



## Scoping Review

# Nutritional status of school-age children and adolescents in low- and middle-income countries across seven global regions: a synthesis of scoping reviews

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Submitted 18 June 2021: Final revision received 12 January 2022: Accepted 9 February 2022: First published online 14 February 2022

### Abstract

**Objective:** To summarise available evidence on the nutritional status of school-age children and adolescents (5–19 years) from seven global regions and on interventions implemented to improve malnutrition in this population.

**Setting:** Global.

**Design:** Findings were compiled from seven scoping literature reviews, including data from low- and middle-income countries within the following UNICEF-defined global regions: East Asia and Pacific; Europe and Central Asia; South Asia; West and Central Africa; Eastern and Southern Africa; Middle East and North Africa and Latin America and the Caribbean.

**Results:** A double burden of malnutrition was evident across the world regions reviewed: stunting, thinness, anaemia and other micronutrient deficiencies persisted, alongside rising overweight and obesity prevalence. Transitions towards diets increasingly high in energy-dense, processed and micronutrient-poor foods were observed. Evidence from intervention studies was limited, but suggested that providing multiple micronutrient-fortified foods or beverages at school may effectively target micronutrient deficiencies and facilitate weight gain in undernourished populations. Interventions to prevent or manage overweight and obesity were even more limited. There was minimal evidence of using novel technological approaches to engage school-age children and adolescents, or of involving them in designing interventions.

**Conclusion:** The limited data available on nutrition of school-age children and adolescents are neither standardised nor comparable. Consensus on methods for assessing nutritional status and its determinants for this age group is urgently needed to set targets and monitor progress. Additionally, strategies are required to ensure that nutritious, safe and sustainable diets are available, affordable and appealing.

### Keywords

Nutrition

School-age children

Adolescents

Low- and middle-income countries

Interventions

The United Nations Sustainable Development Goal 2 calls for an end to all forms of malnutrition by 2030<sup>(1)</sup>. To this end, global investment in nutrition has predominantly focused on children under 5 years of age and on pregnant

and lactating women. In recent years, the adolescent period (defined by the WHO as between the ages of 10 and 19 years) has gained recognition as a potential second window of opportunity for achieving targeted gains in

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growth and development, with long-term nutrition and health benefits for current and future generations<sup>(2-5)</sup>. However, the lack of inclusion of school-age children (5–9 years) and adolescents in research, policy and programming limits our understanding of the burden of malnutrition in these age groups, as well as of effective interventions<sup>(6-8)</sup>.

As children transition through adolescence and puberty, they experience rapid physical, behavioural and emotional growth. They also gain independence and the social determinants of their health behaviours broaden<sup>(9)</sup>. During this time, adolescents may be highly susceptible to the adoption of unhealthy lifestyles (including diet and activity behaviours), which can persist into adulthood<sup>(9,10)</sup>. In low- and middle-income countries (LMIC), this is exacerbated by rapid urbanisation, which exposes adolescents to increasingly obesogenic environments characterised by energy-dense and ultra-processed diets and low levels of physical activity, often alongside food insecurity<sup>(11-13)</sup>.

According to the latest global Demographic and Health Survey data for non-pregnant adolescent girls (15–19 years) (Lelijveld *et al.*, unpublished results), the prevalence of thinness ranges between 2% in the Europe and Central Asia (ECA) region and 7% in South Asia (SA). On the other hand, the East Asia and Pacific (EAP) region demonstrates a 4% prevalence of overweight and obesity, compared with a prevalence of 40% in Middle East and North Africa (MENA) region. Anaemia prevalence has remained high, affecting approximately 26% of adolescent girls in ECA and 52% in West and Central Africa (WCA). Given the rapidly transitioning patterns of malnutrition experienced in LMIC, as well as the limited inclusion of both girls and boys during later childhood and adolescence in monitoring of nutrition indicators at national and regional levels, exploration into available data describing the burden of malnutrition within and between regions is needed. In addition, better understanding of the determinants of malnutrition in these age groups, including dietary patterns, as well as differences according to age, sex and setting (e.g. rural *v.* urban), would be valuable in developing and targeting interventions.

To date, few interventions have been implemented to improve nutritional status in 5–19-year-olds. Additionally, while previous systematic reviews have explored evidence from interventions which tackle specific nutrition indicators (e.g. overweight and obesity<sup>(14)</sup>) and/or via specific approaches (e.g. lifestyle modification<sup>(15)</sup>) reviews have failed to explore interventions targeting all forms of malnutrition in LMIC via diverse approaches, while taking into account context-specific prevalence and determinants of malnutrition across global regions.

Thus, this review aims to (1) summarise available evidence on the nutritional status of school-age children and adolescents (5–19 years) from LMIC in seven global

regions and (2) describe evidence on the design, primary outcome(s) and main findings of interventions implemented to improve malnutrition in this population.

## Methods

In preparing this paper, data were compiled from seven scoping literature reviews conducted by the authors focusing on LMIC within the following seven UNICEF-defined world regions: EAP; ECA; SA; WCA; Eastern and Southern Africa (ESA); MENA; and Latin America and the Caribbean (LAC). Due to the heterogeneity in the availability, design and outcomes of studies across countries, scoping review methodology was used to ensure that studies were not excluded based on systematic review criteria and that research gaps related to the heterogeneity of research in the area could be identified. All reviews were conducted between January 2020 and January 2021 to summarise the nutritional status of school-age children and adolescents (5–19 years old), as well as interventions implemented to target malnutrition in this population.

### Search strategy

Literature searches were carried out using the PubMed, Embase, Cochrane, Web of Science (ESA and MENA), Africa Wide Information (ESA), ADOLEC (LAC), Global Health (EAP) and ScienceDirect (ECA) databases. A population, interventions, control and outcome (PICO) framework (Table 1) was used to define search terms (Supplementary Appendix A) and to guide the screening of articles. The results were reported according to the PRISMA guidelines for scoping reviews.

### Screening of articles and selection of studies

For all of the reviews, the search results were extracted and imported into reference management software (Mendeley or EndNote X9). All duplicates were removed, and the results were screened by a single researcher, based on their title and abstract. Full texts were then screened for eligibility according to the following criteria:

### Inclusion criteria

- Guided by the PICO framework (Table 1)
- Peer-reviewed publications, with conference abstracts (LAC; EAP; ECA) and grey literature (EAP) included in some cases
- Only human studies
- No restrictions on study design
- Articles in English, Portuguese, French or Spanish
- Articles published since 2005 (ECA, ESA, MENA), 2010 (LAC, EAP, WCA) and 2016 (SA, due to the availability of a UNICEF analysis, including literature published between 1990 and 2015<sup>(16)</sup>)

**Table 1** Population, interventions, control and outcome (PICO) framework

Population	Intervention	Comparison	Outcome
School-age children and adolescents 5–19 years living in low- and middle-income countries (LMIC) in each of the following UNICEF-defined global regions: East Asia and Pacific (EAP); Europe and Central Asia (ECA); South Asia (SA); West and Central Africa (WCA); Eastern and Southern Africa (ESA); Middle East and North Africa (MENA); Latin America and the Caribbean (LAC)	None required Any intervention type (ESA, MENA, LAC), or any intervention that successfully improved nutritional status (EAP, ECA, SA, WCA)	None required	Prevalence of: <ul style="list-style-type: none"> <li>• Stunting</li> <li>• Wasting</li> <li>• Thinness</li> <li>• Overweight and/or obesity</li> <li>• Anaemia and/or Fe deficiency</li> <li>• Iodine deficiency and/or goitre</li> <li>• Vitamin A deficiency</li> <li>• Vitamin D deficiency</li> <li>• Zn deficiency</li> <li>• Dietary intakes and/or patterns</li> </ul>

Outcome definitions and classifications: stunting, height-for-age  $<-2$  standard deviations (sd) below the WHO Child Growth Reference median; wasting, weight-for-height  $<-2$  sd below the WHO Child Growth Reference median<sup>(90)</sup>; thinness, BMI-for-age  $<-2$  sd below the WHO Growth Reference median<sup>(90)</sup>; overweight, BMI-for-age  $>+1$  sd above the WHO Growth Reference median OR BMI-for-age expressed as  $\geq 85$ th percentile of the CDC growth reference OR BMI-for-age equivalent to BMI  $\geq 25$  kg/m<sup>2</sup> using International Obesity Task Force (IOTF) cut-offs by sex; obese, BMI-for-age  $\geq +2$  sd above the WHO Growth Reference median OR BMI-for-age expressed as  $\geq 95$ th percentile of the CDC growth reference OR BMI-for-age equivalent to BMI  $\geq 30$  kg/m<sup>2</sup> using IOTF cut-offs by sex<sup>(90–92)</sup>; anaemia, children  $<12$  years (haemoglobin, Hb,  $<115$  g/l), children 12–14 years and females 15+ years (Hb  $<120$  g/l), males 15+ years (Hb  $<130$  g/l); iron deficiency, serum ferritin  $<15$   $\mu$ g/l; iron-deficiency anaemia, various classifications used but involve a combination of anaemia and concurrent low ferritin level (iron deficiency + Hb  $<120$  g/l)<sup>(93)</sup>; iodine deficiency, median urinary iodine concentration (UIC)  $<100$   $\mu$ g/l<sup>(94)</sup>; goitre, grade 1 – a goitre that is palpable but not visible when the neck is in the normal position (i.e. the thyroid gland is not visibly enlarged), nodules in a thyroid that is otherwise not enlarged fall into this category; grade 2 – a swelling in the neck that is clearly visible when the neck is in a normal position and is consistent with an enlarged thyroid gland when the neck is palpated<sup>(95)</sup>; vitamin A deficiency, serum retinol concentrations  $<0.70$   $\mu$ mol/l<sup>(96)</sup>; vitamin D deficiency, 25(OH)D  $<20$  ng/ml (deficiency), 25(OH)D 21–29 ng/ml (insufficiency)<sup>(97)</sup>; zinc deficiency, children  $<10$  years (serum zinc  $<65$   $\mu$ g/dl)<sup>(98)</sup>.

### Exclusion criteria

- Children and/or adolescents with a diagnosed disease (including COVID-19), with an addiction, or who were pregnant
- EAP and SA reviews excluded studies with a sample size of  $n < 100$ , due to the large number of results

### Data extraction

Data for the following outcomes of interest were extracted from relevant research articles for each regional literature review: stunting, wasting; thinness, overweight and/or obesity, anaemia and/or Fe deficiency, iodine deficiency and/or goitre, vitamin A deficiency, vitamin D deficiency, Zn deficiency and dietary intakes and/or patterns. Definitions and classifications of outcomes are provided with Table 1. Results are pooled by region to allow for regional comparisons. Available data describing determinants of nutrition outcomes, including differences by age, sex and setting (rural *v.* urban), are also discussed in narrative findings per outcome.

Since this paper aimed to provide a comprehensive overview of the available literature describing the nutritional status of adolescents and school-age children, and because the number of studies for individual countries and/or outcomes of interest varied substantially within and across regions, a formal risk of bias assessment was not carried out, in order to avoid excluding relevant studies. Due to the heterogeneity of studies and the limited results for many countries, it was not possible to conduct a meta-analysis or to apply weighting criteria to individual study results. The regional prevalence ranges provided are therefore based on the lowest and highest prevalence described across countries within the region.

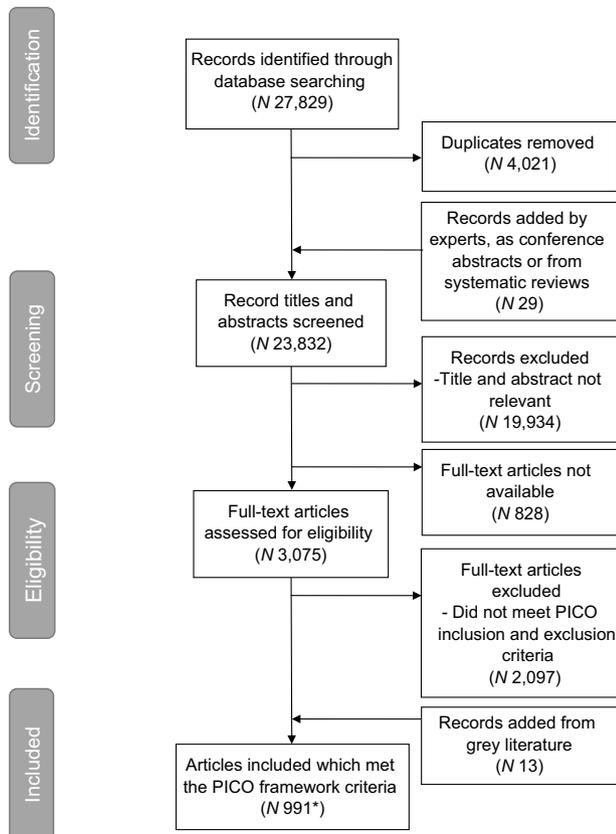
### Results

#### Availability of research articles

Figure 1 presents a flow diagram of the search results across the seven literature reviews. A total of 27 829 articles were identified for title and abstract screening. Following full text screening of 3075 articles, a total of 991 were included (a full list of all included studies by region can be found in Supplementary Appendix B).

Summaries of the available evidence for countries within each region are depicted in Fig. 2(a) to (g). SA was the region represented in the largest number of studies ( $n$  247), with most data available from India ( $n$  144). Nigeria, in WCA, was also represented in a large number of studies ( $n$  96), as was Turkey ( $n$  72) in ECA region. There were large discrepancies in the availability of evidence across contexts, and even within regions. For example, WCA had a relatively large number of total studies ( $n$  193); however, twelve of the twenty-four countries were represented in only three or fewer studies. A particularly low number of published studies were available for the LAC region ( $n$  96), with twenty out of thirty-seven countries having no relevant published studies.

