Strategies and interventions for healthy adolescent growth, nutrition and development

***Overview**: This paper aims to provide evidence and guidance on the development and implementation of nutrition-related policies and interventions to support healthy growth and development of adolescents worldwide.*

Co-leads: Dougal Hargreaves, Emily Mates, Purnima Menon

Co-authors (alphabetical order) and contributions

- Harold Alderman: evidence on social protection and education
- Delan Devakumar: evidence review
- Wafai Fawzi: evidence on health/education platforms
- Geva Greenfield: evidence review
- Weeam Hammoudeh: evidence review
- Shan Shan He: Youth Ambassador
- Anwesha Lahiri: India adolescent case study and data analysis
- Zheng Liu, China case study
- Phuong Nguyen: Indian adolescent case study; global data assessments
- Vani Sethi: India adolescent case study
- Haijun Wang, China case study
- Lynette Neufeld: editing and consistency across series
- George Patton: conceptualisation, editing

Abstract

Adolescence is a pivotal point in the life-course, characterised by transformative physical, cognitive and emotional growth, an openness to change and a drive to reshape the social environment. It offers unique opportunities to adopt changes in diet and physical activity that can persist into later life. Yet pre-existing nutritional problems including micronutrient deficiencies, food insecurity and poor-quality diets persist at the same time as adolescents face the rapid emergence of an obesity epidemic.

Adolescent growth and nutrition has been largely overlooked in intervention and policy research. Most intervention studies have emphasised micronutrient supplementation with few taking into account the multiple drivers of adolescent diets. Effective interventions and policies will need to cut across sectors, be supported by multifaceted and multilevel policy and extend across education, health, food systems, social protection and digital media. Better data standardisation and systems will be essential in coordinating and monitoring these responses. In a context of shifts in planetary ecosystems and commercial drivers, resilient food systems will need to both ensure access to healthy and affordable foods and provide the infrastructure and incentives for continuing physical activity. Intergenerational partnerships with young people will be essential in bringing about transformative change and ensuring that food policies reflect their needs and aspirations.

Key messages

- Despite micronutrient deficiencies and food insecurity persisting in many places, and overweight and obesity rapidly increasing, adolescents have been largely overlooked in global nutritional policy frameworks.
- Adolescent nutritional problems remain invisible as there are neither established targets nor standardised data collection systems that would inform action.
- Adolescent nutritional action for both boys and girls provides a foundation for the healthy start to life for the next generation.
- Although multifaceted and multisectoral actions offer great promise, intervention research has overwhelmingly focused on single micronutrients to date.
- Greater government fiscal and policy action to both restrict the availability of highly processed foods and enhance healthy and diverse adolescent diets is urgently needed.
- Greater retention in education means that schools can provide healthy food environments, nutritionally sensitive social protection at times of crisis and the skills, knowledge and motivation to adopt and sustain healthy diets.
- Adolescent nutrition advocacy should occur in partnership with young people and be framed within broader commercial, cultural and ecologic contexts.

1. Introduction

Adolescence (10-24 years) is characterised by transition, exploration and openness to change, offering opportunities for radical shifts in diet, physical activity and other risks for Non- Communicable Diseases (NCDs). This same novelty seeking and openness to change also makes adolescents a vulnerable group to commercial exploitation and other unhealthy influences, with lifelong and intergenerational consequences. Given the rapid and transformative growth of puberty, adolescents' nutritional requirements differ from both younger and older groups.(1) Yet, even as nutrition has become more prominent in the nurturing of human capital, adolescents have still not been included the global nutritional policies and frameworks.(2) The consequences have been a failure to invest consistently in either adolescent-responsive nutritional programmes or research. There has been too much focus on single micronutrient supplements and a failure to tackle the multiple drivers of malnutrition and poor diet.(3) As a result, long-standing nutritional problems such as iron deficiency anaemia persist with little improvement in recent decades (ref comment); thinness and food insecurity are still highly prevalent in some contexts, while this generation is simultaneously facing a rapidly escalating crisis of overweight and obesity.(1)

In this paper, we illustrate how a nutrition-focused strategy based on adolescent interventions offers a new lens on tackling the global syndemic of obesity, undernutrition and climate change,(4) increasingly recognised as an existential challenge to human and planetary health. The conceptual framework for this series (ref) illustrates the diverse influences on adolescents' nutrition choices, including social influences from peers and family members, economic factors, environmental sustainability, and values of fairness and human rights. Their perspectives, engagement and creative solutions are likely to be

crucial in meeting this challenge. As with other areas of adolescent health, the most effective strategies for adolescent nutrition are likely be both multi-faceted and adapted to local context.

Specifically, in this paper we aim to:

1. Summarise current understanding of how effective strategies and interventions have been at improving adolescent growth and nutrition.
2. Explore how multi-faceted strategies, encompassing different sectors and platforms, can be deployed to reach adolescents with effective actions for healthy eating and optimal growth.
3. Offer recommendations on the essential steps for improving adolescent nutrition that can, in turn, support wider societal and planetary health goals.

