The nutritional status of school-aged children: Why should we care?

Cora Best, Nicole Neufingerl, Laura van Geel, Tina van den Briel, and Saskia Osendarp

Abstract

Background. *The nutritional status of school-aged children impacts their health, cognition, and subsequently their educational achievement. The school is an opportune setting to provide health and nutrition services to disadvantaged children. Yet, school-aged children are not commonly included in health and nutrition surveys. An up-to-date overview of their nutritional status across the world is not available.*

Objective. *To provide a summary of the recent data on the nutritional status of school-aged children in developing countries and countries in transition and identify issues of public health concern.*

Methods. *A review of literature published from 2002 to 2009 on the nutritional status of children aged 6 to 12 years from Latin America, Africa, Asia, and the Eastern Mediterranean region was performed. Eligible studies determined the prevalence of micronutrient deficiencies or child under- and overnutrition using biochemical markers and internationally accepted growth references.*

Results. *A total of 369 studies from 76 different countries were included. The available data indicate that the nutritional status of school-aged children in the reviewed regions is considerably inadequate. Underweight and thinness were most prominent in populations from South-East Asia and Africa, whereas in Latin America the prevalence of underweight or thinness was generally below 10%. More than half of the studies on anemia reported moderate (> 20%) or severe (> 40%) prevalence of anemia. Prevalences of 20% to 30% were commonly reported for deficiencies of iron, iodine, zinc, and vitamin A. The prevalence of overweight was highest in Latin American countries (20% to 35%). In Africa, Asia, and the Eastern Mediterranean, the prevalence of overweight was generally below 15%.*

Conclusions. *The available data indicate that malnutrition is a public health issue in school-aged children in developing countries and countries in transition. However, the available data, especially data on micronutrient status, are limited. These findings emphasize the need for nutrition interventions in school-aged children and more high-quality research to assess nutritional status in this age group.*

Key words: Anthropometry, malnutrition, micronutrient, nutritional status, school-aged children

Introduction

Many governments, multilateral and bilateral organizations, and other actors recognize that good health and nutrition of children during the primary-school years contribute to educational achievement, growth, and development [1]. Schools are a practical platform to deliver an integrated package of interventions, such as nutritious meals or snacks, micronutrient supplements or on-site fortification, infection control, health promotion, and life-skills education, to improve the health and nutrition of schoolchildren.

Despite advocacy for health and nutrition services in primary schools, there is a clear lack of data on the actual nutritional status of children in this age group in developing countries and countries in transition. Most research focuses on malnutrition in young children under 5 years of age, whereas school-aged children are often omitted from health and nutrition surveys or surveillance. There is evidence that treatment programs providing nutritional care combined with other interventions to younger children (2 to 3 years of age) have a greater beneficial effect on nutritional status and other developmental outcomes than when provided to older children (5 to 6 years) [2, 3]. The United Nations agencies, together with implementing partners, promote national early child development policies [4]. A joint review with the World Health Organization (WHO) and World Bank stated that early child development programs are the most cost-effective interventions in developing countries, not only with regard to improving child health and academic performance, but also considering the potential long-term societal impact of the intervention, such as reducing poverty and diminishing disparities between socioeconomic groups [5]. This explains why nutrition assessments mostly focus on young children. Yet, when resources permit, it is important to investigate the nutritional situation of school-aged children who may also be at risk of compromised growth and development.

It is well documented that suffering from under- or overnutrition during the school years can inhibit a child's physical and mental development. Stunting (low height-for-age) is associated with long-term consequences, such as impaired intellectual achievement and school performance [6, 7], and also leads to reduction in adult body size and, subsequently, reduced work capacity and obstetric complications [7]. Thinness (low body mass index [BMI]-for-age) in school-aged children can result in delayed maturation, deficiencies in muscular strength and work capacity, and reduced bone density later in life [8]. The overweight or obese schoolchild also faces increased risks of high blood pressure, metabolic syndrome, non-insulin-dependent (type 2) diabetes, and psychological disorders [9].

Adequate micronutrient status is critical for good health and development during childhood. Severe anemia, which can result from iron, folate, or vitamin B_{12} deficiency, among other causes, negatively impacts work capacity, intellectual performance, and child cognitive development [10]. Vitamin A plays a critical role in eye health and immune function [11] and also plays a role in the etiology of anemia. Sufficient iodine is crucial to the growing child to optimize mental development and prevent goiter and its complications [12], while zinc is essential for many biologic processes and zinc deficiency can also affect brain development and cognition [13]. There is increasing evidence that improving the nutrition of schoolchildren can have a measurable positive impact on cognition, linear growth, and other health outcomes [8, 14–20]. Access to high-quality data on nutrition and health indicators in this age group would aid in prioritizing and setting up deliberate, evidence-based nutrition intervention programs, targeting the nutritional problems that are of real concern.

The most recent review of nutritional status in school-aged children was published by the United Nations Standing Committee on Nutrition (SCN) in 2002 and included data on undernutrition, anemia, iodine deficiency, and vitamin A deficiency [21]. The SCN review highlighted several studies to exemplify the nutritional issues. However, the review did not provide a comprehensive overview of available studies, and the search and selection strategy, as well as the quality of the studies, was not specified.