Figure 3 depicts the number of studies reporting data for each nutrition outcome by global region. A summary of the number of studies reporting data for anthropometric indicators and anaemia by country and region is provided in Supplementary Appendix C. The majority of studies reported data for the prevalence of overweight and/or obesity ( $n$  511), followed by thinness ( $n$  293), with the highest number of studies for both indicators coming from SA ( $n$  125 and  $n$  108, respectively) and the lowest from LAC



**Fig. 1** Flow diagram of search results. PICO, Population, Interventions, Control and Outcome; \*Of the 991 articles included, the breakdown of articles per region was: South Asia, *n* 247; West and Central Africa, *n* 193; Europe and Central Asia, *n* 122; Eastern and Southern Africa, *n* 130; Middle East and North Africa, *n* 120; East Asia and Pacific, *n* 112; Latin America and the Caribbean, *n* 67

region (*n* 39 and *n* 11, respectively). Data describing the prevalence of stunting (*n* 179) and wasting (*n* 60) were more limited. The region with the most studies on stunting prevalence was WCA (*n* 55), while ECA and MENA had the fewest studies (*n* 8 each). Almost half (*n* 28) of the studies presenting data on wasting prevalence were conducted in ESA (mainly in Ethiopia, *n* 14), with eighteen studies being available for WCA (mainly in Nigeria, *n* 10). For the remaining regions, between one and five studies presented data on wasting prevalence. The majority of studies reporting data on the prevalence of anaemia and/or Fe deficiency and/or Fe deficiency anaemia (IDA) (*n* 162) came from SA (*n* 48) and the least from MENA (*n* 8) and ECA (*n* 7). Fewer studies were available for other micronutrient deficiencies: iodine deficiency and/or goitre (*n* 58), vitamin A deficiency (*n* 36), vitamin D deficiency (*n* 47) and Zn deficiency (*n* 26). The availability of evidence varied by region, with SA (*n* 14) and EAP (*n* 13) predominantly reporting data on iodine deficiency and/or goitre, ESA (*n* 10) and WCA (*n* 9) predominantly reporting data on vitamin A deficiency and MENA (*n* 14) predominantly reporting data on vitamin D deficiency.

## Narrative results per nutrition outcome

### Stunting

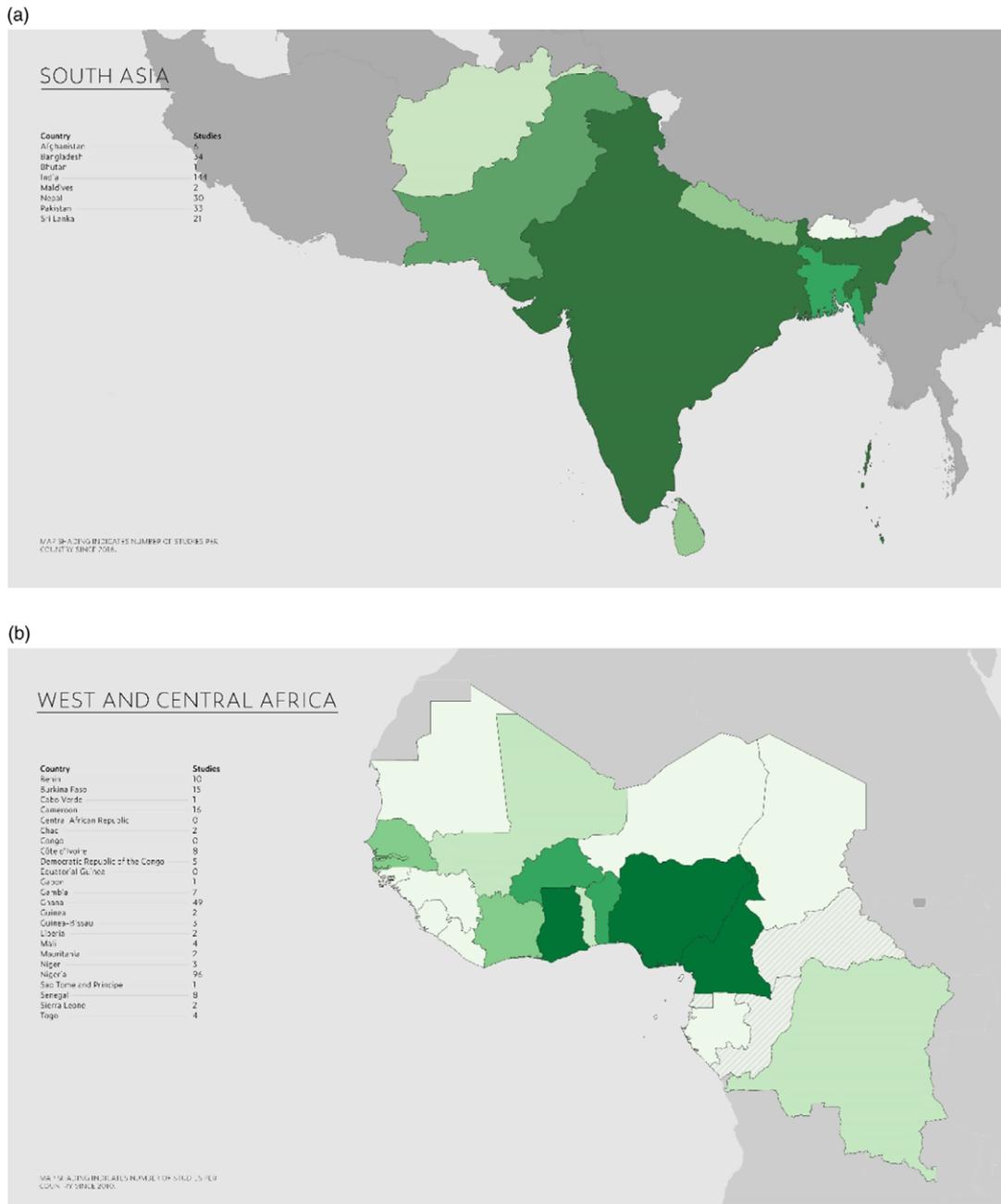
The lowest prevalence of stunting was documented in Brazil (1.7%)<sup>(17)</sup>, in LAC region, and the highest was in the Democratic Republic of the Congo (61.0%)<sup>(18)</sup>, in WCA (Fig. 4(a) and Supplementary Appendix D). Results for sex differences in stunting prevalence varied between studies; however, the prevalence was consistently higher in boys in ESA and WCA. One study in LAC demonstrated a higher risk of severe stunting in boys<sup>(19)</sup>. While longitudinal data from EAP showed a decline in stunting prevalence with age (up to 15 years)<sup>(20)</sup>, cross-sectional data from EAP and SA suggested a higher prevalence of stunting at older ages<sup>(21–28)</sup>. Across regions (LAC, ESA, WCA, SA), rural children and adolescents were more likely to be stunted than their urban counterparts. Other predictors of stunting included malaria parasitaemia, low socio-economic status (SES), parental (or father's) unemployment status, a lower level of maternal education, attending a public *v.* a private school and being born to a single mother with higher parity. Lower nutrition knowledge, skipping breakfast, infrequently consuming snacks and having lower poultry consumption were also associated with higher stunting prevalence. Data from LAC and WCA showed that stunted children were more likely to be anaemic<sup>(29)</sup> and to have low memory and cognitive scores<sup>(30)</sup>, respectively.

### Wasting

The lowest documented prevalence of wasting was in WCA region (0.3% in Cameroon)<sup>(31)</sup>, and the highest was in Ethiopia (58.3%), in ESA<sup>(32)</sup> (Fig. 4(b) and Supplementary Appendix D). Data from ESA showed differences in how wasting prevalence have changed over time, with repeated cross-sectional surveys conducted in Mozambique between 1992 and 2012 showing a decline from 19.0% to 12.0% (8–15 years of age)<sup>(33)</sup>, while national data from Zimbabwe indicated a very slight increase in wasting prevalence from 3.1% in 2009 to 3.6% in 2011<sup>(34)</sup>. In WCA region, public (*v.* private) schooling, a rural (*v.* an urban) dwelling and low (*v.* high) SES were predictors of wasting in school-age children and adolescents.

### Thinness

Nauru and Vanuatu, in EAP region, had the lowest documented prevalence of thinness (0.0%)<sup>(35,36)</sup>, while the highest prevalence was documented in Nigeria (95.7% (within country range: 5.6%–95.7%))<sup>(37)</sup>, in WCA (Fig. 4(c) and Supplementary Appendix D). There was substantial variation in the prevalence of thinness within regions, with the lowest prevalence in WCA being 0.6% in Cameroon<sup>(38)</sup>. Pooled analysis in SA found that, while the prevalence of thinness had declined over time, the overall burden had increased, due to growing population sizes<sup>(39)</sup>. Data from WCA, MENA, ESA and EAP showed a higher prevalence of thinness in boys compared with

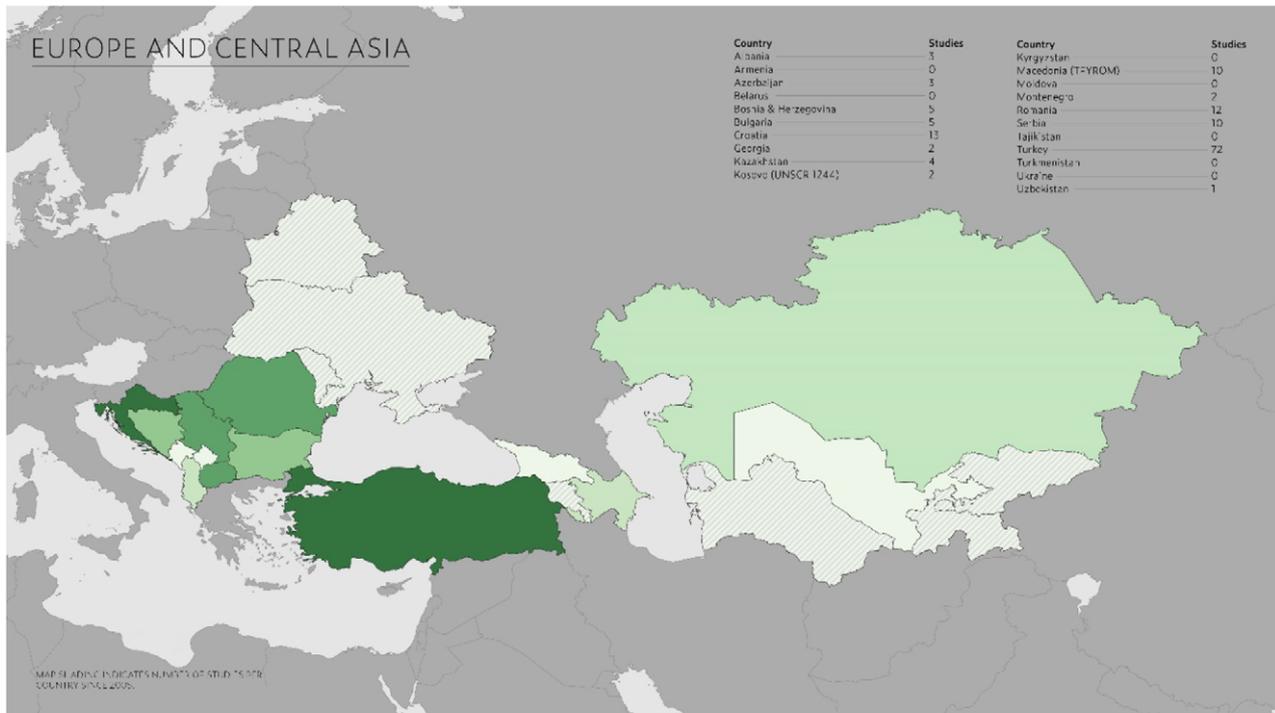


**Fig. 2** Maps depicting the number of studies with data available from single-country and multi-country studies in the following regions: a, South Asia; b, West and Central Africa; c, Europe and Central Asia; d, Eastern and Southern Africa; e, Middle East and North Africa; f, East Asia and the Pacific; g, Latin America and Caribbean. (a) □, 0; ■, 4–17; ■, 31–39; □, 1–3; ■, 8–30; ■, 40+; (b), □, 0; ■, 3–5; ■, 9–15; □, 1–2; ■, 6–8; ■, 16+; (c) □, 0; ■, 3–4; ■, 8–12; □, 1–2; ■, 5–7; ■, 3+; (d) □, 0; ■, 4–17; ■, 31–33; □, 1–3; ■, 8–30; ■, 34+; (e) □, 0; ■, 3–4; ■, 7–13; □, 1–2; ■, 5–6; ■, 4+; (f) □, 0; ■, 3–4; ■, 7–13; □, 1–2; ■, 5–6; ■, 4+; (g) □, 0; ■, 3–4; ■, 6–8; □, 1–2; ■, 5–6; ■, 9+

girls. The same pooled analysis of national and sub-national surveys in SA also showed a higher prevalence of thinness in boys<sup>(39)</sup>; however, other individual studies from SA showed mixed evidence for sex differences. Older age was positively associated with thinness in

LAC and MENA, but negatively associated in SA. In WCA, public (*v.* private) schooling, a rural (*v.* an urban) dwelling and low (*v.* high) SES were predictors of thinness. Thinness was also associated with public (*v.* private) schooling in SA, and with lower SES in SA and ECA. Rural

(c)



(d)

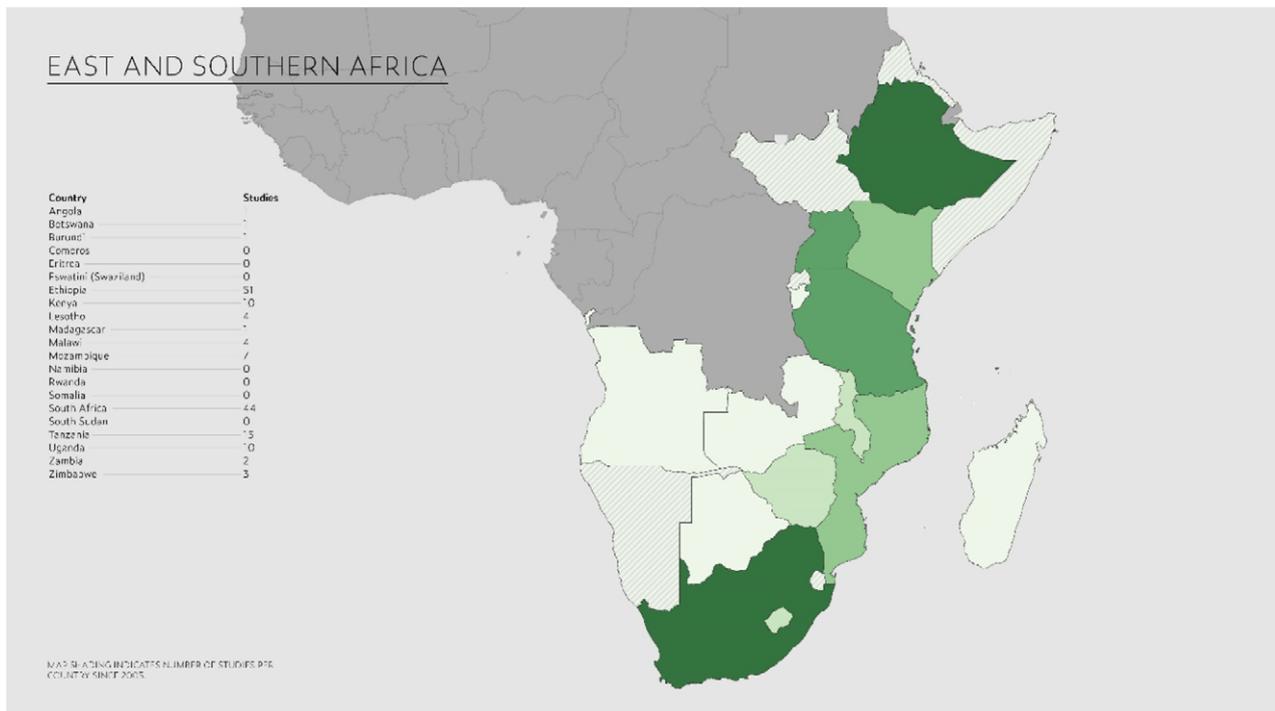


Fig. 2 (continued)

