
39. Okeyo, A. P. et al. The food and nutrition environment at secondary schools in the Eastern Cape, South Africa as reported by learners. *Int. J. Environ. Res. Public Health* <https://doi.org/10.3390/ijerph1714038> (2020).
40. Moodley, G., Christofides, N., Norris, S. A., Achia, T. & Hofman, K. J. Obesogenic environments: access to and advertising of sugar-sweetened beverages in Soweto, South Africa, 2013. *Prev. Chronic Dis.* **12**, E186 (2015).
41. Khonje, M. G., Ecker, O. & Qaim, M. Effects of modern food retailers on adult and child diets and nutrition. *Nutrients* <https://doi.org/10.3390/nu12061714> (2020).
42. Laar, A. et al. Implementation of healthy food environment policies to prevent nutrition-related non-communicable diseases in Ghana: national experts' assessment of government action. *Food Policy* **93**, 101907 (2020).
43. El-Ammari, A., El Kazdoui, H., Bouftini, S., El Fakir, S. & El Achhab, Y. Social-ecological influences on unhealthy dietary behaviours among Moroccan adolescents: a mixed-methods study. *Public Health Nutr.* **23**, 996–1008 (2020).
44. Debela, B. L., Demmler, K. M., Klasen, S. & Qaim, M. Supermarket food purchases and child nutrition in Kenya. *Glob. Food Secur.* <https://doi.org/10.1016/j.gfs.2019.100341> (2020).
45. Nadeem Gill, F. An assessment of adolescent eating habits in public schools of Chak Shahzad, Islamabad. *Int. J. Nutr. Food Sci.* **5**, 304–309 (2016).
46. Rath, N., Riddell, L. & Worsley, A. Food environment and policies in private schools in Kolkata, India. *Health Promot. Int.* **32**, 340–350 (2017).
47. Caspi, C. E., Sorensen, G., Subramanian, S. V. & Kawachi, I. The local food environment and diet: a systematic review. *Health Place* **18**, 1172–1187 (2012).
48. Williams, J. et al. A systematic review of the influence of the retail food environment around schools on obesity-related outcomes. *Obes. Rev.* **15**, 359–374 (2014).
49. Kirkpatrick, S. I. et al. Dietary assessment in food environment research: a systematic review. *Am. J. Prev. Med.* **46**, 94–102 (2014).
50. Driessen, C. E., Cameron, A. J., Thornton, L. E., Lai, S. K. & Barnett, L. M. Effect of changes to the school food environment on eating behaviours and/or body weight in children: a systematic review. *Obes. Rev.* **15**, 968–982 (2014).
51. Foster, G. D. et al. A policy-based school intervention to prevent overweight and obesity. *Pediatrics* **121**, e794–e802 (2008).
52. *One in Five Children, Adolescents and Youth is Out of School* (UNESCO Institute of Statistics, 2018).
53. Osei-Assibey, G. et al. The influence of the food environment on overweight and obesity in young children: a systematic review. *BMJ Open* **2**, e001538 (2012).
54. Burchi, F., Fanzo, J. & Frison, E. The role of food and nutrition system approaches in tackling hidden hunger. *Int. J. Environ. Res. Public Health* **8**, 358–373 (2011).
55. Taillie, L. S. et al. Best practices for using natural experiments to evaluate retail food and beverage policies and interventions. *Nutr. Rev.* **75**, 971–989 (2017).
56. Pitt, E., Gallegos, D., Comans, T., Cameron, C. & Thornton, L. Exploring the influence of local food environments on food behaviours: a systematic review of qualitative literature. *Public Health Nutr.* **20**, 2393–2405 (2017).
57. Cetateanu, A. & Jones, A. How can GPS technology help us better understand exposure to the food environment? A systematic review. *SSM Popul. Health* **2**, 196–205 (2016).
58. Lytle, L. A. & Sokol, R. L. Measures of the food environment: a systematic review of the field, 2007–2015. *Health Place* **44**, 18–34 (2017).
59. Wilkins, E. L., Morris, M. A., Radley, D. & Griffiths, C. Using geographic information systems to measure retail food environments: discussion of methodological considerations and a proposed reporting checklist (Geo-FERN). *Health Place* **44**, 110–117 (2017).
60. McKinnon, R. A., Reedy, J., Morrisette, M. A., Lytle, L. A. & Yaroch, A. L. Measures of the food environment: a compilation of the literature, 1990–2007. *Am. J. Prev. Med.* **36**, S124–S133 (2009).
61. Liu, B., Widener, M., Burgoine, T. & Hammond, D. Association between time-weighted activity space-based exposures to fast food outlets and fast food consumption among young adults in urban Canada. *Int. J. Behav. Nutr. Phys. Act.* **17**, 62 (2020).
62. Spire, M. et al. Snapshots of urban and rural food environments: EPOCH-based mapping in a high-, middle-, and low-income country from a non-communicable disease perspective. *Nutrients* <https://doi.org/10.3390/nu12020484> (2020).
63. Keats, E. C. et al. The dietary intake and practices of adolescent girls in low- and middle-income countries: a systematic review. *Nutrients* <https://doi.org/10.3390/nu10121978> (2018).
64. Kupka, R., Siekmans, K. & Beal, T. The diets of children: overview of available data for children and adolescents. *Glob. Food Secur.* <https://doi.org/10.1016/j.gfs.2020.100442> (2020).
65. Tatlow-Golden, M. & Garde, A. Digital food marketing to children: exploitation, surveillance and rights violations. *Glob. Food Secur.* <https://doi.org/10.1016/j.gfs.2020.100423> (2020).
66. Frongillo, E. A., Baranowski, T., Subar, A. F., Toozé, J. A. & Kirkpatrick, S. I. Establishing validity and cross-context equivalence of measures and indicators. *J. Acad. Nutr. Diet* **119**, 1817–1830 (2019).
67. L'Abbe, M. et al. Monitoring foods and beverages provided and sold in public sector settings. *Obes. Rev.* **14**, 96–107 (2013).
68. Kelly, B. et al. Monitoring food and non-alcoholic beverage promotions to children. *Obes. Rev.* **14**, 59–69 (2013).
69. Ni Mhurchu, C. et al. Monitoring the availability of healthy and unhealthy foods and non-alcoholic beverages in community and consumer retail food environments globally. *Obes. Rev.* **14**, 108–119 (2013).
70. Wilson, I., Huttly, S. R. A. & Fenn, B. A case study of sample design for longitudinal research: young lives. *Int. J. Soc. Res. Methodol.* **9**, 351–365 (2006).
71. Glanz, K., Sallis, J. F., Saelens, B. E. & Frank, L. D. Nutrition environment measures survey in stores (NEMS-S): development and evaluation. *Am. J. Prev. Med.* **32**, 282–289 (2007).
72. White, M. et al. What role should the commercial food system play in promoting health through better diet? *Brit. Med. J.* **368**, m545 (2020).
73. Fanzo, J., Shawar, Y., Shyam, T., Das, S. & Shiffman, J. Challenges to establish effective public-private partnerships to address malnutrition in all its forms. *Int. J. Health Policy Manag.* <https://doi.org/10.34172/ijhpm.2020.262> (2021).
74. Swinburn, B. et al. Monitoring and benchmarking government policies and actions to improve the healthiness of food environments: a proposed government healthy food environment policy index. *Obes. Rev.* **14**, 24–37 (2013).
75. *Measuring the Healthiness of Ghanaian Children's Food Environments to Prevent Obesity and Non-communicable Diseases* (MEALS4NCDs, 2020); <https://www.meals4ncds.org/en/>
76. *NCD Risk Factor Collaboration Website* (NCD-RisC, 2017); <http://ncdrisc.org/index.html>
77. Fanzo, J. et al. The Food Systems Dashboard is a new tool to inform better food policy. *Nat. Food* **1**, 243–246 (2020).
78. Bene, C. et al. Global drivers of food system (un)sustainability: a multi-country correlation analysis. *PLoS ONE* **15**, e0231071 (2020).
79. Du, M., Tugendhaft, A., Erzse, A. & Hofman, K. J. Sugar-sweetened beverage taxes: industry response and tactics. *Yale J. Biol. Med.* **91**, 185–190 (2018).
80. Mbowa, C. et al. in *Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems* (eds Shukla, P. R. et al.) Ch. 5 (IPCC, Cambridge Univ. Press, 2019).
81. Willett, W. et al. Food in the Anthropocene: the EAT–Lancet commission on healthy diets from sustainable food systems. *Lancet* **393**, 447–492 (2019).
82. *Food Systems Summit 2021* (United Nations, 2021); <https://www.un.org/sustainabledevelopment/food-systems-summit-2021/>