2. What works in adolescent nutrition?

The most effective health actions for adolescents take into account their rapid emotional development and identity formation and the social forces, such as peer context, that drive adolescent decision-making.(5, 6) It is one reason why interventions that may be effective in primary school age children, such as education and behavioural skills training, have a more limited impact.(7) Similarly, effective campaigns to influence other adolescent health behaviours, such as smoking, often focus more on short-term impacts, in contrast to campaigns targeted at adults where long-term risks are highlighted.(8)

Successful adolescent interventions generally resonate with their values and social context. In the US and other modern food environments, autonomy, peer approval and norms have become increasingly important in driving adolescent food choices; understanding and harnessing these factors may be central to designing effective nutrition policies and programmes for this age group.(7)

Adolescents' greater capacity and willingness to change their behaviour is reflected in greater sensitivity to environmental influences. Migrants who move before or during adolescence are more likely to adopt harmful eating habits of the host country than those who arrive as adults.(9) They are also more likely to adopt harmful eating habits than age-matched counterparts in the host country, suggesting a double vulnerability.(10) Another illustration of openness to change is that a majority of people who adopt a vegan diet (at least in high-income settings) do so in their late teens or early twenties.(11) As long as all nutritional needs are met, this can be a positive choice with many health and environmental benefits.

Adolescent nutritional interventions necessarily vary in their form and effectiveness by age, sex, income level, geography (e.g. rural versus urban), along with social, cultural, and country context. Some interventions will be adolescent specific such as those through schools. Others may be adolescent inclusive but adapted to meet the different social and developmental context of adolescents. Interventions will also vary by their geographic context in their focus on undernutrition, micronutrient

deficiencies, overweight/obesity, or a combination. Lastly, some interventions have proven effectiveness in more than one nutritional context, while many others have a much more limited evidence base.

In the following section, we review existing evidence on approaches to intervention for adolescent nutrition within four broad domains: education and health sectors, the food system, and wider community/social influences (see Table 1 for a summary of key interventions and how they align with the conceptual framework for this series and Supplementary methods S1 for search terms and others details of the systematic review of reviews).

Education sector

Schools provide a platform for a potentially wide range of interventions. The most common and long-standing intervention are school meals (through provision or subsidised sale of food), which have been implemented in diverse ways in both high-income countries (HICs) and low- and middle-income countries (LMICs) (12) and have potential for long-term, multi-sectoral benefits.(13) Historically, many such programmes did not include specific nutrition objectives, often included poor quality foods (both nutritionally and in their appeal to young people) and were not coupled with nutrition education. Reviews suggest such programmes typically had minimal impact on dietary change or nutrition outcomes.(14) Furthermore, many school food programmes focus on younger children and rarely have impact evaluations disaggregated by age group. As a result, their ability to meet the distinct nutritional needs of adolescents (described by Norris, Frongillo et al in this series)(1) is often not clear.

Recently, several countries have developed and tested new approaches to school food programmes - for example through policy directives (e.g., banning of sugar sweetened beverages as in Mexico,(15) menu modifications (e.g., improved foods, inclusion of fortified foods, as in Brazil,(16) see also Neufeld et al

this series),(3) and choice architecture (e.g., improving selection, appeal and prominence of more nutritious food choices, as in the USA),(17-19). The school curriculum offers opportunities to improve dietary diversity and the wider food environment, as well as practical skills around growing and preparing food, skills that are in decline in many food environments.(20, 21) In some settings, initiatives such as school gardens and engagement with local food producers may also be valuable, although evidence suggests that impact depends largely on appropriate education linked to the gardens and training for teachers or other school staff to manage them.(22) Aligned with these innovations there is an increasing recognition of the need for a 'whole school approach' and promoting nutrition through all available means.(23) This includes changes to class curriculum to embed nutrition, facilitation of physical activity and active transport, creating a healthy food environment, supporting monitoring, screening and supplementation programmes (as needed), and reinforcement through individual engagement by school staff.(24)

Beyond food, schools provide an important platform for delivery of interventions targeted to high-risk groups, such as weekly iron and folic acid (WIFA) supplementation for adolescent girls. Anaemia remains an important public health challenge in many countries and is associated with increased fatigue, difficulties in learning, higher risk of infections and an increased risk to both mother and baby in future pregnancies. In populations with a high prevalence of iron deficiency anaemia, WIFA can reduce anaemia by 35% in adolescent and adult women (25). Such programmes appear cost-effective when compared to economic losses due to iron deficiency anaemia.(26, 27) However, WIFA programmes have been implemented in only a handful of countries, anaemia in adolescents boys has been absent from the data and action agenda and to date, most countries have seen no or only minor reductions in adolescent anaemia.(28) One reason for the lack of progress is that anaemia is multi-causal and that the proportion of anaemia due to iron deficiency varies substantially by context.(29) There is therefore a

need to improve the quality of data tracking anaemia, to ensure that programmes can address its different causes (30, 31).

While school enrolment has considerably increased since 2000 and is a central platform for action to improve nutrition, 37% of the secondary school-age population in sub-Saharan Africa never attend school and many of those enrolled are irregular attendees.(32) New approaches are needed to reach out-of-school adolescents and those who rarely attend to improve nutrition literacy, ensure food and nutrition security, and address specific nutrition issues. Ghana and India offer examples of WIFA programmes where both adolescents in school and those who are out-of-school are included. In India, the Anganwadi centres offer networks of peer support groups and women's self-help groups.(33) Elsewhere, schools have delivered videos of 1 or 2 minute in classrooms to encourage the take-up of supplements at clinics, thus having the potential to reach parents and siblings as well as neighbours of school pupils.(27) Take-home rations from school feeding programmes have also been utilised to reach other vulnerable household members.

The contribution of inequitable gender norms and associated high levels of early marriage and teenage pregnancy to poor nutrition in adolescent girls and their offspring requires concerted action. Continued engagement with education is arguably the most effective nutritional intervention available in some low-resource settings. In addition, school curricula offer an under-utilised opportunity for acquiring skills in childcare, nutrition and food preparation.