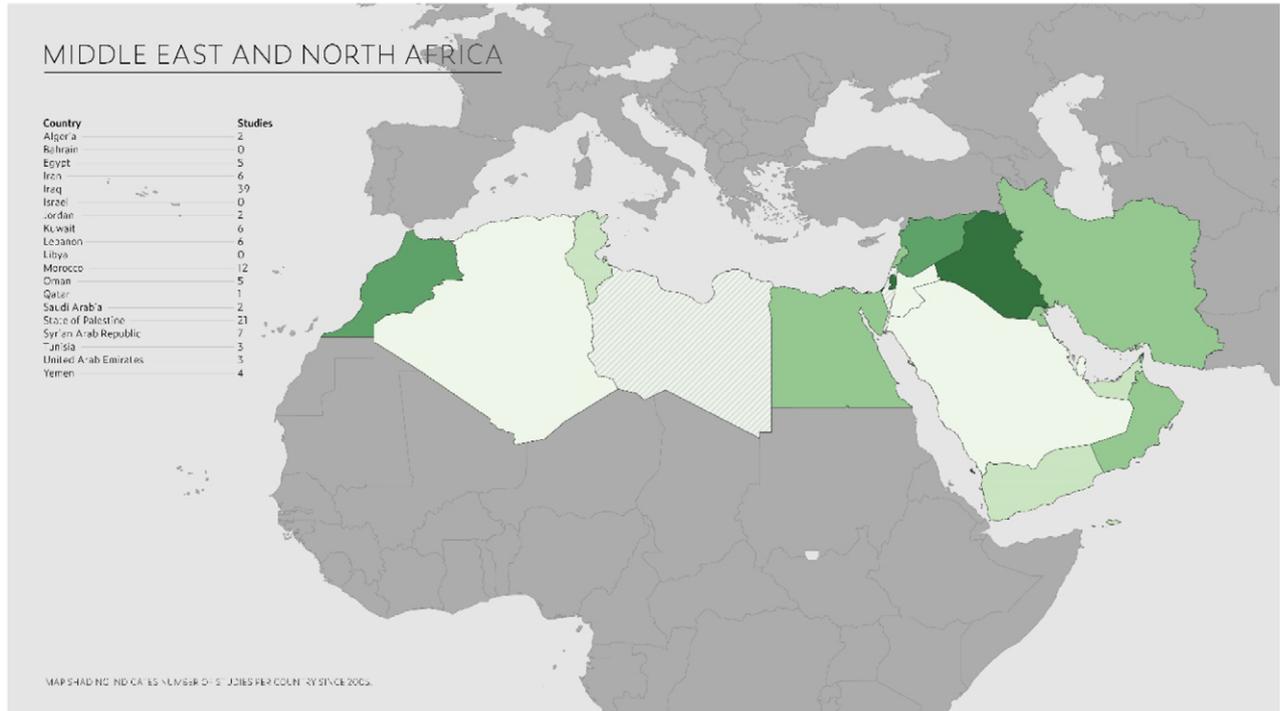
dwelling was positively associated with thinness in some, but not all, studies in SA. Other predictors included larger family size and living in joint families, lower levels of maternal education and father’s literacy, poor dietary diversity, poor water, sanitation and hygiene (WASH) practices and a history of illness. Food insecurity and

maternal unemployment were predictors of thinness in MENA.

*Overweight and obesity*

The range of overweight and obesity prevalence varied widely within and between regions (Fig. 4(d) and

(e)



(f)

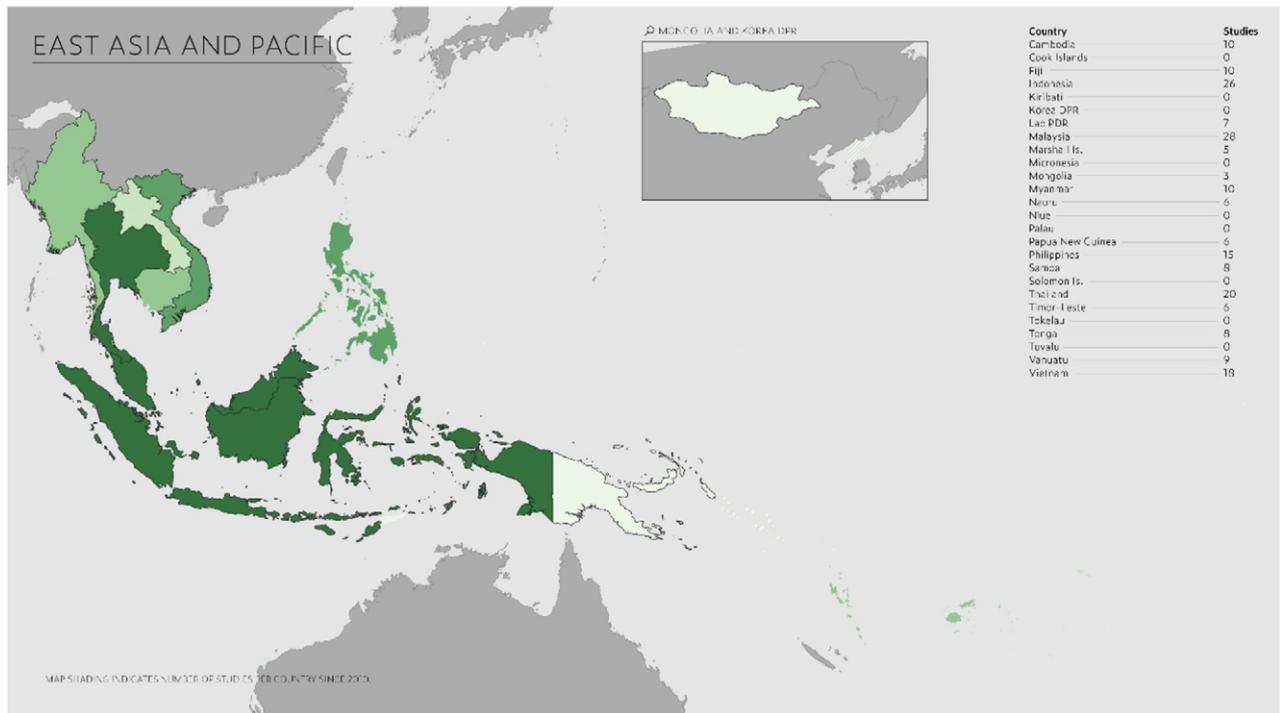


Fig. 2 (continued)

Supplementary Appendix D). The lowest documented prevalence rates for overweight and obesity were 0.0%, using data from Nigeria (WCA)<sup>(40–42)</sup>. The highest prevalence of overweight was 73.0% in Brazil (LAC)<sup>(43)</sup>, and

the highest obesity prevalence was 37.2% (Nigeria in WCA and Venezuela in LAC)<sup>(44,45)</sup>.

In some regions (LAC, MENA, SA), results for sex differences in overweight and obesity prevalence were

(g)

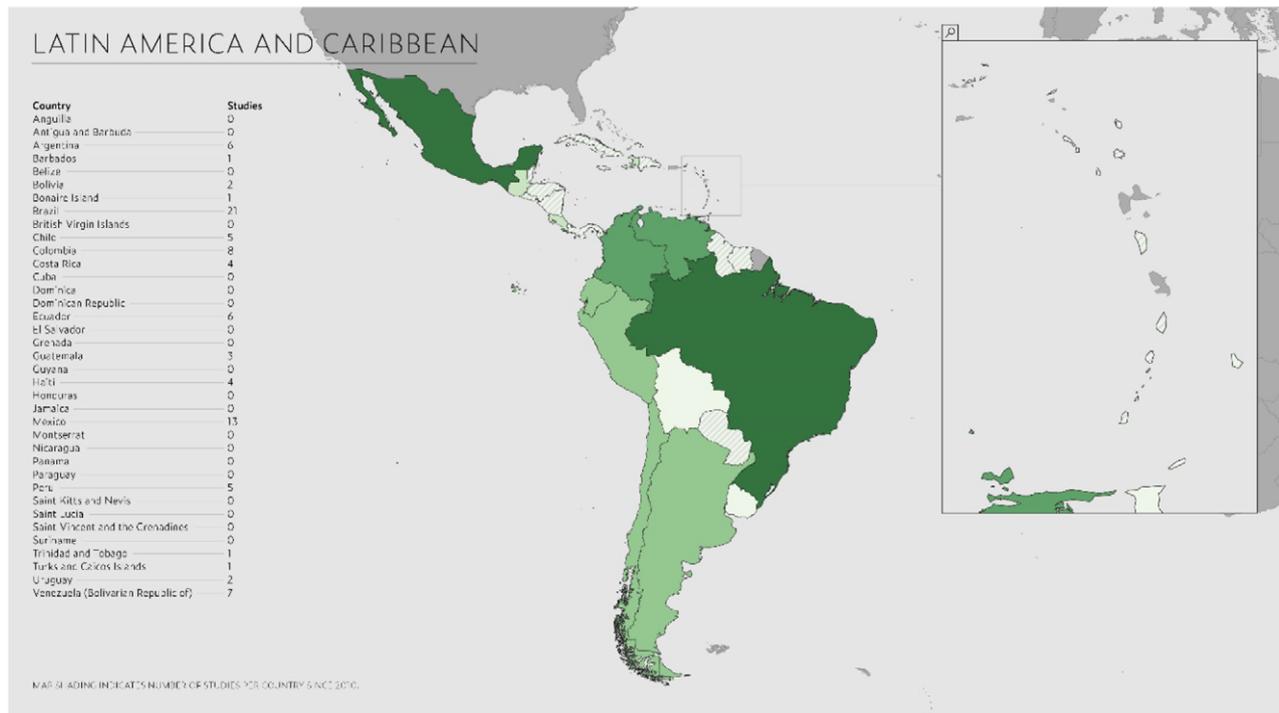


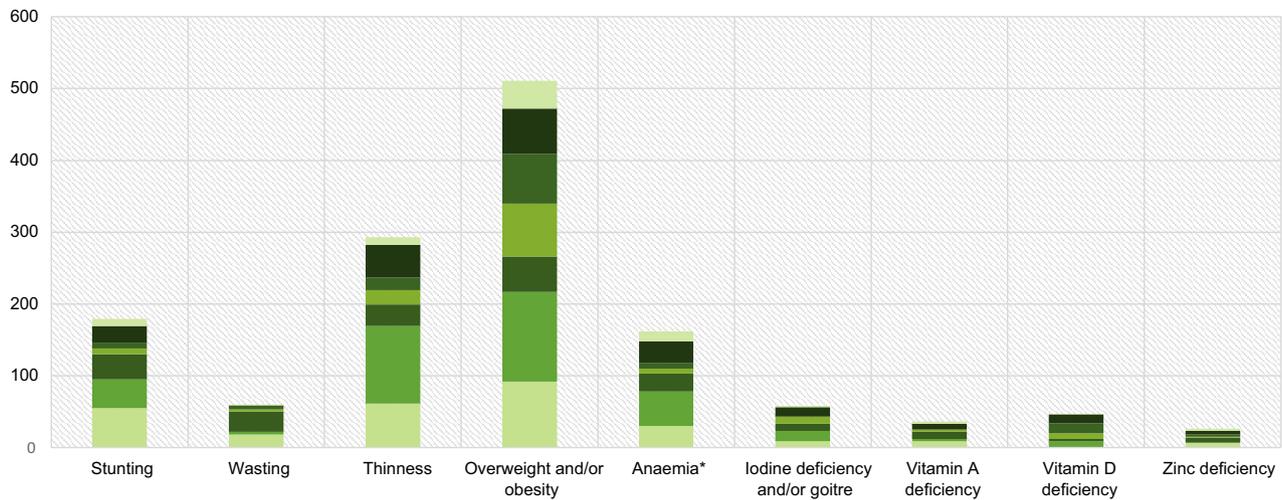
Fig. 2 (continued)

mixed; however, studies in WCA and ESA showed consistently higher overweight and/or obesity prevalence rates in girls. Age-related differences in prevalence also varied, with studies in EAP and ECA suggesting higher prevalence of overweight and obesity in younger ages and those in ESA suggesting an increase with age. Private schooling (LAC, ESA, SA), urban dwelling (ECA, ESA, SA, WCA) and higher SES (ECA, ESA, SA, MENA, WCA) were consistently identified as risk factors for overweight and obesity. Dietary behaviours positively associated with overweight and obesity across regions included higher intakes of processed snacks, sugar-sweetened beverages, fast-food, total sugar and lower intakes of fruit and vegetables, as well as skipping breakfast, purchasing food at school, visiting restaurants more frequently and purchasing more food from street vendors. Lower levels of physical activity and/or more time spent being sedentary or using screens on digital devices also increased the risk of overweight and obesity, while higher levels of maternal/parental education reduced the risk. A higher maternal BMI and parental obesity, as well as higher family income and being more food secure, were positively associated with overweight and obesity in adolescents. Data from WCA showed that adolescents with overweight and obesity were more likely to have high systolic blood pressure and a distorted body image.