Acknowledgements

We gratefully acknowledge the following individuals for their technical expertise during the workshop: A. Samuels, A. Demaio, A. Laar, C. Corvalan, C. Hayashi, C. Jalal, D. Tschirley, E. Nsokie, E. Kamau-Mbuthia, E. Keats, G. Kennedy, G. Hallen, H. Danton, J. Leroy, J. Tench, J. Rivera, K. Engesveen, K. Lichtner, L. Olson, M. Arabi, M. Corradini, M. Spires, M. Bloem, M. Woldt, P. Vos, R. Egan, R. Kupka, S. Hanck, S. Pedersen, S. de Pee, S. Downs, S. Sundberg, S. Barquera, S. Namaste, S. Nordhagen, S. Kadiyala, T. Nguyen and Z. Leung. A special thanks to A. Laar, E. Nsokie, H. Danton, K. Engesveen, M. Corradini, M. Spires, M. Woldt, R. Kupka, S. Pedersen, S. de Pee, S. Downs, S. Nordhagen and T. Nguyen for their review of the first draft of the manuscript. We thank G. Belayneh and C. McPherson for their administrative support for the workshop. The Centre for Global Child Health, Hospital for Sick Children, Joannah and Brian Lawson Centre for Child Nutrition, University of Toronto and the Global Alliance for Improved Nutrition co-funded the technical workshop.

Author contributions

This Perspective is the result of discussions from a two-day technical workshop (January 2020), co-hosted by the Centre for Global Child Health, the Hospital for Sick Children, the Lawson Centre for Child Nutrition (University of Toronto) and the Global Alliance for Improved Nutrition. B.C., C.O., D.E.R., L.M.N., J.F., M.R.L., D.W.S. and Z.A.B.

planned the workshop. B.C., C.O., D.E.R., L.M.N., D.W.S. and Z.A.B. facilitated the workshop. B.C. and C.O. wrote the first draft of the manuscript with substantive input from E.A.F. and A.H. All authors provided input, contributed to the revisions and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s43016-021-00299-5>.

Correspondence should be addressed to Z.A.B.

Peer review information *Nature Food* thanks Christopher Turner, Ahmed Raza and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

© Springer Nature Limited 2021