Health sector

Health professionals can be a trusted source of nutrition advice for adolescents, providing information and implementing screening and treatment programmes that can be adapted both to the individual's needs and the local setting. Interventions in healthcare settings, or those delivered by health

professionals in community or education settings are therefore an important component in adolescent nutrition strategies.(34) In more severe cases, under-nutrition or overweight/obesity may be a primary reason for seeking healthcare: in other cases, nutrition, eating and growth problems may be identified as part of a screening programme, or opportunistically, when a clinician is assessing another problem. Aside from WHOs Global Accelerated Action for the Health of Adolescents (AA-HA!) Guidance,(35) there are few clinical guidelines targeted towards adolescents; depending on the setting, the use of nutritional supplements and interventions such as treatment for parasites may be guided by population-based screening programmes, clinical assessment and/or laboratory investigations. In all settings, an opportunistic approach to nutrition assessment and counselling during all contacts with adolescents is key. Specialist interventions in the treatment of eating disorders or medical complications of obesity including gastric banding, are important for a small proportion of adolescents but are beyond the scope of this paper.

A wide variety of individual and group-based interventions have been developed for overweight and obese adolescents, including: nutrition advice and supervised diet programmes; behavioural approaches such as motivational interviewing;(36) physical activity interventions; and programmes which combine some or all of these components.(37, 38) A review of 18 studies with patients aged 4-18, mostly in the US and other high-income countries, found that primary care interventions led to a small but significant reduction in body mass index (2-11% reduction in BMI z-score). Interventions appeared to be more effective when they included a behaviour change or psychology component (14, 39) and/or a family component.(40) Longer duration and higher intensity interventions were also more likely to be effective.(37) In the smaller subset of adolescent studies, the impact of primary care interventions on obesity were mixed; the only study with a clear impact involved an intensive programme of 28 contacts over a 5-month period.(41)

Neufeld et al (3) highlight the growing influence of social media on dietary choices, body image and psychological wellbeing, both through advertising and marketing to adolescents and subsequent peer interactions. These same processes underpin interest in e-health and m-health interventions for overweight and obese adolescents, although most are management rather than prevention-focused. This is a rapidly changing field where interventions range from those intended to increase knowledge, through to self-monitoring apps providing immediate feedback on performance, which harness the reach of social media to promote healthy behaviour and influence societal norms.(42, 43) Proponents highlight young people as early adopters of new technology and the potential of social media to shape peer norms in a life phase where peer influence is greater than at any other point in the life cycle. The potential has grown with mobile phones and computers used in almost every area of young people's lives in both HICs and many LMICs. Although digital health interventions for adolescent nutrition are promising areas of research, consistent impact has yet to be demonstrated.

Health interventions combining dietary, physical activity and behavioural strategies with family and perhaps digital components, have potential to reduce overweight and obesity in adolescents(40). However, wide variation in the effect of apparently similar interventions suggests that further work is needed to refine and improve these interventions in a way that address the needs of different adolescent groups. For example, physical activity organised or delivered by peers appears to bring greater engagement, sense of responsibility and retention among adolescents in disadvantaged communities than adult-led activities.(44) Similarly, one of the issues highlighted in a few studies among First Nations, Inuit and Metis (FNIM) communities in Canada is that interventions are more effective if they incorporate culturally relevant nutrition information and if the community has a sense of ownership.(45)

Food system, household resources, regulatory and food environments

A recurring limitation of nutrition interventions in the health and education sectors is that the benefits of increased information or motivation can be outweighed by additional costs or practical barriers to making healthy choices.(46) Additionally, these limitations can sometimes be exacerbated by commercial exploitation of adolescents as a potentially vulnerable group, particularly through social media.(3) Supply-side interventions, such as farming subsidies and other agriculture interventions, can have large influences on food availability and consumption at population level and illustrate the key role of governments in balancing commercial and public health interests.(47, 48) Similar potential impact and political tensions apply to food regulation, for example, the World Health Organisation's campaign to ban trans-fatty acids (49), initiatives to regulate Front-of-Pack nutrition labelling,(50) and targeted taxes and policies to reduce the intake of sugar sweetened beverages (SSB) are all important initiatives with potential for significant impact at population level.

A meta-analysis based largely on intervention studies supports the efficacy of subsidies to increase consumption of healthy foods and taxation to reduce intake of unhealthful beverages and foods in adults and children. A 10% decrease in price increased consumption of healthy foods by 12%, while a 10% increase in price (i.e. tax) decreased consumption of unhealthy foods by 6%.(51) For example, in Seattle sales volumes of SSBs fell by 22% following introduction of a new tax, (52) in England a new tax was effective in reducing the sugar content of available drinks and total sugar consumption,(53, 54) while Chile's introduction of new regulations in 2014 was associated with a 23.7% reduction in purchase volume of beverages that were high in sugar, sodium or fats.(55) A combination of taxation, regulation, and public education campaign appears to maximise impact.(56, 57)

There is sparse evidence on the specific impact of these nutrition interventions on adolescents. Screen advertising bans appear to have more consistent impact on primary school age children,(58, 59) while

there is some evidence that restricting tobacco and alcohol advertising may have greater impact on adolescents than adults.(60, 61) Evidence from minimum alcohol pricing and additional taxes on SSBs shows disproportionately large impact among those with lower disposable income, reflecting a greater sensitivity to price and among those with less established patterns of consumption:(62) both would favour greater impact among young people than older adults.