### Micronutrient deficiencies

#### Anaemia and iron

There were wide ranges in anaemia prevalence documented within countries, as well as between countries and regions (Fig. 4(e) and Supplementary Appendix D). The lowest prevalence of anaemia was found in LAC region (3.9%, in Mexico)<sup>(46)</sup> and the highest in EAP (98.5%, in Indonesia)<sup>(47)</sup>. Fewer studies reported on the prevalence of Fe deficiency and/or IDA; however, available data showed that Fe deficiency prevalence ranged from 3.7% in Nepal (SA)<sup>(48)</sup> to 71.3% in Ghana (WCA)<sup>(49)</sup>, with IDA prevalence ranging from 0.2% in Malaysia (EAP)<sup>(50)</sup> to 37.4% in Ethiopia (ESA)<sup>(51)</sup>. In LAC, the prevalence of anaemia (and of stunting and thinness) was consistently high in studies from Haiti and Venezuela, as well as in indigenous and underserved/rural (*v.* urban) populations, children and adolescents attending public (*v.* private) schools and for children and adolescents from low (*v.* high) SES households. Similar findings for associations between living in slum or rural areas and low SES and anaemia prevalence were documented in ECA, ESA and SA. Other predictors of anaemia in SA included low dietary diversity – particularly linked to irregular consumption of green leafy vegetables, milk, egg, fruits and meat – worm infestation, lack of Fe and folic acid supplementation and poor hand washing



**Fig. 3** Total number of studies reporting data for anthropometric indicators, anaemia and micronutrient deficiencies by region. \*Includes studies that also provide data for iron (Fe) deficiency and/or Fe deficiency anaemia. ■, West and Central Africa; ■, South Asia; ■, Eastern and Southern Africa; ■, Europe and Central Asia; ■, Middle East and North Africa; ■, East Asia and the Pacific; ■, Latin America and the Caribbean

practices. There were mixed results for age- and sex-related differences in anaemia prevalence, with studies from some regions (LAC and WCA) presenting inconsistent results. For studies from other regions, some showed higher anaemia prevalence in girls (SA) and at older ages (SA, MENA), while others indicated higher prevalence in boys (ECA) or at younger ages (EAP).

#### *Iodine and goitre*

Across regions, data suggested low prevalence of iodine deficiency and/or goitre overall, due to implementation of effective salt iodisation programmes (Table 2). For example, nationally representative longitudinal data from Sri Lanka showed a reduction in the prevalence of iodine deficiency (2.7% to 1.6%) and goitre (18.0% to 1.9%) between 2000 and 2016<sup>(52)</sup>. However, there was variation within and between regions, with both the lowest (0.0% in Indonesia)<sup>(53)</sup> and the highest (88.1% in Papua New Guinea)<sup>(54)</sup> prevalence of iodine deficiency documented in EAP region. Data from studies in ECA, SA and WCA suggested a greater likelihood of iodine deficiency in girls and at older ages.

#### *Vitamin A*

Overall, the prevalence of vitamin A deficiency ranged from 0.0% in Nigeria (WCA)<sup>(55)</sup> and Turkey (ECA)<sup>(56)</sup> to 74.0% in (SA)<sup>(57)</sup> (Table 2). There were also wide ranges in the prevalence of vitamin A deficiency documented within countries where more than one study was available (e.g. between 0.0% and 51.5% prevalence in Nigeria)<sup>(41,55)</sup>. Few studies disaggregated data by sex and age; however, one study in EAP (Philippines) showed a higher prevalence of vitamin A deficiency in children 6–12 years of age (10.7%) compared with those 13–19 years of age (4.0%)<sup>(58)</sup>.

#### *Vitamin D*

The prevalence of vitamin D deficiency ranged from 5% in Guatemala (LAC)<sup>(59)</sup> to 100% in Mongolia (EAP)<sup>(60)</sup> and Saudi Arabia (MENA)<sup>(61)</sup> (Table 2). In EAP and ESA, the prevalence of vitamin D deficiency was higher for urban adolescents than for their rural counterparts. Sex differences were also evident, with lower prevalence rates shown in boys from ECA, MENA and SA – potentially due to higher levels of sun exposure. There was also evidence of seasonal differences in vitamin D deficiency, with comparatively higher risk of deficiency at the end of winter in ECA and in summer in MENA (less time spent outdoors due to high temperatures). Other predictors of vitamin D deficiency in SA included low sun exposure, low Ca intake, use of sun protection and darker skin.

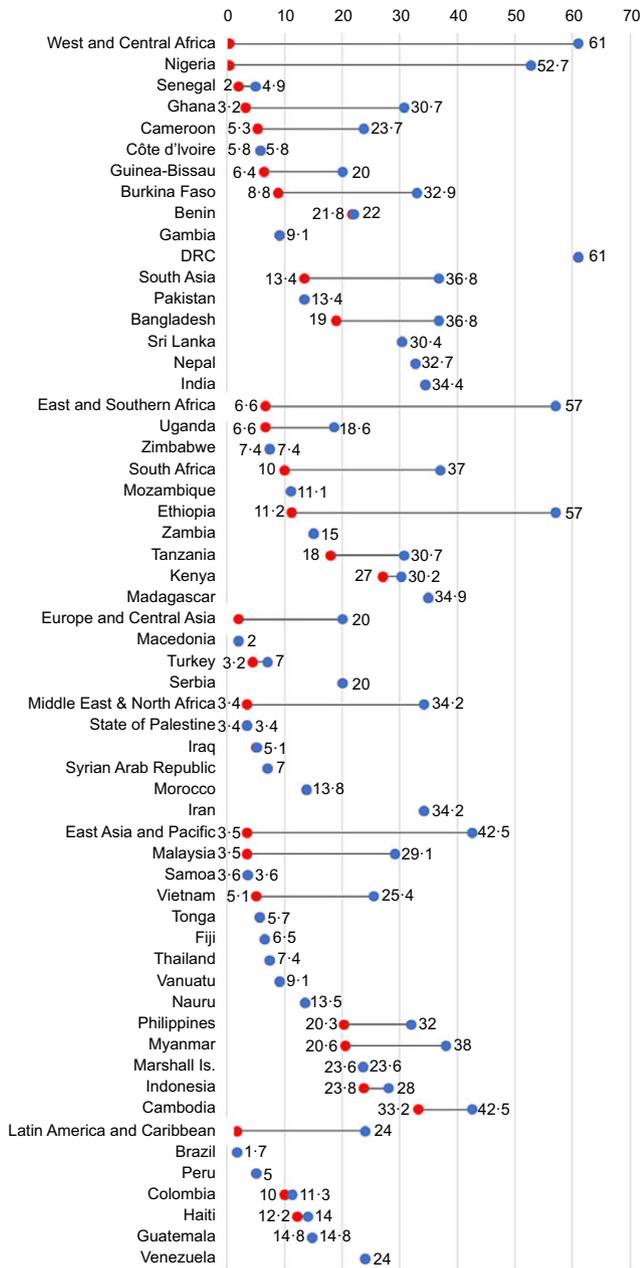
#### *Zinc*

Both the highest and lowest prevalence of Zn deficiency was documented in ESA; 3% in Kenya<sup>(62)</sup> and 75.6% in South Africa<sup>(63)</sup> (Table 2). Overall, studies from ESA showed a positive association between prevalence of Zn deficiency and being male, food insecurity and poverty, while data from Turkey (ECA) showed no differences in prevalence according to sex or SES.

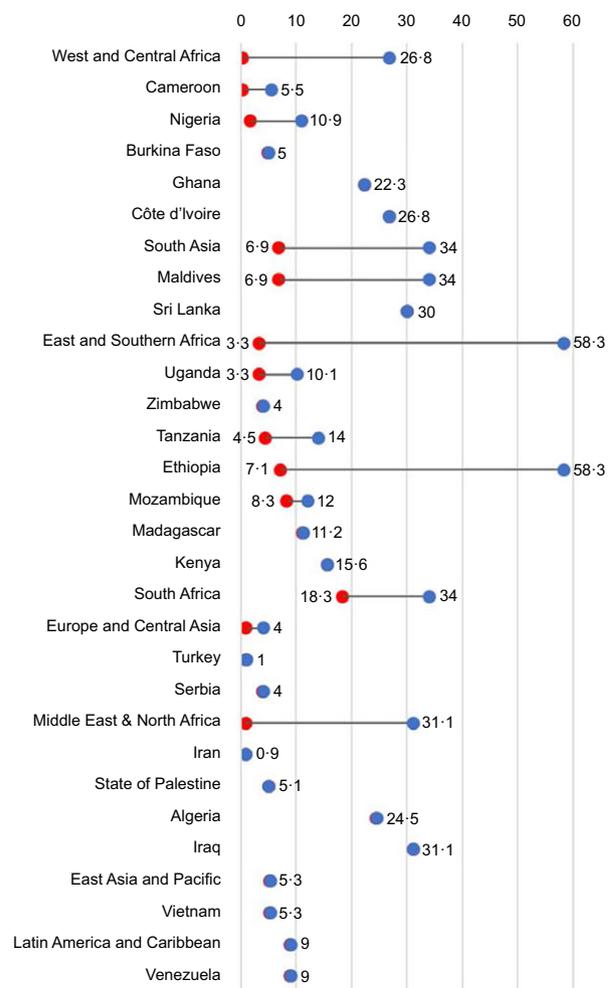
#### *Dietary intakes and patterns*

A total of 241 articles presented data on dietary intakes and patterns. The number of available studies ranged from fifty-four in WCA to eighteen in ESA. Methods for describing diets of school-age children and adolescents varied between studies; however, some commonly used indicators included assessment of food insecurity, nutrition knowledge, dietary intakes and patterns, dietary diversity, breakfast consumption and junk/fast-food consumption.

(a) Prevalence of stunting (%)



(b) Prevalence of Wasting (%)



**Fig. 4** Range in prevalence of nutrition indicators by country and region for: a, stunting; b, wasting; c, thinness; d: overweight and obesity; e, anaemia; red circles depict the lowest and blue circles the highest prevalence in the range; where only one value was available for a country only a single (blue) circle is depicted

Data collection for these indicators was questionnaire-based and included dietary assessment via FFQ (quantitative, semi-quantitative or non-quantitative) or 24-h-recall questionnaires (either on single or multiple days), as well as various other questionnaire tools. A summary of the commonly assessed dietary indicators and the main findings per region are provided in Table 3.

Overall, the findings showed that school-age children and adolescents commonly skipped breakfast, with some

studies suggesting that this was more likely in girls and in those from rural areas, as well as those experiencing greater household poverty. Food insecurity and a lack of affordability of, and access to, food (healthy diets in particular) was a strong driver of poor dietary diversity and unhealthy food choices. In contrast, some studies showed a reduction in dietary diversity for higher wealth categories that was often coupled with higher junk/fast-food consumption. There was evidence of

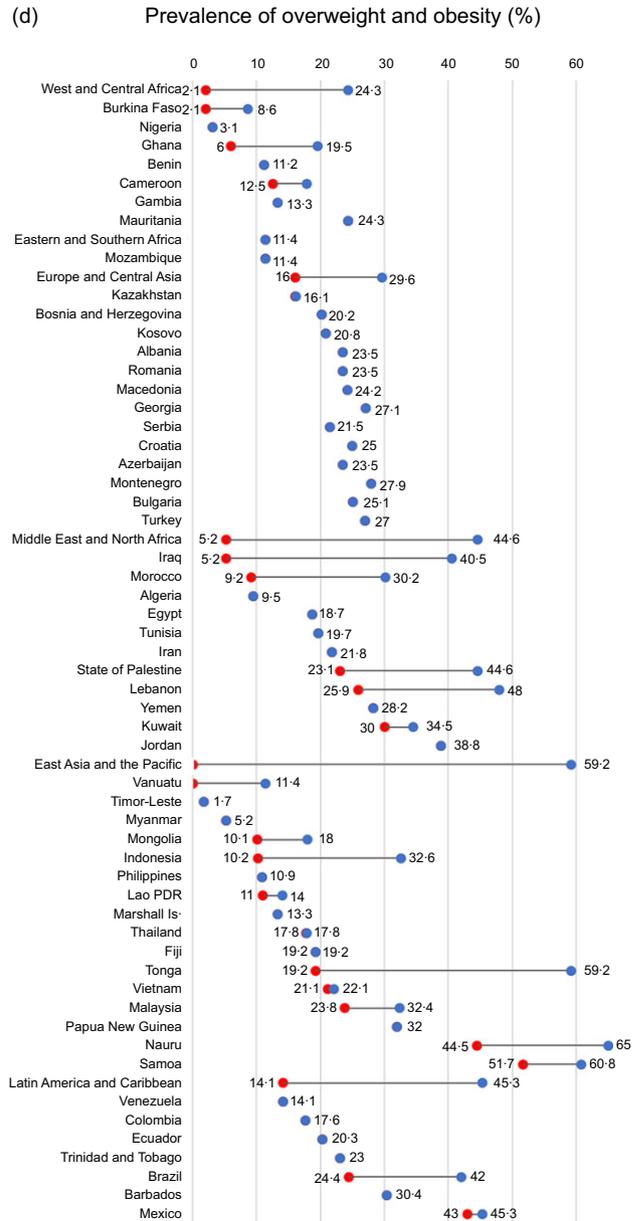
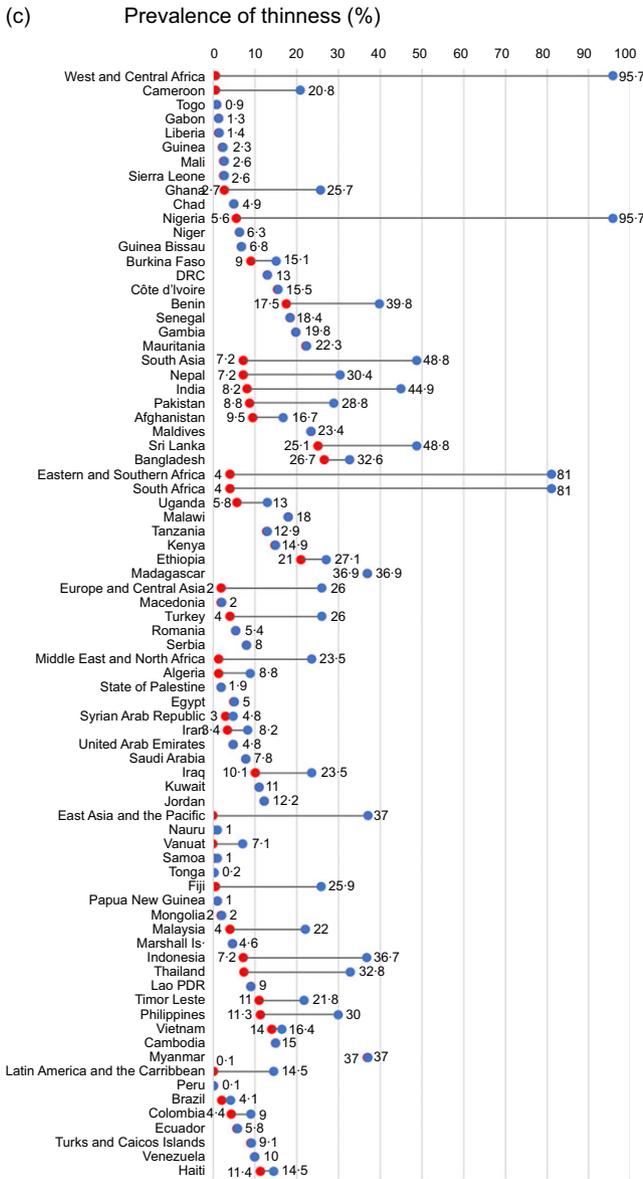


Fig. 4 (continued)

transitioning dietary patterns across regions, with diets varying between more traditional patterns (e.g. high intakes of cereals and grains, vegetables, nuts, seeds and legumes, coconut, local beverages and meat) and patterns increasingly high in processed foods, fats and oils, snacks, SSB and sweets. This was echoed in the food practices reported in all regions, where snacking, eating in restaurants and consuming high quantities of junk/fast-foods were increasingly common, and where intakes of micronutrient-rich fruits and vegetables were low. Where data on nutrition knowledge were available, this was found to be poor in MENA and ECA (between 7% and 14% demonstrating moderate or good levels of knowledge), but higher in SA and WCA. In Nepal (SA) specifically, knowledge around obesity was attributed to the inclusion of nutrition

education in the school curriculum. However, even in cases where adolescents reported having good knowledge on what constituted unhealthy foods, these items were commonly consumed. Besides affordability and access, dietary behaviours were influenced by a range of factors, including food advertising, children and adolescents' level of autonomy around food choices, seasonality and the views or practices of family members, peers and school administrators.

