



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

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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

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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

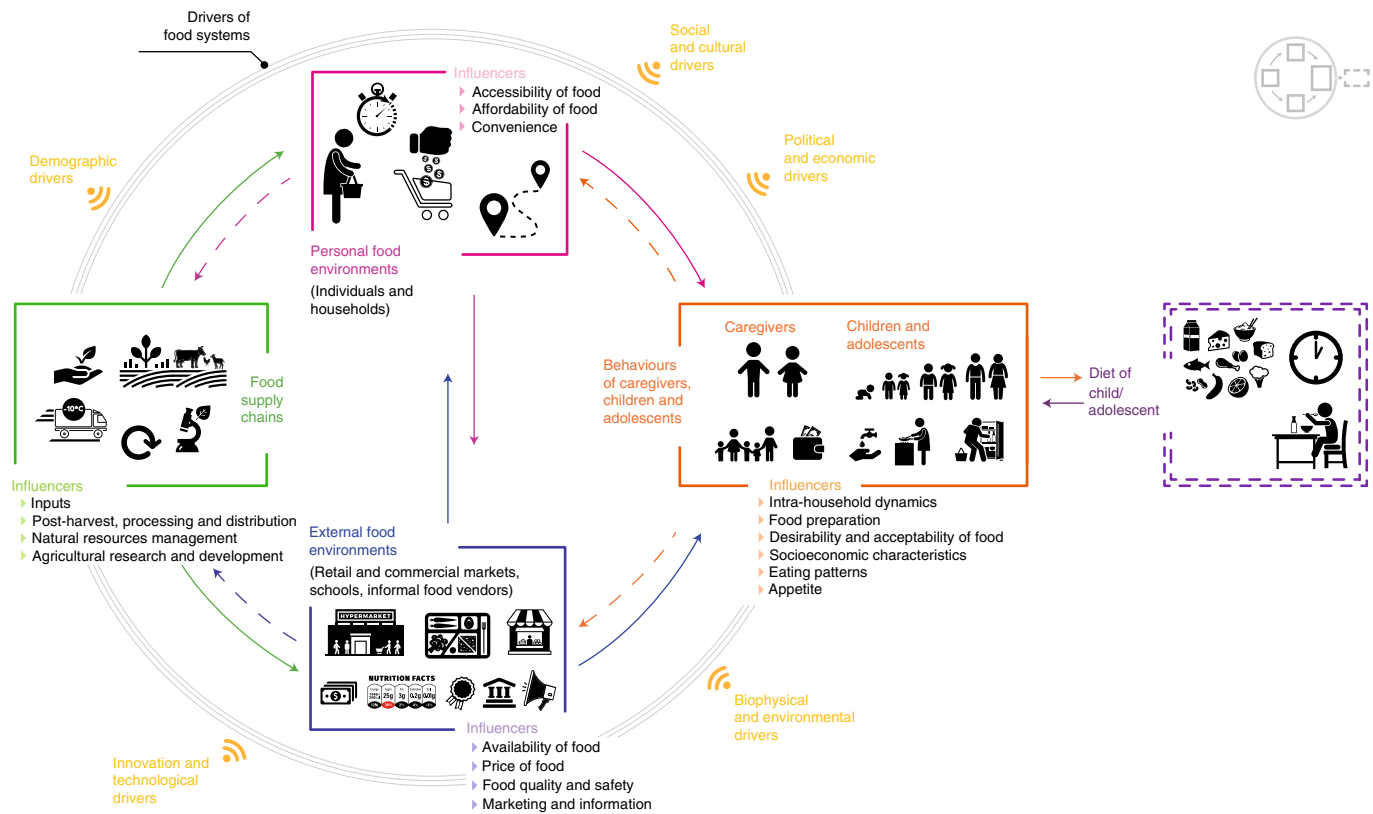


Fig. 1 | The Innocenti Framework on Food Systems for Children and Adolescents. The Innocenti Framework illustrates the influence of food system drivers (structural factors including demographic change, political and economic environment, technological advances, natural resource management and social 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

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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>.

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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.

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