Equally important are demand-side interventions to improve people's ability and motivation to buy nutritious food. In both HICs and LMICs, economically vulnerable families struggle to provide healthy diets for children in their homes; indeed, child hunger and poor diets at home are key challenges worldwide. The COVID-19 pandemic and associated lockdowns have exacerbated pre-existing food insecurity in many countries – often disproportionately affecting young people who have less secure employment and fewer resources to fall back on. US data show that food insecurity in early adolescence predicts more rapid increase in BMI by the age of 31; (63) in addition to health impact, it may also reduce educational engagement and attainment.(64) In rural Tanzania, food insecurity among adolescents was linked to illness and ability to take on adult farming responsibilities (which may involve greater energy expenditure)(65)– a cycle that may be exacerbated as the increasing effects of climate change are seen.(66)

Social safety net programmes play a key role in supporting families around food and nutrition and in ensuring that children can access schools and complete their education. Many of these social transfer programmes, such as the food assistance programmes in the US that include nutrition education for families with children, have been shown to be effective in improving family and child diets.(67, 68) Globally, economically developing and nutritionally transitioning countries spend an average of 1.5 percent of gross domestic product (GDP) on these programmes. With some regional variation, on average, spending on safety nets increases as a share of gross national product (GNP) with national income. Cash transfers (CTs) (which may be conditional or unconditional) represent an increasing share

of transfers in most regions (69) but globally only a few cash transfer programmes include adolescents in the target group, such as South Africa's Child Support Grant.(70) Even without being explicitly targeted towards adolescents, there is good evidence that CTs can be effective in influencing wider adolescent outcomes, including extending schooling, delaying parenthood and reducing HIV risk.(71) Emerging evidence suggests that they may also be a powerful tool to support adolescent nutrition in some contexts, with potential to combine healthy meals, micronutrient supplementation with the wider educational and social goals listed above, but current evidence is limited and a potential caveat is that CTs can lead to excess weight gain.(71) As with interventions in other sectors, CTs clearly need to be planned as part of an integrated strategy that is designed and evaluated according to local needs and priorities. Additionally, developmental stages must be considered, taking into account how different priorities for spending change through early, mid and late adolescence. (7)

Even where healthy food is available and affordable, adolescent choices may be heavily influenced by commercial influences. These include advertising and marketing factors (for example clarity of labelling, and supermarket placement, as well as social media influences) as well as convenience. Neufeld et al (3) describe how the proximity to schools of shops selling unhealthy food can influence adolescent food choices and result in higher consumption patterns.

Social & community influences

The social brain of adolescents has been well-described(72) and food choices illustrate the different levels at which these social influences can operate; from peer groups and local communities, to virtual networks and international social movements.

Community-grounded interventions offer opportunities to work with a wide range of local institutions. Community organisations can deliver both interventions and support strategies that improve local food

environments and food choices: from non-governmental organisations and religious communities, to local businesses and sports or music clubs. Many of the most effective obesity interventions are designed to be delivered in community settings, taking into account a specific social context.(39) For example, mentoring from members of the African American community increased the impact of nutrition interventions for African American young people in one US study.(73) Unfortunately, despite their enormous potential there is a relatively sparse literature evaluating the impact of interventions based in these community sector organisations, to date.

Community interventions provide opportunities for targeting social norms and the environmental context in which nutritional choices are made. First, a range of policies to promote active transport, including cycle lanes, pedestrianised zones, and safety measures for those walking or cycling, have been implemented by national and local governments and are often targeted specifically at young people.(74) Secondly, local governments can influence planning rules, such as restrictions to fast-food restaurants near schools or licensing of street-food vendors. For example, exposure to fast-food outlets was strongly associated with junk food intake in one study of Canadian adolescents.(75)

Looking at social influences more broadly, adolescents today have opportunities to link to a much wider range of social networks than previous generations. Information technology and social media have transformed the way in which both social and commercial influences in adolescence are expressed and experienced. While social media has sometimes been linked to harmful nutrition outcomes, for example in reinforcing weight related stigma and normalising unhealthy body images, it has also opened up opportunities for young people to connect with people outside their immediate community and has transformed social opportunities for those with limited mobility.

Social media illustrates a need to shift from viewing adolescents as passive recipients of interventions to active partners pursuing shared goals. The work of the Real Food Systems Youth Ambassadors(76)

demonstrates how young people are playing increasing leadership roles in new social movements, which often combine local action with networking and campaigning through social media. Similarly, Bhalo Khabo Bhalo Thakbo, the "Eat Well, Live Well" Movement(77) is a social media campaign led by adolescents and supported by over 5 million people in Bangladesh. It targets both individual responsibility where supporters take a pledge to buy and eat more healthy food and a system-level goal to '*change the way food is produced, manufactured and sold';* both political and consumer power of young people is explicitly mobilised to campaign for change.

3. Multi-faceted interventions to address multiple sectoral challenges to better nutrition

While the literature reviewed above presents some evidence for the effectiveness of specific nutrition interventions (summarised in Table 1 and the World Health Organisation e-Library of Evidence for Nutrition Actions (eLENA)),(78) there is a compelling case that no single intervention or platform will be effective alone. Just as the importance of integrated interventions to improve maternal and child nutrition is increasingly recognised,(79) the forces shaping adolescent growth and dietary intake demand coordinated multifaceted action across sectors in order to achieve the greatest benefits. Further, the multi-faceted action at local and national levels must reflect the diverse contexts in which adolescents live.(3) Norris, Frongillo et al(1) highlight the limited progress in achieving multiple nutrition goals: no country has been successful in preventing an unhealthy nutrition transition in which one set of problems (underweight) is replaced by another set, i.e. overweight and obesity, often with ongoing concerns about micronutrient deficiencies and inequalities. To date, nowhere have we managed to either reverse the trend or achieve an ideal transition. There are several reasons for this: a lack of timely adaptation of policy settings to a different nutritional reality; a failure to adopt double-duty or triple-duty actions; the failure to target this age group before metabolic adaptations and obesity become

entrenched; and most importantly, the piecemeal and fragmentary approach in which simple single-faceted interventions have generally predominated.