Interventions

A summary of the intervention studies, identified according to intervention type and primary outcome, is provided in Table 4. Intervention studies targeting malnutrition in school-age children and adolescents were limited in all

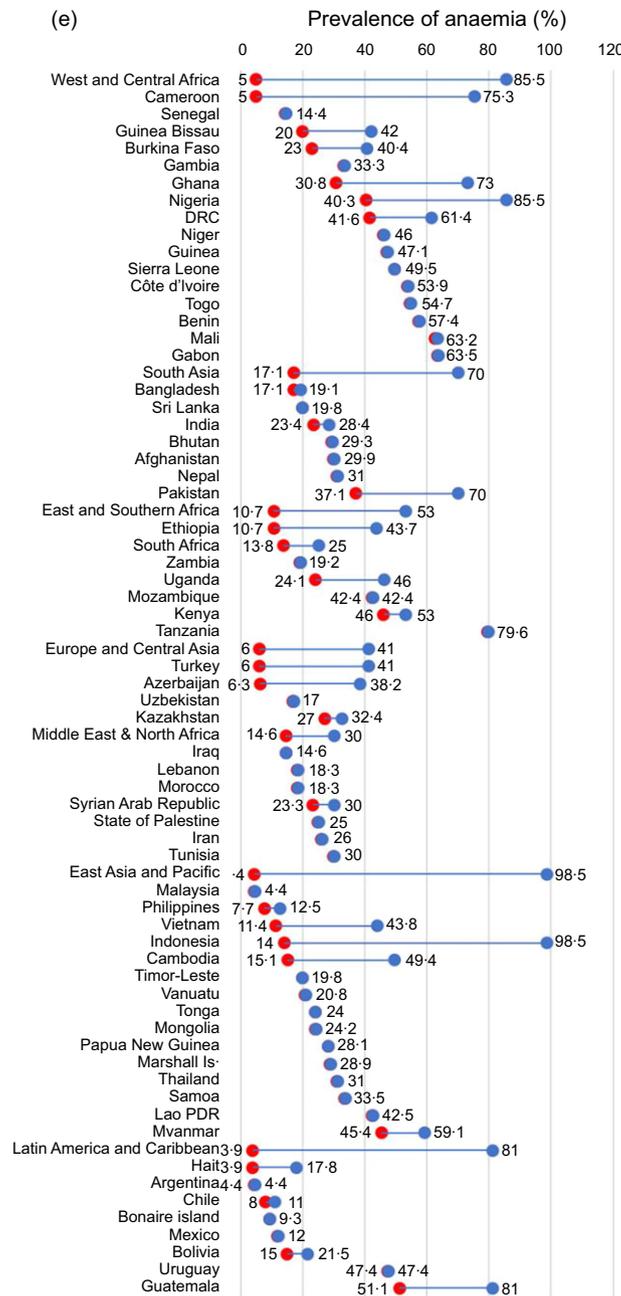


Fig. 4 (continued)

regions (*n* 103), with the most studies available in LAC (*n* 30). Little evidence was available from regions in Africa, especially in ESA (*n* 7) and from African countries in MENA (*n* 1). In regions where intervention studies were available, few countries were represented. For example, in LAC, two-thirds of the interventions took place in Mexico and Brazil (*n* 10 each).

The primary outcomes of interventions were anaemia and/or micronutrient deficiencies (*n* 42, 41% of intervention studies); overweight and obesity (*n* 33, 32%); undernutrition (stunting, wasting or thinness) (*n* 18, 17%) and improved nutrition knowledge or dietary practices

(*n* 10, 10%). Most interventions included boys and girls, with a total of 10 (10%) including girls only. A total of twenty-two intervention studies targeted school-age children (5–9 years), forty-three targeted adolescents (10–19 years) and the remaining thirty-eight included participants across these age groups. The majority of interventions were implemented in schools (*n* 98, 95%), with three being implemented at community or provincial level, one in a clinical setting and one in a university setting.

Interventions targeting micronutrient deficiencies (*n* 42) focused primarily on reducing the prevalence of anaemia and/or Fe deficiency via supplementation and fortified



**Table 2** Summary of available studies describing prevalence of micronutrient deficiencies in school-age children and adolescents, by region

Region	Iodine deficiency and/or goiter				Vitamin A deficiency		Vitamin D deficiency			Zn deficiency			
	<i>n</i>	<i>n</i> girls only	Iodine deficiency prevalence (% range)	Goitre prevalence (% range)	<i>n</i>	<i>n</i> girls only	Prevalence (% range)	<i>n</i>	<i>n</i> girls only	Prevalence (% range)	<i>n</i>	<i>n</i> girls only	Prevalence (% range)
West and Central Africa	9		1.6; 56.2	2.2; 73.5	9		3.0; 51.1	0			6		13.6; 69.0
South Asia	13	1	6.3; 31.8	2.2; 9.3	3		1.2; 74.0	9		8.4; 93.0	1		54.0
Eastern and Southern Africa	10		3.4; 86.0		8	2	4.1; 70.9	3		7.0; 42.0	6	1	3.0; 75.6
Europe and Central Asia	10		2.0; 13.0	7.0; 57.6	2	1*	0.0; 21.0	7	1	21.0; 80.0	1		27.8
Middle East and North Africa	0				0			12	2; 1, boys only	18.8; 100.0	3		12.4; 12.7
East Asia and the Pacific	13		0.0; 88.1	2.1; 9.3	8		1.0; 11.0	12		15.0; 100.0	5		21.6; 69.6
Latin America and Caribbean	2		5.3; 10.0		3		0.5; 11.6	1		5.0; 21.0	3		12.9; 21.6

\*Study conducted in women of reproductive age (15–49 years).

Iodine deficiency, median urinary iodine concentration (UIC) <100 µg/l<sup>(94)</sup>; goitre, grade 1 – a goitre that is palpable but not visible when the neck is in the normal position (i.e. the thyroid gland is not visibly enlarged), nodules in a thyroid that is otherwise not enlarged fall into this category; grade 2 – a swelling in the neck that is clearly visible when the neck is in a normal position and is consistent with an enlarged thyroid gland when the neck is palpated<sup>(95)</sup>; vitamin A deficiency, serum retinol concentrations ≤0.70 µmol/l<sup>(96)</sup>; vitamin D deficiency, 25(OH)D <20 ng/ml (deficiency), 25(OH)D 21–29 ng/ml (insufficiency)<sup>(97)</sup>; Zn deficiency, children <10 years (serum Zn <65 µg/dl)<sup>(98)</sup>; N indicates number of available articles presenting data on micronutrient deficiencies from single-country studies and from single-country studies including girls only; prevalence range per region based on the lowest and highest prevalence described across countries within the region.

**Table 3** Summary of commonly reported dietary indicators and main findings per region

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
West and Central Africa	54	1		- Adolescents demonstrated a good knowledge of a balanced diet and good hygiene practices, but adopting good practices was challenging due to economic circumstances and environmental conditions (Côte d'Ivoire)	<p>Mean <math>\pm</math> sd intakes/d (regional ranges): energy, 1365 <math>\pm</math> 23 kcal (Senegal, S) to 4177 <math>\pm</math> 7569 kcal (Ghana, G); protein, 36 <math>\pm</math> 1 (S) to 170 <math>\pm</math> 478 g (G); fat, 52 <math>\pm</math> 1 (S) to 142 <math>\pm</math> 355 g (G); carbohydrate, 176 <math>\pm</math> 3 (S) to 628 <math>\pm</math> 1279 g (G); Fe, 11 <math>\pm</math> 4.8 (Burkina Faso, BF) to 49 <math>\pm</math> 155 mg (G); Ca 344 <math>\pm</math> 247 (BF) to 605 <math>\pm</math> 1417 mg (G), Zn 6.2 <math>\pm</math> 2.9 (BF) to 6.6 <math>\pm</math> 3.1 mg (BF), vitamin A 334 <math>\pm</math> 255 (BF) to vitamin A 362 <math>\pm</math> 255 mcg RAE (BF); folate, 189 <math>\pm</math> 101 (BF) to 211 <math>\pm</math> 133 mcg DFE (BF); adolescents from higher SES groups more likely to consume excess energy from fat than those from lower SES groups</p> <p>% with inadequate intakes (regional ranges): energy, 67.8 % (Nigeria, N) to 99.0 % (Senegal, S); carbohydrate, 16.7 % (N); Fe, 46.0 % (S); Ca, 100.0 % (S); Zn, 69.0 % (S); vitamin A, 79.0 % (S); folate, 100.0 % (S)</p> <p>Derived dietary patterns: (i) 'sweet tooth pattern', high intakes of sugar-sweetened snacks and beverages and high-fat foods and (ii) 'traditional pattern', high in cereals and grains, local beverages, nuts, seeds and legumes, vegetables, and fish and seafood; pupils who lived with their parents took pocket money to school and those who lived in the wealthiest homes were more likely to follow the 'sweet tooth pattern' (Ghana)</p> <p>- Daily consumption of starchy staples and processed cereals (between 63.8 % and 96.7 %) and fats and oils were high (95.6 %), consumption of milk and milk products was low (between &lt;1.0 % and 47.8 %) and consumption of fruit and vegetables was very low (a third consumed these daily and &lt;1.0 % consumed at least two portions of vegetables per day) (Nigeria)</p>	-30.3 % of 6–12-year-olds had low DD (Nigeria)	- Skipping breakfast common: 12.2 % of school-age children skipped breakfast at least once per week and more than half of adolescents skipped breakfast occasionally or often; breakfast consumption more likely in those from rural settings (Nigeria)	-40.0–70.0 % of adolescents consumed savoury snacks, cakes/biscuits/puffs, sweets and fizzy drinks in the previous 24 h (Côte D'Ivoire)
					% with inadequate intakes (regional ranges): energy, 67.8 % (Nigeria, N) to 99.0 % (Senegal, S); carbohydrate, 16.7 % (N); Fe, 46.0 % (S); Ca, 100.0 % (S); Zn, 69.0 % (S); vitamin A, 79.0 % (S); folate, 100.0 % (S)	- Mean $\pm$ sd DD of school-age children and adolescents ranged from 6.5 $\pm$ 1.6 (out of a maximum of 14) to 9.3 $\pm$ 1.9 (maximum score of 12) (Ghana)	-28.0 % of school-age children never ate breakfast and between 13.8 % and 31.0 % of adolescents did not eat breakfast often ( $\leq$ 3–4 d/week); breakfast consumption more likely in those attending private v. public schools (Ghana)	-60.2 % of adolescents consumed fast-food at least once per week, 75.6 % often ate sweets and between 51.5 % and 87.9 % drank soft drinks daily or often (Nigeria)
						-22.2 % of school-age children and adolescents had high DDS ( $\geq$ 6 food groups) (Nigeria)	- Breakfast skipping positively associated with lack of food in the household and lack of pocket money (Nigeria)	- Between 56.4 % and 63.3 % of children and adolescents ate chips, sweets and/or chocolates, 48.4 % ate fried foods and 53.4 % drank SSB 3 or more times/week; higher intakes in children attending private v. public schools (Ghana)
								- Sweet and energy-dense food consumption was more likely in adolescents who consumed more food outside the home (Benin)