Emerging evidence of the potential impact of a multi-faceted approach is illustrated by two strategies to reduce overweight and obesity among children and young people in China and the Netherlands. In China, a team at Peking University developed a comprehensive intervention to promote knowledge, healthier diet and physical activity (drawing on literature reviews(80, 81) and engagement work with local stakeholders). Following mixed results from an initial cluster-randomised study (82) a further trial was designed with greater emphasis on engaging teachers, families and members of the local community to promote adherence. From baseline to 9 months, the mean BMI decreased in the intervention group, whereas it increased in the control group (mean difference -0.46 kg/m2 (95% confidence interval [CI]: -0.67 to -0.25, P<0.001). The intervention was also beneficial on other adiposity outcomes, dietary and sedentary behaviours, obesity-related knowledge, and physical fitness (all P values < 0.05). A larger impact was seen on dietary behaviours than physical activity. Subsequently, local education bureaux have incorporated the intervention into regular school health services and further refinements are now underway, with a view to addressing community and local environmental factors such as access to convenience stores.(83)

Another example of a multi-faceted, multi-sectoral intervention is the Amsterdam Healthy Weight Programme (abbreviated in Dutch as AAGG), which was introduced in 2013 in response to local concerns about the prevalence of childhood overweight and obesity. The programme took a whole systems approach with a wide range of complementary interventions designed to promote healthier diets, physical activity and good quality sleep - all based on a philosophy that '*the healthy choice should be the easy choice'* for children and young people, parents, and everyone in the community.(74)

Early data showed that obesity prevalence in the most deprived group of 0-18 year olds fell by around a quarter between 2012 and 2015 (8% to 6%), while the total prevalence of overweight and obesity fell from 21% to 18.5%.(74) While the absolute reduction in obesity is relatively small, these findings should be seen in the context of rising trends in many comparable cities and the difficulty in achieving rapid change when obesity has been rising steadily over decades. However, longer-term data on the sustainability and impact of this approach are needed, along with lessons for other cities and information on specific impact for adolescents and younger children.(84)

Similar multi-faceted local strategies have also reported some success in reducing childhood obesity (0-5 years) in Leeds, England(85) and four US projects. In the US, strategies in New York City and Philadelphia targeted students in grades K-8. In New York City, obesity in this age group over the period 2006–2007 to 2010–2011 declined from 21.9% to 20.7%, representing a relative decline of 5.5% ($p < 0.001$). In Philadelphia 2006–2007 to 2011-12, obesity declined from 21.5% to 20.5%, representing a 4.7% relative decrease (7.7% for severe obesity) ($p < 0.001$).(86) Emerging efforts in India, another country with a large population of adolescents and young adults that was developed using insights from a recent nationwide survey, are described in Box 2.

Data-informed governance for intersectoral action

Standardised and more comprehensive data are key to effective intersectoral action and accountability of policymakers. Too often adolescent nutritional problems remain invisible, as there are neither established targets nor standardised data collection systems that would inform action (Table 2 and Supplementary Table 1). Data should also inform the design and delivery of multi-faceted interventions for adolescents, which reach them at the right time, in the right place, with the right interventions for their life-stage. Similarly, data allows targeted responses to the specific nutritional needs of different populations, supporting a shared understanding and a shared commitment *across sectors*, coupled with

focused actions *within sectors* to resolve key bottlenecks.(87-89) When multi-faceted, multi-sectoral solutions reach adolescents where they live, study, play and eat, they have great potential. Therefore, data-informed governance for actions across sectors must hold the adolescent at the centre of all planning and must align actions in ways that address the drivers of poor nutrition for adolescents at each stage of their life and within each sector.(5)

The use of data and local insight to drive intersectoral action should start with strategy-focused diagnostics: what are adolescents eating; what is their nutritional status; what is happening in their schools; what are families with adolescents struggling with; what do local food retail environments look like; what is happening within the health sector; and how are national policies taken up differently in different places? Adolescent nutrition profiles will differ between different food environments – reflecting variations in available food, social expectations and the degree of autonomy exercised by adolescents in different settings.(3) Second, with greater shared understanding, barriers and actions *within* each sector or area could be identified and acted upon. For example, if school meals are poor because national nutrition guidelines are suboptimal, then guidelines will need revision; if families with adolescents are struggling financially, then social protection measures may be needed; if adolescents are encountering only unhealthy foods in their food environment, then market-focused efforts will be needed. Third, regular monitoring of locally-grounded and adolescent-centred action plans are essential. To build local and national accountability, it will be critical to engage adolescents, their families, their schools and local government to review and identify priorities, set targets and track progress.

The major available global databases on adolescents around the world include those maintained by agencies such as UNICEF and WHO, as well as those hosted and maintained by national governments in high-income countries (see **Table 2 and Box 1**). More disaggregated data on adolescents and greater standardisation of data between countries would support a more data-driven approach to adolescent

nutrition policies. Of the domains in the framework for adolescent nutrition in our series, data are most sparse around economic development, urbanisation and food and agriculture systems, and how they intersect with adolescents. Similarly, the key outcomes we emphasise in this series – diets and nutritional effects and wellbeing – are also priorities for investment in better data, as well as creativity in efforts to construct databases that consolidate data from diverse sources in ways that help us understand how the domains of the framework play out for adolescents and young adults. Box 1 and Supplementary Table A illustrate how a recent investment in such a multi-sectoral *data* strategy in India has helped to identify priority actions and inform multi-faceted local and national strategies.

4. Recommendations

The world's adolescents are at a nutritional tipping point. Long-standing problems of micronutrient deficiencies, low weight and food insecurity, and short stature persist, as newer problems of obesity and metabolic disturbances rapidly emerge. Pervasive neglect in policy, programming and research means that the field lacks knowledge, systems and human resources compared to other age groups. More than ever before, adolescent nutrition is tied to global changes in urbanisation, food systems, industry marketing, digital technologies, accompanied by planetary change and more recently pandemic disruptions. We make the following recommendations for action to ensure adolescents' own health, and that of the next generation they will be caring for, while minimising environmental impacts:

Build commitment to adolescent nutrition through evidence-based and accountable systems

1. **Establish targets for adolescent nutrition in its global tracking and accountability**

mechanisms. Optimal nutrition of adolescent girls and boys is a pillar of human capital, but no global targets have been set either for undernutrition or overweight and obesity. The research community, UN agencies, international NGOs, donors and national governments will only bring about the radical changes needed if data-based accountability mechanisms are established.

2. **Strengthen and extend national data collection systems to include standardised indicators and determinants of adolescent nutritional status (e.g., dietary intake), and coverage of interventions among both adolescent boys and girls.** Most countries lack data to monitor adolescent nutrition and ensure timely action in the context of rapid global shifts. Data should be central to national efforts to prioritise action and to assess progress in adolescent nutrition and development.
3. **Donors and research funding agencies should invest in and prioritize the knowledge gaps thwarting action for adolescent nutrition.** There are glaring gaps in our understanding of adolescent nutrition ranging from its consequences for maturation of physiological systems through to the shifting determinants of adolescent food choices and how to move action beyond the 'silver bullets' of single micronutrient supplements, to the multiple drivers of food choice.

Enhance policy and programmatic actions that favour healthy adolescent nutrition

4. **National governments and relevant state jurisdictions should use fiscal and policy levers to promote the availability and affordability of healthy foods for children and adolescents and restrict the marketing of, reduce access to, and extend taxation of increasingly ubiquitous inexpensive unhealthy foods.**
5. **Researchers should partner with consumer and shareholder activists to hold food**

manufacturers and distributors, from global to local, accountable for their food policies and marketing directed to children and adolescents. Across all countries, adolescents are increasingly consuming unhealthy foods high in sugar, fats and salt and of low nutritional value. All actors in the food system must support healthy food environments and restrict sales of unhealthy alternatives.

6. **National and jurisdictional governments should guarantee the availability of healthy food through school meals, particularly in settings of poverty and food insecurity, and at times of crisis.** Many adolescents and their families live in extreme poverty and climate environmental changes are likely to bring even greater food insecurity. The expansion of education and the integration of nutrition in educational settings offers the opportunity to extend nutritionally sensitive social protection schemes.
7. **Ministries of education should mandate the creation of healthy school food environments including the enforcing of nutritional standards for school meals, subsidising of nutritious foods, restricting the sale and advertising of processed foods and encouraging engagement with the local community, including parents and farmers.** Nutrition is central for school learning and ultimately human capital. Equally, schools can play an important role in adolescents' nutrition through the curriculum, the foods consumed at school and the nutritional norms adopted by the student group.
8. **Ministries of education and schools should expand school curricula, for both girls and boys, in ways that extend to relevant skills-based training, including understanding the production of nutritious and sustainable foods, and the scope for adapting local agriculture to environmental change.** Particularly where aligned with the interests of youth in rural and farming communities, to support them as champions of change for nutrition, school curricula offer opportunities beyond the promotion of

developmentally appropriate food literacy for both boys and girls, to skill-based training in maintaining traditional knowledge and renewing skills around preparation and cooking of nutritious and delicious food.

9. **National and subnational governments should ensure young people have easy access to accurate nutrition information through simple, bold, 'front-of-pack' warning labels, as well as promoting healthy diets in social media with messages grounded in an understanding of the drivers of adolescent food choice.** Increasingly food choices are shaped by mass and social media, amplified by food, beverage and fashion industries, shifting norms around sexual attractiveness, body image, physical and mental health.

Place adolescent nutrition advocacy within a broader ecological context

10. **All nutrition constituents should partner with young people in advocacy for diets that are healthy, safe and sustainable.** Highly processed foods are bad for people and the planet: reducing consumption will be a win-win for both human and planetary health. Advocacy for healthy adolescent nutrition needs to embrace the commercial, structural and ecological drivers of food choice as well as the agency of young people to bring about transformative change.

Authorship statement

DH, EM and PM contributed equally to the manuscript. DH, PM, GP conceptualized the manuscript; DH, EM, PM, LN, GP did the final manuscript preparation. DD, EM, GG, WH, DH, HA, WF developed the section on the evidence base on interventions. PN, VS, AL, PM developed the India case study; ZL, HW developed the China case study. PN, PM reviewed availability of global data. SSH contributed the youth perspective. All authors drafted sections of the manuscript, contributed to the interpretation and discussion, and all authors approved the final manuscript.