Table 3 Continued

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
					<ul style="list-style-type: none"> <li>- Half of adolescents rarely ate fruit and vegetables (<math>\leq 4</math> d/week) (Ghana)</li> <li>- <math>\leq 5.0\%</math> of adolescents consumed <math>\geq 5</math> portions of fruit and vegetables per day in urban and rural settings; urban adolescents were more likely to consume at least one soft drink per week (Burkina Faso, Ghana, Nigeria)</li> <li>- Girls reported engaging more in healthy eating behaviours than boys (Ghana)</li> <li>- Seasonality and gender norms (boys afforded more opportunities than girls) were major determinants of adolescent diets (the Gambia); seasonality particularly affected fruit and vegetable consumption (Ghana)</li> </ul>			<ul style="list-style-type: none"> <li>- Regular snacking was more common in girls than boys (Nigeria)</li> </ul>
South Asia	53		<ul style="list-style-type: none"> <li>- 25.8% of adolescents reported that they had sometimes gone hungry in the last month and 13.9% reported that they had always gone hungry (Nepal)</li> <li>- A third of adolescents experienced food insecurity every month (Pakistan)</li> </ul>	<ul style="list-style-type: none"> <li>- Knowledge on obesity linked to inclusion of nutrition education in the school curriculum (Nepal)</li> <li>- Approximately a quarter of adolescents had adequate knowledge of fast-food; girls had better levels of knowledge than boys (India)</li> </ul>	<ul style="list-style-type: none"> <li>- Mean intakes per day (regional ranges): energy, 1597 to 2186 kcal (Bangladesh, B); vitamin A, 163 to 222.4 UG RAE (B); Vitamin D, 0.8 to 1.2 <math>\mu\text{g}</math> (B); Ca, 213.9 to 282.6 mg (B), Zn, 6.6 to 9.1 mg (B)</li> <li>- % with inadequate intakes (regional ranges): energy, 27.8% (Bangladesh, B) to 35.0% (India, I); protein, 45.7% (I); fat, 54.2% (I); Ca, 14.4% (I) to 83.9% (B); Fe, 12.1% (I) to 72.0% (B); vitamin A, 56.4% (B) to 76.3% (B); Zn, 17.0% (I) to 49.5% (B); folate, 29.2% (I); higher intakes of energy, carbohydrate, protein and fat, vitamin B<sub>12</sub>, total folate and dietary fibre among urban adolescents</li> <li>- Diets predominantly cereal-based, with cereals providing between 64.0% and 70.0% of total energy intakes (India)</li> <li>- Inadequate meat consumption; meat intake increased with increasing wealth (India)</li> </ul>	<ul style="list-style-type: none"> <li>- Low DD across studies; 58.0% of adolescents meet MDD (India, Bangladesh)</li> <li>- Lowest DD in younger adolescents and those from rural/tribal communities and least affluent households (India, Bangladesh)</li> <li>- Boys more likely to have a more diverse diet (India, Bangladesh)</li> </ul>	<ul style="list-style-type: none"> <li>- Proportion of adolescents who skipped breakfast ranged from 5.5% to 43.4% (India, Bangladesh)</li> <li>- Rural adolescents more likely than urban counterparts to skip breakfast (Pakistan)</li> <li>- Girls more likely to skip breakfast than boys (India)</li> </ul>	<ul style="list-style-type: none"> <li>- High prevalence of snacking and fast-food consumption in majority of studies, including high intakes of chips, chocolate, bakery products, SSB (India, Nepal, Pakistan, Bangladesh)</li> <li>- Junk food consumption higher in urban areas and in those attending private v. public schools (India)</li> <li>- Girls reported more frequent consumption of junk food, packaged and ready-to-eat foods, non-green leafy vegetables and added fat than boys (India, Pakistan); other studies showed no sex differences (India)</li> <li>- Taste and convenience were main reasons reported for consuming junk food (Bangladesh)</li> </ul>

Table 3 Continued

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
					<ul style="list-style-type: none"> <li>- Low intakes of fruit and vegetable across countries in individual studies (India, Pakistan, Bangladesh, Sri Lanka); data from Global School-Based Student Health Surveys (2009–2017) showed low fruit and vegetable intakes as: 85.2% (Afghanistan), 83.6% (Bangladesh), 90.2% (Maldives), 90.7% (Nepal), 90.0% (Pakistan), 75.8% (Sri Lanka)</li> <li>- Urban v. rural adolescents: higher energy, carbohydrate, protein, fat, vitamin B<sub>12</sub>, total folate and dietary fibre intakes; higher consumption of animal protein, junk food, and fruit, and vegetables, but lower consumption of milk products (India)</li> <li>- Mixed results for sex differences in dietary patterns: in some cases, boys consumed a more adequate diet with greater variety than girls, being more likely to consume protein- and vitamin-rich foods; in other cases, girls were shown to consume more cereals, vegetables and fruit (India)</li> <li>- Mixed results on the effect of age on healthy diets (India)</li> </ul>			
Eastern and Southern Africa	18	4			<ul style="list-style-type: none"> <li>- % with inadequate intakes (regional ranges): energy, 69.0% (Malawi, M); fat, 21.0% (M); protein (no protein consumed in previous day), 18.3% (Tanzania)</li> <li>- Some studies show that more traditional diets continue to be consumed, including bread (urban settings), cassava, coconut, vegetables, meat and fats, with variable contribution of animal products (Mozambique, Malawi, Ethiopia)</li> <li>- Some studies highlight an increase in processed diets high in starchy foods, fats and oils, snacks, SSB and sweets (Botswana, South Africa, Uganda)</li> </ul>	<ul style="list-style-type: none"> <li>- Between 32.0% and 80.0% of children and adolescents did not meet MDD across studies (Ethiopia, Malawi, Uganda)</li> <li>- Mixed results for factors associated with low DD; more likely in Muslim adolescents from higher wealth categories in one case, but associated with rural dwelling and food insecurity in another (Ethiopia)</li> <li>- Low DD more common at a younger age (Ethiopia)</li> </ul>	<ul style="list-style-type: none"> <li>- Breakfast skipping was common (Malawi, South Africa); only 28.4% of children had breakfast before school in Malawi</li> <li>- Decrease in breakfast consumption between 13 and 17 years of age (South Africa)</li> <li>- Breakfast skipping associated with limited food in the household (South Africa)</li> </ul>	<ul style="list-style-type: none"> <li>- Junk/fast-food consumption was common; particularly foods high in sugar and fat, processed snacks and SSB (Uganda, South Africa, Mozambique)</li> <li>- Longitudinal increase in fast-food consumption and snacking while watching TV between 13 and 17 years of age (South Africa)</li> <li>- SSB intakes associated with private v. public schooling and higher SES (Ethiopia)</li> </ul>



Table 3 Continued

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
					<ul style="list-style-type: none"> <li>- Longitudinal reduction in micronutrient-rich foods and increase in foods high in sugar, salt and fat (South Africa)</li> <li>- Low fruit and vegetable consumption across studies (South Africa, Lesotho, Uganda, Malawi); e.g. 91.4% of adolescents in Lesotho consumed less than three portions of vegetables per day and 84.6% consumed less than two portions of fruit per day</li> </ul>		<ul style="list-style-type: none"> <li>- Girls less likely to eat breakfast (Uganda)</li> </ul>	<ul style="list-style-type: none"> <li>- 18.8% of adolescents bought unhealthy snacks from tuck shops daily and 54.3% bought these weekly (Lesotho)</li> <li>- Unhealthy food choices influenced by adolescents' autonomy around making food choices, as well as the affordability and accessibility of healthy food; parents also influenced food choices, commonly purchasing these foods for their children (South Africa, Botswana)</li> <li>- Higher consumption of high-sugar and fried foods in girls v. boys (Uganda, South Africa)</li> </ul>
Europe and Central Asia	27			<ul style="list-style-type: none"> <li>- Low nutrition knowledge, with 7.0% of adolescents having good nutrition knowledge (Serbia)</li> </ul>	<ul style="list-style-type: none"> <li>- Mean intakes per day (regional ranges): energy, 1876 (Turkey) to 2803 kcal (Serbia, S); protein, 14.0–15.0% total energy (S); fat, 39.0–40% total energy (S); carbohydrates, 45.0% total energy (S)</li> <li>- Inadequate intakes of protein, carbohydrates, fibre, vitamin E, vitamin D, folate and Ca, but adequate intakes of energy, total fat and Fe (Turkey)</li> <li>- Two-thirds of adolescents consumed at least one animal product and at least one portion of fruit or veg per day (Turkey)</li> <li>- Adolescents whose parents were more educated had higher proportions of energy consumed as fat and protein (Turkey)</li> <li>- Evidence that food advertising influences dietary behaviours, with greater exposure to healthy food adverts being associated with higher consumption of healthy foods (Romania)</li> <li>- Vegetables contributed 3.0–4.0% of total energy intake and fruit contributed 7.0–8.0% (Serbia)</li> </ul>	<ul style="list-style-type: none"> <li>- 18.0%, 59.0% and 23.0% of adolescents had low (<math>\leq 3</math>), mid (4–7) and high (<math>\geq 8</math>) dietary quality scores, respectively (Turkey)</li> </ul>	<ul style="list-style-type: none"> <li>- Daily breakfast consumption was high in some studies (between 78.0% and 92.0% in Turkey, Serbia) and moderate in others (between 46.0% and 64.0% in Hungary, Croatia, Macedonia, Ukraine and other studies from Turkey)</li> <li>- Longitudinal decline in breakfast consumption between 2002 and 2010 overall (Croatia, Macedonia, Ukraine, Hungary)</li> <li>- Breakfast intake declined with age (Turkey)</li> </ul>	<ul style="list-style-type: none"> <li>- High consumption of junk/fast foods: a third of adolescents consumed fast-food at least once per day, including SSB, chips and cake (Turkey)</li> </ul>
Middle East and North Africa	32	3; 1, boys only		<ul style="list-style-type: none"> <li>- Low knowledge of healthy eating overall; 86.0% of adolescents had poor nutritional knowledge, particularly on what constitutes healthy and unhealthy snacks and food items (United Arab Emirates)</li> </ul>	<ul style="list-style-type: none"> <li>- % with inadequate intakes (regional ranges): energy, 55.7% (boys), 64.8% (girls) (Palestine, P); protein, 15.1% (boys), 43.1% (girls) (P); Ca, 88.0% (girls and boys) (Lebanon), and 74.6% (boys), 83.4% (girls) (Morocco); high v. low SES associated with higher energy, protein, fat, vitamin A, vitamin C and Fe intakes (Lebanon)</li> </ul>		<ul style="list-style-type: none"> <li>- Between 36.0% and 65.5% of adolescents skipped breakfast daily (United Arab Emirates, Egypt, Iran, Bahrain, Palestine)</li> </ul>	<ul style="list-style-type: none"> <li>- Fast-food consumption and eating in restaurants common (Saudi Arabia, Iran, United Arab Emirates, Bahrain)</li> </ul>

Table 3 Continued

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
				<ul style="list-style-type: none"> <li>- In cases where adolescents reported knowing certain foods were unhealthy, many still consumed them (Iran)</li> </ul>	<ul style="list-style-type: none"> <li>- Evidence of diets high in protein, sugar and fat, as well as high intakes of sweets, SSB and savoury snacks (United Arab Emirates Saudi Arabia, Bahrain, Tunisia, Iran, Kuwait, Palestine, Lebanon)</li> <li>- Evidence of diets low in milk, fruits and vegetables (Bahrain, Tunisia, Saudi Arabia, Iran, Kuwait, Palestine, Lebanon, United Arab Emirates)</li> <li>- A smaller number of studies showed diets that were rich in fruits and dried fruits, vegetables, fruit juices, low-fat dairy, legumes and corn (Iran, Tunisia, Lebanon); in Saudi Arabia, those of younger ages more likely to eat fruit and dairy daily</li> <li>- High SES was associated with more meals and higher energy intakes, as well as higher consumption of animal foods, fruit, vegetables and dairy (Lebanon, Palestine)</li> </ul>		<ul style="list-style-type: none"> <li>- Breakfast skipping more common in girls (Iran, Saudi Arabia)</li> <li>- More meal skipping in rural areas (Palestine)</li> </ul>	<ul style="list-style-type: none"> <li>- Qualitative data highlighted that snacking behaviour was influenced by behaviours of other students, family members, peers, school administrators and snack sellers (Iran)</li> <li>- Mixed results for sex differences; girls consumed more French fries, sweets and chocolates, but boys consumed more SSB and energy drinks (Iran, Saudi Arabia)</li> </ul>
EAP	26	3	<ul style="list-style-type: none"> <li>- Food insecurity common, particularly affecting areas where prevalence of overweight and obesity were higher</li> </ul>		<ul style="list-style-type: none"> <li>- Median intakes per day (Lao PDR): 1743 kcal (boys), 1490 kcal (girls); 79.8 % consumed inadequate energy</li> <li>- % with inadequate intakes (regional ranges): energy, 20.7 % (Indonesia, I) to 91.0 % (I); protein, 0.0 % (I) to 72.0 % (I); fat, 0.0 % (I) to 36.9 % (I); carbohydrates, 0.0 % (I) to 65.1 % (I); fibre, 81.7 % (I); Ca, 25.1 % (I) to 99.5 % (I); Fe, 21.3 % (I) to 92.0 % (I); vitamin A, 0.0 % (I) to 81.0 % (I); Zn, 38.0 % (Philippines, P) to 95.4 % (I); folate, 70.0 % (P) to 93.8 % (I)</li> <li>- More rural (72.0 %) v. urban (56.0 %) children did not meet their protein requirements (Indonesia)</li> <li>- Only 39.5 % consumed any fruits and vegetables daily (Indonesia)</li> </ul>	<ul style="list-style-type: none"> <li>- Low DD; the lowest 10<sup>th</sup> percentile of school children consumed only two of 14 food groups in the last week, while the 50<sup>th</sup> percentile consumed only five (Myanmar) and 46.2 % consumed &lt;5 food groups per day (Indonesia)</li> </ul>	<ul style="list-style-type: none"> <li>- 68.0 % of adolescents skipped breakfast at least once a week, 41.0 % skipped it ≥3 times (Fiji)</li> </ul>	



Table 3 Continued

Region	n	n girls only	Food insecurity	Nutrition knowledge	Dietary intakes/patterns	Dietary diversity	Breakfast consumption	Junk/fast-food consumption
Latin America and Caribbean	31		- Approximately half of adolescents experienced some level of food insecurity (Colombia)		- Mean intakes/d (regional ranges): energy, 1433 kcal (Venezuela, V) to 2378 kcal (Bolivia, B); protein, 13.8 % (Ecuador, E) to 17.1 % total energy (Brazil, B); carbohydrates, 51.8 % (Argentina, A) to 63.6 % total energy (Colombia, C); fat, 22.1 % (C) to 32.4 % total energy (A) - % with inadequate intakes (regional ranges): energy, 60.0 % (boys), 55.6 % (girls) (Bolivia, B); protein, 8.9 % (boys), 7.9 % (girls) (B); Ca, 83.0 % (boys), 86.7 % (girls) (B) to 99.8 % (boys), 100.0 % (girls) (Costa Rica, CR); Fe, 0.4 % (boys), 14.4 % (girls) (CR) to 20.0 % (boys), 41.1 % (girls) (B); vitamin A, 46.0 % (boys), 40.1 % (girls) (CR) to 83.0 % (boys), 82.8 % (girls) (B); Zn, 21.8 % (boys), 23.0 % (girls) (CR); folate, 1.7 % (boys), 13.6 % (girls) (CR) to 32.6 % (boys), 38.9 % (girls) (B) -14.0 % and 3.0 % of adolescents consumed $\geq 3$ portions of fruit and vegetables respectively per day and 87 % consumed at least one portion of meat, fish or poultry (Brazil) -81.2 % of adolescents ate $\geq 2$ meals/d and 65.0 % ate $\geq 1$ snack/d, while 14.5 % and 27.3 % consumed $\geq 2$ portions of vegetables and fruits, respectively (Turks and Caicos Islands) -90.0 % of adolescents did not consume five portions of fruit or vegetables daily (Uruguay) - Girls were more likely to eat $\geq 3$ meals/d than boys (Turks and Caicos Islands)	- Mean DDS ranged from 5.05 to 6.42 (out of a possible 14) (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, Venezuela)  - Mean DDS in Haiti was $4.4 \pm 1.6$	- Breakfast consumption was high; between 75.0 % and 81.6 % of adolescents consumed breakfast daily (Ecuador, Turks and Caicos Islands, Argentina)	- Between 64.0 % and 91.0 % of children and adolescents consumed SSB daily (Brazil)  - SSB consumption in the home was high (Chile)  -50.0 % and 24.0 % of adolescents consumed SSB and fast-food respectively $\geq 2$ times/week; intake was higher among adolescents of medium and high income than those from low-income households and fast-food intake specifically was higher in older adolescents (Uruguay)

DD, dietary diversity; DDS, dietary diversity score; MDD, minimum dietary diversity; SES, socio-economic status; SSB, sugar-sweetened beverage. A full list of study references by region is provided in Supplementary Appendix B.