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Declaration of interests.

DH is the Deputy Chief Scientific Adviser at the Department for Education (England)

5. Tables and figures for main text

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Table 1: Mapping evidence-based interventions to the conceptual framework

Platform	Type of intervention	
	Food & nutrition environment	**Nutritional agency[1]**
Education		
Undernutrition	-Provision of meals and micronutrient supplements(12, 78) -Provision of school meals(14, 78) -School platforms used to support nutrition of out-of-school adolescents(33) -Deworming children and Women of Reproductive Age(78)	-Nutrition education – for example, school gardens (22) -Knowledge of dietary diversity, food environment and practical skills (20, 21) -Use opportunity of school curricula to support nutrition and food preparation (34)
Micronutrient deficiencies	-Provision of meals and micronutrient supplements(12) Weekly Iron and Folic Acid (WIFA) supplements to reduce anaemia(25, 78) -Schools delivering videos (1-2 minutes) in classrooms as motivation for uptake of supplements in clinics(27) -Daily Iron Supplementation (also in malarial areas)(78) -Provision of Micronutrient Powders(78) -Deworming children and Women of Reproductive Age(78) -Inclusion of fortified foods (16)	-Nutrition education – for example, school gardens (22) -Knowledge of dietary diversity, food environment and practical skills (20, 21) -Use opportunity of school curricula to support nutrition and food preparation (34)
Overweight or obesity	-Provision of meals and micronutrient supplements(12) -Exposure to fast food outlets increases intake of junk food(68) -School platforms used to support nutrition of out-of-school adolescents(33) -Decreased consumption of Sugar Sweetened Beverages (SSB) , ⍰free sugar intake (78) (15)	-Nutrition education – for example, school gardens (22) -Knowledge of dietary diversity, food environment and practical skills (20, 21) -Use opportunity of school curricula to support nutrition and food preparation (34) -Improving choice architecture (17-19).
Health		
Undernutrition	-Nutritional care of HIV-infected children(78) -Multiple Micronutrient Supplements and macronutrient supplementation for People Living With HIV and Aids (78) -- Bright Futures: Nutrition(34)	
Micronutrient deficiencies	-Multiple Micronutrient Supplements and macronutrient supplementation for People Living With HIV and Aids (78) - Bright Futures: Nutrition(34)	

[1] Adolescent 'agency' was operationalized in the *Lancet* 2016 Commission across three aspects; i) having the skills and knowledge to advance the conversation (across the board, young people and decision makers), ii) having forums available for young people to engage, and iii) ensuring there are resources available for engagement.

Overweight or obesity	-Increased potassium and decreased sodium intake for ↓Blood Pressure(78)	-Use of social media to promote healthy behaviour or influence social norms(42, 43) -Overweight and obesity control interventions(36-38) -Including Behaviour Change Communication component(14, 36, 39) -Including family component(40) - Longer term and/or higher intensity interventions (37).
Food System/household resources/regulatory		
Undernutrition	-Fortification of maize(78) -Social protection/cash transfer programmes including nutrition education(67, 68)	
Micronutrient deficiencies	-Cash transfers combining healthy meals and/or micronutrient supplementation (71)	
Overweight or obesity	-Regulations to limit access to unhealthy meals drinks or snacks during the school day(90) -Reducing the impact of marketing of foods and non-alcoholic beverages on children(78) -subsidies and taxes to reduce the intake of unhealthy beverages and foods(52-55) -Minimum alcohol pricing and increased taxes on SSBs (62)	
Social/Community Influences		
Undernutrition		-increasing community ownership of interventions, inclusive of culturally relevant information(45) -Mentoring from community members to increase impact of interventions(73)
Micronutrient deficiencies		
Overweight or obesity	-Policies to encourage active transport and safe walking/cycling (74)	-Youth-led movements e.g. -Eat well, Live well (77) -Real Food Systems Youth Ambassadors (76)
Multisectoral		
Undernutrition		
Micronutrient deficiencies		
Overweight or obesity	-Addressing overweight and obesity through multiple interventions (schools, parent engagement, etc. (85, 86) ▪ Joint Strategy to address obesity in China(81, 82) ▪ Reductions of overweight and obesity through interventions of the Amsterdam Healthy Weight Programme(74)	

- **Table 2: A review of global databases on adolescent health**

	Population Council Adolescent Data Hub	Demographic and Health Survey (DHS) data	Health Behavior in School Age Children (HBSC)	United States Adolescent Health	WHO Maternal, Newborn, Child and Adolescent Health data portal	UNICEF Adolescent health data (Multiple Indicator Cluster Survey)
DATABASES	127 LMIC countries 473 datasets (453 observational, 20 experimental, 358 national representative data) Age 10-14, 15-19 and 20-24y	All DHS surveys conducted from 2000-17 with availability of data for girls or boys age 15-19y	WHO collaborative cross-sectional national survey Data was collected every 4 years on 11-15-year-olds in 49 countries and regions across Europe and North America.	US national and state level Age 9-20y	Global health data, including regional and country data Age 10-19y	More than 100 countries around the world Age 15-19y
DOMAINS						
Natural systems and planetary health	*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
Social, cultural and gender norms	Gender Attitudes/Beliefs Community engagement Crime Social Networks Subjective Expectations	*No data*	Social environments	Healthy Relationships	National policies	*No data*
Economic development, urbanization, food & agriculture systems	Economics Health Care Access and Utilization Migration and Mobility	Iron Supplementation	*No data*	*No data*	*No data*	*No data*
Household, school, peer dietary & activity patterns	Demographic Characteristics Education Family/ Household Structure Time Use	*No data*	*No data*	Demographics	*No data*	Education Marriage Early Demographics Participation
INDIVIDUALS: Physical Activity	*No data*	*No data*	*No data*	*No data*	*No data*	*No data*
INDIVIDUALS: Cognitive & Emotional Growth	Mental Health	*No data*	*No data*	Mental Health	*No data*	Mental Health
INDIVIDUALS: Food Choice & Dietary Intake	*No data*	Women's diet diversity score	*No data*	*No data*	*No data*	*No data*
Outcomes	Physical Health Reproductive Health	Anemia Anthropometry Adolescent childbearing	Health and well-being Health behaviors	Reproductive Health Physical Health & Nutrition Substance Abuse	Adolescent sexual and reproductive health Morbidity Mortality/cause of death	Childbearing Violence

Box 1: Use of data to generate multi-faceted policy actions for adolescent nutrition in India

India is home to 253 million adolescents and has the largest number adolescents in any country, globally. Despite recognition that adolescent nutrition is important, there has long been an absence of data on (i) specific age groups (10-14 years), (ii) specific outcomes and risk factors such as micronutrient deficiencies, worm infestation, non-communicable disease risk, anthropometry, physical activity, mental health and household food security[i], (iii) school-based services. Another data challenge was limited use of gold standard methodologies.

The Comprehensive National Nutrition Survey (CNNS) 2016-18* addressed these gaps head on. It used robust tools and methods to provide nationally representative data on nutrition status of pre-schoolers (0-4 years), school-age children (5-9 years) and adolescents (10-19 years). Surveying 35,856 adolescents 10-19 years and a sub-set of 16,181 for biological samples, the CNNS revealed numerous adolescent nutrition challenges, including underweight, anaemia, overweight, poor diet quality, and limited physical activity (Supplementary Tables 2,3 & 4). It also highlighted limited coverage of school-based services and inequities among rural and poor population. The findings clearly called for multifaceted actions cutting across food systems, health and education sectors.

Building both on these findings and on a series of policy engagements, the Government of India is gearing up to strengthen nutrition components in ongoing programmes reaching adolescent boys and girls, and to enact legislation to ban unhealthy foods in the areas within and around school campuses.

1. Multi-stakeholder policy and research groups will further analyse the data to answer policy questions on coverage, risk factors and determinants of anaemia and poor adolescent nutrition.

2. Data from the report is being used to back health and promotion peer-to-peer activities under the 'Eat Right School' initiative of Food Safety Standards Authority of India (FSSAI), to create an environment of safe food and healthy eating for students and teachers in various schools[ii]. It is also being used to back legislation under development aiming to regulate the marketing of unhealthy foods in schools.

3. A new school health curriculum has been launched to ensure that 1 hour per week and 26 hours in a year are devoted to health and nutrition activity-based learning, across government schools.

4. Health and nutrition promotion activities in schools, covering physical activity, reducing accessibility of unhealthy foods in schools, mass campaigns around healthy snacking, reducing salt, sugar and sweets/fried foods are gaining momentum under the Eat Right India Movement.

Overall, this highlights the value of investing in and closely examining data, conducting relevant analysis and directly engaging with policy stakeholders across sectors. This has allowed an acknowledgement of the challenge of nourishing India's adolescents and identification of specific policy actions for the short- and long-term.

*Sethi V, Lahiri A, Bhanot A, Kumar A, Chopra M, Mishra R, Alambusha R, Agrawal P, Johnston R and de Wagt A. Adolescents, Diets and Nutrition: Growing well in a Changing World, The Comprehensive National Nutrition Survey, Thematic Reports, Issue 1, 2019.

Box 2: Research needs to support better actions for adolescent nutrition

We base several of the recommendations in this series on an evidence base that is still too limited. Too much remains unknown, especially around specific platforms and specific age groups. Some critically important areas for further investment are below, focusing on neglected age groups, neglected intervention areas and neglected platforms:

1) Age groups: *Data and research* on nutrition challenges and determinants appears to be most lacking for males and for the 10-14-year age group even though, programmatically, many countries have school platform based programmes reaching this age group. *Programmatically*, the later adolescent age groups are most neglected. Programmes for secondary school students will reach the middle group of 15-19-year olds, but both data and programmes for young adults 20-24 years of age are largely focused on reproductive health and child bearing. All age groups are aggressively targeted by commercial marketing, despite this neglect in academic research and government programmes.

2) Intervention areas: Across the range of intervention areas, school interventions are likely the best researched, but there remain many questions about health platforms and adolescents, including on how to tailor antenatal care services for adolescents in ways that enable access, engagement and inclusivity. Similarly, there are large gaps in our understanding of the full range of impacts of multifaceted interventions such as those tested in China and recently launched in India. In large countries such as these, tailored and context-specific research efforts will also be important to inform policy and programme actions.

3) Platforms: Reaching out-of-school adolescents more effectively is a critical need, and current research is limited. Depending on the country, alternative platforms to reach this group may include community groups and non-governmental organisation, juvenile justice system, refugee services and homeless health services. Similarly, little is known about platforms to improve nutrition and food choices of adolescent boys since the focus is almost always on girls and young women. Additionally, while social media is not a neglected platform for research in general, it has not been harnessed enough around topics such as nutrition; this is a major gap given the high and expanding use of social media among young people around the world.

Across all these areas, research will need to be context-specific, ensuring adequate attention both to the range of food environments and to the range of school and health environments that adolescents are reached by.

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