**Table 4** Summary of intervention studies across world regions, according to intervention type and primary outcome

	Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
Single micronutrient supplementation										
Region (N <sup>n</sup> )	WCA (1)			ESA (1 <sup>1</sup> )	EAP (1)		EAP (1); MENA (2 <sup>1</sup> ); SA (1)	LAC (1)		
Duration (m)	12			5	3		3–6	9		
Main findings	- Ca carbonate: ↑ height at 15.5 years, earlier (7.4 m) age at peak height velocity (boys only) supplementation improved vitamin D status v. control in all cases			- Fe: ↓ anaemia prevalence v. control	- Vitamin A: improved Hb levels, Fe status; ↓ anaemia prevalence		- Vitamin D v. placebo OR v. oily fish/sunlight exposure + control: - Zn: ↑ serum Zn levels, ↓ Zn deficiency (2.6% overall); no difference for supplement v. control			
- Intervention group stopped growing earlier; significantly shorter at a mean age of 23.5 years (boys only)	- Supplementation more effective than oily fish consumption/sunlight exposure; greatest improvement as dose ↑ (i.e. 2000 mg > 1000 mg > 600 mg)									
MMN supplementation										
Region (N <sup>n</sup> )	EAP (1)			SA (1 <sup>1*</sup> )	EAP (1 <sup>1</sup> )	WCA (1)	SA (1)			
Duration (m)	5			6.5	4	6	6			
Main findings	- MMN: ↑ height, HAZ v. control			- IFA + vitamin B <sub>12</sub> v. IFA only: ↑ Hb	concentration, ↓ anaemia prevalence both groups	- MMN sprinkle: improved Hb levels, Fe status v. placebo (anaemic girls)	- MMN beverage: ↑ serum retinol, Zn v. control			
- IFA + vitamin B <sub>12</sub> : improved vitamin B <sub>12</sub> , greater improvement serum ferritin status v. IFA only	- Greatest effect on anaemia prevalence with sprinkle at lowest Fe dosage	- No effect on HB, serum ferritin concentrations v. control		- Vitamin D + Ca: improved vitamin D status; greater change in those with lower baseline levels						
Single v. MMN supplementation										
Region (N <sup>n</sup> )							LAC (1)			
Duration (m)							3			
Main findings							- Fe v. Fe + Ca: ↓ prevalence of IDA, Fe depleted stores in both groups			
Fortified beverages (including water) v. supplementation										
Region (N <sup>n</sup> )		EAP (1)				LAC (1)	EAP (1)	EAP (1)		
Duration (m)		3.5				6	2	6		

Table 4 Continued

	Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
Main findings		- MMN-fortified drink v. vitamin C-only drink: ↑ weight in both groups; greater effect with MMN				- MMN supplement + MMN-fortified milk v. MMN supplement + unfortified milk: ↓ prevalence Zn, Fe deficiency in both groups; greater effect in MMN supplement + MMN-fortified group	- Vitamin D-fortified milk: improved vitamin D status (↑ height) v. vitamin D supplement/unfortified milk groups	- Iodised drinking water v. iodised oil capsules: ↓ goitre prevalence, ↑ iodine status both groups		
		- Improved Hb levels, Fe status in both groups; improved Zn status, ↓ Zn deficiency in MMN group				- ↑ in vitamin A deficiency in both groups; smaller ↑ in MMN supplement + MMN-fortified group		- Lower risk of excess iodine in iodised water group		
Commercial fortification of staples										
Region (N <sup>a</sup> )				EAP (1)*						
Duration (m)				12						
Main findings				- Commercially fortified rice: improved Hb levels, ↓ prevalence of anaemia after one year						
Fortified foods										
Region (N <sup>a</sup> )	LAC (1); SA (1)	EAP (1)		ESA (1); SA (1); LAC (1)	EAP (3); LAC (2 <sup>1</sup> ); SA (1 + 1*); WCA (3)	ESA (1*); SA (2); WCA (1)				
Duration (m)	1–6.5	4		3.5–7	2–7	1–7				
Main findings	- MMN-fortified food product/snack: no difference in HAZ v. control	- Fe-fortified daily rice meal v. unfortified rice meal: ↑ weight both groups; greater effect in fortified group		- MMN-fortified rice: ↑ Hb levels v. control	-MMN-fortified biscuits: greater improvement in Hb levels, reduction in anaemia and Fe deficiency prevalence v. Fe supplement/placebo	- MMN-fortified biscuits/maize: ↑ Hb levels, ↓ prevalence of vitamin A, vitamin D deficiencies v. control; mixed results for effect on anaemia (improvement/no effect on prevalence demonstrated)				
	- Significant reduction in anaemia prevalence; improved levels of serum metabolites in intervention v. control	- Improved Hb levels in fortified group		- Fe + iodine-fortified salt: no improvement in anaemia prevalence in pooled efficacy trials	- MMN-fortified meal: improved vitamin A, Fe status, no effect Hb levels, anaemia prevalence					





Table 4 Continued

	Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
- Amaal Jaggery + pumpkin leaves: ↑ HB, vitamin C, Fe levels										
Direct meal provision										
Region (N <sup>n</sup> )	SA (1); WCA (1)	ESA (1)			SA (1)	ESA (1)				
Duration (m)	12–24	27			12	3				
Main findings	- Millet- v. rice-based meal: ↓ stunting prevalence (↑ BAZ)	- Daily school meal of maize, beans, greens (Githeri) with meat v. milk v. oil: ↑ rate of weight gain for all groups v. control (no meal)			- MMN salted meal: improved Fe status v. worsened status in control group	- ↑ provision of green leafy vegetables: no improvement in Hb, serum ferritin, serum retinol, Zn status				
	- Daily school meal: no effect on HAZ (or BAZ); influenced food allocation at household level, with intervention children receiving less family food in the home v. control	- All feeding groups: ↑ rate of increase in mid-upper-arm muscle area (lean body mass) v. control; greatest ↑ in rate for meat, then milk group; no overall ↑ in height								
		- ↑ total + arithmetic test scores in all groups v. control, steepest rate in meat group; meat + fat groups ↑ longitudinal performance in arithmetic tests v. milk + control groups								
Education + training of educators/school food providers										
Region (N <sup>n</sup> )									EAP (1)	
Duration (m)									3	
Main findings									- Nutrition training for school food handlers: improved healthy food provision in school	

Table 4 Continued

	Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
Online education programmes									- Some effect on knowledge and perceptions of healthy food for adolescents; behaviour change driven by change in food availability	
Region (N <sup>n</sup> )			EAP (1); LAC (2)							
Duration (m)			6–12							
Main findings			- Online healthy eating, physical activity education: no/small change in anthropometry; intervention group less likely to transition from normal weight to overweight during the study - Some improvement in behaviour (e.g. ↓ SSB intake)							
In-person education programmes										
Region (N <sup>n</sup> )		ESA (1 <sup>1</sup> )	ECA (2); LAC (4); MENA (1)					SA (1)	EAP (1)	LAC (2); MENA (1); WCA (2 + 1 <sup>†</sup> ); EAP (1)
Duration (m)		6	2.5–9					12	1	2–9
Main findings		- Nutrition education to improve consumption of pulses: ↓ wasting prevalence (by 3%) v. control	- Nutrition alone/nutrition + physical activity education: no/small change in anthropometry v. control (effect on likelihood of shifting between BAZ categories; normal weight to overweight and/or overweight to obese)  - Improved dietary behaviours (e.g. ↑ legume, vegetable intake; ↓ frequency of cookie, SSB intake in intervention v. control); beneficial effects on metabolic markers					- Nutrition/iodine education: ↓ in prevalence of excessive UIC; ↑ in iodine deficiency	Education materials + teaching on cosmetic OR health benefits of fruit and vegetables v. education materials only (control): improved knowledge in all groups; bigger improvement in intervention groups v. control  - Teaching on cosmetic benefits associated with improved attitude to fruit + vegetables, improved behaviour (amount, types, colours consumed) v. improved attitude	- Nutrition education using printed materials, in-person education/ game-enhanced approaches  - No effects of printed-only materials on behaviour; in-person approaches improved nutrition knowledge, healthy diet behaviours (e.g. improved macronutrient, micronutrient intakes, improved breakfast habits) v. control



Table 4 Continued

Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
		- ↑ amount of physical activity, overall lifestyle scores for intervention v. control						only in health benefits group	- Game-enhanced education approach: improved adolescents' healthy eating knowledge, attitudes, practices
Education + support/peer groups									
Region (N <sup>n</sup> )	SA (1)								
Duration (m)	12								
Main findings	- Health screening + education via teacher + peer-led sessions: improved diet, hygiene habits; ↓ thinness prevalence - Lack of parental involvement perceived to limit effects								
Social and behaviour change communication approaches									
Region (N <sup>n</sup> )	WCA (1)	LAC (11); SA (2); EAP (2); MENA (1)							LAC (1); SA (1); WCA (1)
Duration (m)	1-5	3-36							3-6
Main findings	- Nutrition education + physical education classes (+ nutrition education for teachers + parents): improved nutrition knowledge v. control; no significant change in dietary diversity	- Diet/diet + physical activity programmes for weight loss/obesity prevention: education, diet/energy counting techniques†, motivational play, goal setting, healthy cooking workshops, nutrition consultations, private calls/text messages; some included educational leaflets/ training for parents: no overall impact on BAZ across most programmes; some showed ↓ weight, WC, skinfold measurements v. control; those including parents and ongoing in-person/ communication support mechanisms showed more effect on ↓ BAZ, body composition							- Experiential learning/ game-based (cards, board games, clubs) diet/physical activity interventions: positive effects on perceptions of + preferences for healthy foods; ↑ consumption of fruit + vegetables, ↓ junk food + SSBs; ↑ engagement in physical activity

Table 4 Continued

	Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
	- Stunting prevalence lower in intervention v. control (no clarity on any changes from baseline)		- Sex differences in effects (n 1): intervention effect on ↓ BAZ in boys, but not in girls - Tailor-made dietetic intervention programme (overweight + obese adolescents): significant change in BMI percentile; ↓ energy, processed, high-sugar, high-fat foods/beverages, ↑ fruit intakes - Across interventions: positive effects on diet +/or activity behaviours: ↑ physical activity, fitness and ↓ sedentary time; ↑ vegetable intake, ↓ fried food; interventions involving parents showed ↓ availability of unhealthy foods, drinks, snacks at home							
Exercise programmes										
Region (N <sup>n</sup> )			WCA (1)							
Duration (m)			1							
Main findings			- Exercise programme: small reductions in body weight, BAZ							
Multi-component programmes										
Region (N <sup>n</sup> )	ESA (1); SA (1)	MENA (1)	EAP (2); LAC (3 <sup>1</sup> )						LAC (1)	
Duration (m)	12	6	6–18						7	
Main findings	- Comprehensive health programme, including deworming, vitamin A supplementation, healthcare referral, education on nutrition, sanitation: ↓ stunting prevalence in intervention v. control	- Classroom-based education + snacks: ↑ BAZ, total daily energy, fibre, protein, saturated fat, micronutrient intakes v. control	- Multi-component diet + physical activity programmes: nutrition education (adolescents with/without parents, teachers), physical activity classes, educational materials, interactive seminars/workshops, diet/activity diaries, parents' newsletters + text messages, life skills, food/built environment components (e.g. healthier school meals)						- Multi-component nutrition + health programme: education + workshops with children, parents, food kiosk staff	



Table 4 Continued

Stunting	Wasting/thinness	Overweight + obesity	Anaemia	Anaemia + Fe deficiency	Anaemia + other deficiency (+/- Fe)	Vitamin D deficiency	Other deficiencies	Nutrition knowledge	Dietary behaviours
- School garden + WASH, health, nutrition intervention: no effect on stunting, thinness v. school garden + education only (control); improved nutrition knowledge, healthy behaviours (e.g. fruit, vegetable consumption)		- Overall: no change in BMI for intervention v. control groups (non-significant reduction in obesity prevalence at 18-month follow-up in one study); significant reduction in WC in intervention v. control  - Intervention v. control groups: improved healthy food availability in school, home environments; improved diet behaviours of adolescents, including ↑ vegetable consumption, less high-sugar, high-fat foods, SSB; ↑ physical activity, ↓ screen, sedentary time							- Intervention associated with ↓ WC, ↓ consumption of unhealthy snacks, added sugar
Healthcare interventions		EAP (1†)							
Region (N <sup>n</sup> )		12							
Duration (m)		- Hospital + outpatient rehabilitation programme for overweight adolescents: health professional counselling for adolescents + parents, nutrition education, nutrition + exercise programmes							
Main findings		- No effect on weight loss; improvements in body composition, metabolic indicators							

EAP, East Asia and Pacific; ECA, Europe and Central Asia; SA, South Asia; WCA, West and Central Africa; ESA, Eastern and Southern Africa; MENA, Middle East and North Africa; LAC, Latin America and the Caribbean; BAZ, BMI-for-age Z-score; HAZ, height-for-age Z-score; MMN, multiple micronutrient; SSB, sugar-sweetened beverage; WC, waist circumference; *n* represents the number of interventions per region, of which <sup>n</sup> is the number implemented in girls only; duration refers to the range in duration across available studies.

\*Implemented at household/community/provincial level.

†Implemented in clinical setting.

‡Included university students (16–25 years).

A full list of study references by region is provided in Supplementary Appendix B.



food (e.g. biscuits or meals) and beverages (e.g. milk or water) ( $n$  20). The remaining micronutrient interventions either incorporated other micronutrients (iodine, vitamin A or multiple micronutrients; MMN) within anaemia reduction programmes ( $n$  8) or targeted other single-micronutrient deficiencies, including vitamin D ( $n$  7), iodine ( $n$  1), Zn ( $n$  3) and Ca ( $n$  2). The duration of interventions ranged from one to 12 months. Overall, benefits of supplementation and fortification were seen in improved Fe and vitamin D status, as well as Hb levels, reduced anaemia prevalence and reduced prevalence of vitamin A, Zn and iodine deficiencies in some cases. There was evidence of greater improvement in these outcomes from using fortification as compared with using supplementation and from using MMN approaches as compared with single micronutrients (particularly Fe) or iron and folic acid. Supplementation with vitamin D facilitated greater improvement in vitamin D status than either sunlight exposure or oily fish consumption, and while both iodised oil capsules and iodised water increased urinary iodine concentration (UIC), there was a greater risk of excess in those receiving capsules. One study in the Gambia showed that, while Ca supplementation facilitated greater linear growth and higher stature at 15 years of age for boys, it also resulted in earlier cessation of growth and shorter stature in adulthood (23 years)<sup>(64)</sup>.

The majority of interventions addressing undernutrition ( $n$  18) took place in SA ( $n$  5) and WCA ( $n$  4); the duration of interventions ranged from one to 27 months. The majority of interventions addressing overweight and obesity ( $n$  33) took place in LAC ( $n$  19) and EAP ( $n$  6) and ranged from 2.5 to 36 months in duration. The provision of food or beverages, particularly fortified with MMN, was associated with reductions in stunting and/or thinness. In cases where fortified foods did not effectively reduce stunting prevalence, beneficial effects on micronutrient status and anaemia prevalence were shown. In one study from Kenya, while food provided at school had no overall effect on height, gains in weight, lean muscle mass and cognitive function were observed, particularly when the meal included meat, rather than milk or oil<sup>(65)</sup>. Providing nutrition education and 'healthy' snacks (including sandwiches and fruit) in schools reduced thinness and increased daily intakes of energy, fibre, protein and micronutrients; however, saturated fat intake also increased. Other multi-component programmes, including a combination of school gardens, nutrition, WASH and health education, supplementation, deworming and healthcare referral, showed mixed effects on thinness and/or stunting; however, those that were ineffective in reducing stunting and thinness prevalence did show positive effects on nutrition knowledge and health behaviours (e.g. increased consumption of fruit and vegetables).

Interventions targeting overweight and obesity comprised a range of social and behaviour change communication (SBCC) approaches. These included educational

leaflets, in-person education and counselling, group learning and workshops, as well as interactive approaches (e.g. cooking classes, exercise programmes and game-based methods). Multi-component programmes that included a combination of nutrition education, diet and physical activity programmes, as well as targeting the food environment, the built environment and the building of life skills seemed most effective in improving access to healthy food in school or home environments, as well as improving behaviours related to diets and physical activity. Few interventions had any effect, or a large effect, on the overall prevalence of overweight and obesity; however, some studies documented beneficial effects on weight, body composition (waist circumference and skinfolds) and metabolic markers (e.g. glycaemic control). Programmes that were more successful in facilitating behaviour change and/or anthropometric changes often involved other stakeholders (e.g. parents and teachers) in the intervention programme. There was limited evidence of using novel approaches (e.g. social media platforms and game-based approaches) to engage children and adolescents. However, in Nigeria, two studies that incorporated game-enhanced approaches (board games, clubs and vouchers) to nutrition and health education showed positive effects on participants' knowledge and perceptions of healthy eating, promoted the consumption of more nutritious foods (e.g. fruits and vegetables) and facilitated more engagement in physical activity<sup>(66,67)</sup>.

## Discussion

This review summarises evidence on the burden of malnutrition in school-age children and adolescents in LMIC from seven global regions, as well as on interventions implemented to improve nutritional status. While a total of 990 studies were identified, large geographical data gaps were found to exist, due to the fact that the bulk of evidence concentrated on a small number of countries. Studies presenting prevalence data focused on certain anthropometric and nutrition indicators, particularly overweight and obesity, thinness and anaemia, with a dearth of evidence available on the prevalence of other micronutrient deficiencies. With the exception of the LAC and EAP regions, there was limited evidence available on interventions targeting the rising burden of overweight and obesity. The majority of interventions targeted micronutrient deficiencies (mainly anaemia and/or Fe deficiency). Thus, there was little acknowledgement across regions of the broader spectrum of nutrition challenges affecting adolescents, the similar and interrelated causes of undernutrition, overweight and obesity and micronutrient deficiencies and the benefits of double-duty actions to address these. In contrast, substantial evidence exists from high-income countries, including detailed data on food intake, the role of food environments and commercial marketing



and advertising (traditional and social media) in driving food choices and interventions targeting the rising burden of overweight and obesity<sup>(68,69)</sup>, and programmes such as school feeding are widely available<sup>(70)</sup>, despite the fact that the majority of the world's children and adolescents (5–19 years) live in LMIC<sup>(71)</sup>.

Despite limitations in data availability, evidence was found of an emerging double burden of malnutrition across world regions, with stunting and thinness remaining especially high in the WCA, ESA and SA regions. Overweight and obesity affected all world regions, especially countries in LAC, EAP and MENA, where prevalence rates were consistently high across countries. All regions were affected by anaemia, although there was variability between countries. Where data were available, most regions experienced high rates of iodine, vitamin A, vitamin D and Zn deficiencies. Dietary transitions associated with rapid urbanisation were evident across all regions, with diets high in energy-dense, processed and micronutrient-poor foods increasingly being consumed.

A large degree of methodological variability was observed across the studies included in this review, limiting our ability to compare findings within and between regions. In particular, inconsistencies in the use of reference populations (WHO, International Obesity Task Force, US Centers for Disease Control and context-specific references in some cases) and thresholds used to classify thinness, overweight and obesity limited the comparability between studies and may account for some of the variability described. Similarly, the lack of a universal method to assess diet diversity and/or quality in school-age children and adolescents meant that a range of methods and indicators were used. Studies lacked consistency in the age ranges examined, with subjects from various subgroups within the 5–19-year age range being included. There was also inadequate availability of sex-disaggregated data, as well as data for other subgroups, such as those out of school, those living in rural (*v.* urban) settings, those with disabilities and those in vulnerable contexts, such as refugee populations. There is a need for consensus on the methodology to be used in assessing the nutritional status of school-age children and adolescents, to allow for comparable assessments of the burden of malnutrition across global regions, as well as to set international and national targets and to monitor progress against agreed targets<sup>(72)</sup>.

A range of risk factors for nutrition outcomes were identified across studies. Our findings suggest that undernutrition (stunting, wasting and thinness) is more prevalent in boys, and overweight and obesity are more prevalent in girls, particularly as children age and transition through puberty and beyond. As supported by previous research, this may in part be because girls are less likely to be physically active and more likely to engage in sedentary behaviours (e.g. watching television)<sup>(73–75)</sup>, as well as being more likely to skip breakfast

and to consume foods high in fat and sugar. An absence of sex-related trends in food security and dietary patterns have also been demonstrated<sup>(73)</sup>.

There was consistent evidence that urban dwelling, being from a higher socioeconomic background, being more food secure and consuming breakfast and healthy snacks decreased the risk of undernutrition. Conversely, in more obesogenic environments, these same factors were associated with higher consumption of processed and junk/fast-food items, a greater likelihood of eating outside the home and a higher risk of overweight and obesity. In both cases, micronutrient deficiencies persisted. This highlights the increasingly ubiquitous nature of malnutrition in LMIC, and that, despite variations in nutritional outcomes between contexts, interventions that improve access to, and consumption of, healthy, diverse diets should be prioritised as double-duty actions to improve outcomes across the malnutrition spectrum. However, better insight into what drives poor diet and activity behaviours in children and adolescents, and how best to target boys and girls as they age, across diverse contexts, is critical in order to ensure that the barriers that exist to making healthy dietary choices are addressed. This will require a food systems approach to make nutritious, safe, affordable and sustainable diets available, appealing and aspirational, while contributing to long-term environmental sustainability and planetary health<sup>(76,77)</sup>.

Regarding intervention studies, it was found that the majority targeted anaemia through fortification or supplementation programmes, while those aimed at prevention or management of undernutrition, or overweight and obesity, were more limited. There were few studies in general, and there was little comparability between studies on intervention targets and the baseline nutritional status of subjects, as well as the type, dose and duration of the interventions implemented. This made it challenging to draw conclusions regarding effective intervention approaches for school-age children and adolescents.

However, our synthesis of evidence suggests that MMN-fortified foods or beverages may be effective in reducing micronutrient deficiencies, alongside weight gain, in undernourished populations. Supplementation and non-fortified food-based approaches were less successful, as was sunlight exposure in the case of vitamin D. Previous evidence from systematic reviews assessing the effects of fortified foods and beverages in adults, adolescents and children across high-, middle- and low-income countries have demonstrated varied results on anaemia and Fe status, with inconclusive effects on growth, morbidity and cognitive outcomes<sup>(78–80)</sup>. However, these reviews also highlighted similar issues around the comparability of findings. Other evidence has highlighted the benefits of MMN fortification and supplementation as compared with single-micronutrient approaches<sup>(81)</sup>. The recent *Lancet* Series on Maternal and Child Undernutrition Progress highlighted the strong evidence supporting MMN supplementation during



the antenatal period for improved birth outcomes and suggested the potential benefit of extending this into the preconception period for adolescent girls and young women in high-burden contexts<sup>(82–84)</sup>. Current WHO guidelines recommend daily Fe-only or weekly Fe and folic acid supplementation in menstruating, non-pregnant women and adolescents, depending on the anaemia burden<sup>(82,83,85)</sup>. However, evidence is lacking on implementation strategies to examine the acceptability and effectiveness of supplementation dose, delivery and duration, either for these guidelines or for MMN approaches<sup>(8)</sup>. Additionally, evidence is scarce regarding the benefits for nutritional status, development and morbidity in school-age children and adolescents in the short and longer term<sup>(86,87)</sup>, and further exploration is needed of the effectiveness of MMN programmes within a package of nutrition-specific and nutrition-sensitive interventions, for girls and boys and across contexts.

Interventions targeting overweight and obesity via education and SBCC strategies showed beneficial effects on nutrition knowledge; however, evidence on the impacts on behaviour change and growth outcomes was inconclusive. Most interventions assessed anthropometric outcomes over a short-term follow-up period (up to a year maximum), with only three studies (in LAC) following up between 18 months and 3 years. There is a need for multi-component programmes that start early and extend through the childhood and adolescent years, which consider the wider food environment, and which involve other stakeholders (peers, family and teachers), in order to facilitate behaviour change, improve dietary diversity and quality and improve nutritional status. Such strategies should provide effective double-duty approaches to promoting healthy growth and body size, as well as tackling micronutrient deficiencies across contexts, and should be proactive in those regions where undernutrition remains the priority and where overweight is rising. The use of novel technological approaches to engaging adolescents, as well as approaches designed by adolescents themselves, both of which were largely absent in our findings, are also critical in order to ensure that interventions appeal to adolescent needs and interests. Interventions that extend beyond schools (e.g. using health platforms and social/community-based platforms) are also needed to address the needs of the approximately one-in-five children and adolescents globally who do not attend school<sup>(88)</sup>.

### Limitations

This review has provided a comprehensive summary of available literature from seven global regions; however, methodological differences between the literature reviews feeding into this synthesis may have limited comparability. For example, three reviews included articles published since 2005 (ECA, ESA, MENA), three included articles

published since 2010 (LAC, EAP, WCA) and one included articles published since 2016 (SA). Additionally, the EAP and SA reviews excluded studies with sample sizes of  $n < 100$  and the EAP review also included data from grey literature. Despite differences in search criteria, the large number of search results in SA were comparable to those published in the UNICEF review<sup>(16)</sup>, specifically showing persistent burdens of stunting and thinness, alongside emerging burdens of overweight and obesity, which were higher in more affluent, well-educated and urban households. In reviews that did not screen according to sample size, only between 1.5% and 9.0% of studies had  $n < 100$  subjects, and in the EAP review grey literature corroborated the results from peer-reviewed publications. Thus, these differences were unlikely to substantially influence the overall findings per region. Similarly, due to the wide research and streamlining of methods, for example the databases searched, across literature reviews, it is feasible that some manuscripts from particular regions were overlooked; e.g. regional databases such as SciELO were not searched and may have provided additional studies for the LAC region. Future research that involves more targeted searches by researchers living in LMIC may be beneficial in filling some context-specific gaps in the data identified in this literature review synthesis.

As described above, differences in methodology between individual studies also limited comparability within and between countries and regions. This restricted our ability to draw conclusions on the burden of malnutrition and on effective interventions. It is also an important finding in and of itself: highlighting key research gaps, as well as a need for global consensus on the indicators used to describe nutritional status and to assess dietary quality in school age children and adolescents. In addition, previous findings have demonstrated a high degree of comparability between standards of weight classification (i.e. US Centers for Disease Control, International Obesity Task Force and WHO growth standards) in adolescents and in their associations with health outcomes<sup>(89)</sup>. This suggests that the potential for misclassification of anthropometric outcomes between studies is likely to be small overall.

### Conclusion

Globally, persistent food insecurity, poor growth and micronutrient deficiencies continue to plague school-age children and adolescents, as the new challenge of obesity emerges. Despite this, the persistent absence of these age groups across research, policy and programming means that the limited information available is neither standardised nor comparable. Consensus is urgently needed on methods for assessing nutritional status and its determinants (e.g. dietary intake and quality), in order to set targets



and monitor progress. In addition, an understanding of double-duty interventions is needed, to ensure that healthy diets are available, affordable and appealing for all adolescents, alongside efforts to promote healthy behaviours that support optimal growth and development for current and future generations.

### Acknowledgements

**Financial support:** UNICEF Headquarters New York, USA, and Ireland's Department for Foreign Affairs. **Conflict of interest:** There are no conflicts of interest. **Authorship:** E.M., E.B., V.B., R.M., S.R., Z.A., A.Y. and N.L. conducted the seven regional literature reviews. E.M., N.L. and S.V.W. conceptualised the paper. S.V.W. was responsible for the synthesis of all literature reviews and summarised the overall findings. All authors contributed to the interpretation of the results. S.V.W. wrote the original draft. All authors contributed to a critical review of the manuscript, approved the final version to be submitted and agreed to be accountable for all aspects of the work. D.S. and A.Y. are staff members of UNICEF. The views expressed in this publication do not necessarily represent the views, decisions or policies of the organisation. **Ethics of human subject participation:** Not applicable

### Supplementary material

For supplementary material accompanying this paper visit <https://doi.org/10.1017/S1368980022000350>

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