The primary aim of our review is to summarize the literature base published between the years 2002 and 2009 pertinent to the nutritional status of school-aged children in developing countries and countries in transition. Compared with the previous review [21], this update, apart from the most recent documentation of the prevalence of undernutrition and of iron, iodine, and vitamin A deficiency, also includes the prevalences of overnutrition and zinc deficiency.

Methods

A literature search was conducted in the Medline database to identify papers on nutritional status in school-aged children from Latin America, Africa, South-East Asia, the Western Pacific, and the Eastern Mediterranean regions. World regions and the associated countries were defined using the WHO definitions (http://www.who.int/about/structure/en/index.html). By choosing these regions, we assured inclusion of both developing and emerging economies while also reviewing over 90% of the countries where the United Nations World Food Programme (WFP) provides food assistance in schools. The search was carried out in May 2009 using the PubMed search engine. The results were restricted to articles in English published between 2002 and May 2009 and including children aged 6 to 12 years. Medical subject heading (MeSH) terms for child malnutrition and nutritional status, including micronutrient deficiencies, and for the countries of interest were used in the search strategy. In addition to the PubMed literature search, data were collected through the WHO Vitamin and Mineral Nutrition Information System (VMNIS) and via WFP country offices and local Unilever offices. Although a number of these publications were never published in the peer-reviewed literature, we included these data if they provided relevant information because they were derived from a trustworthy source, were often coauthored by national governments, and often reported on national nutrition or health surveys. For the same reason, data from these sources were reviewed even if published in the local language, after having been translated into English by local nutritionists.

Titles and abstracts from the initial search results were examined to identify relevant studies. Cross-sectional surveys and baseline data from intervention trials were studied in further detail if they reported the prevalence of anemia, stunting, underweight, thinness, overweight, obesity, or deficiencies of iron, iodine, zinc, calcium, copper, selenium, magnesium, phosphorus,

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folate, or vitamins A, B_1, B_2, B_{12}, C, D, E, or K. Studies were included if the children were enrolled in primary school or if the majority of the investigated children were between 6 and 12 years of age. Studies assessing fewer than 100 subjects were excluded. Studies were also excluded if the study population was selected for specific health characteristics (for example, genetic disorders such as alpha-thalassemia or infection with HIV/AIDS or malaria) or was exposed to a unique environmental condition, such as environmental contamination, or an acute humanitarian emergency situation. Studies on anthropometry that did not use the appropriate indicators (see **table 2**) to assess nutritional status were excluded.

When prevalence data were given for various subgroups (e.g., male/female, age groups, urban/rural, intervention arms), a weighted average across subgroups was calculated to provide one estimate per study. If the sample size of subgroups was not specified, it was assumed that the subjects were equally divided among the groups.

The quality of all included studies was assessed by means of a quality score tool taking into account the representativeness, the validity and consequently the comparability, and the recency of the study. The following three criteria were chosen to represent these principles, and all studies were scored on each criterion: the nutritional indicator and cutoff used to identify malnutrition, the sample size, and the year the study was conducted. The three scores were added to obtain a total quality score, with a score of 6 or 7 indicating high-quality data, a score of 4 or 5 medium-quality data, and a score of 3 or below poor-quality data. This qualification assured that a study could only achieve a high quality score if an appropriate indicator was used to measure malnutrition, the study included an adequate number of subjects, and data were collected after 1998. An overview of the criteria and scoring system used to evaluate the studies on their quality is given in **tables 1** and **2**.

In this review, the emphasis is on the findings of the high-quality studies. The results are presented as average prevalences of malnutrition per world region, with data from high-quality studies given more weight than data from studies of medium or low quality. In addition, median and interquartile ranges (IQR) of prevalences reported by high-quality studies are given. An overview of all reviewed studies and their quality scores is available as an appendix (tables A to F) at the WFP Policy/Publications website (www.wfp.org/publications/list). The appendix can be found under the title "The nutritional status of school-aged children: Why should we care?" by browsing under the topic "Nutrition". Alternatively, readers may e-mail the corresponding author for copies of the appendix. At least two of the authors double-checked all relevant data from each reviewed publication in order to ensure accuracy.

Results

The Medline database search retrieved approximately 1,000 citations. By screening their titles and abstracts, 886 articles were judged to be of potential relevance and studied in more detail. In total, 369 studies were included in the review, of which 24 were derived from the WHO vitamin and mineral database and 14 from local nutritionists. The included studies provide data on 76 different countries in Latin America, Africa, South-East Asia, the Western Pacific, and the Eastern Mediterranean (**fig. 1**).

Anthropometric data

The mean prevalences of stunting, underweight, thinness, overweight, and obesity for each region, weighted by the quality score of all contributing studies, are shown in **table 3**.

Two hundred studies were found that assessed over- or undernutrition in school-aged children in developing countries and countries in transition. Since we excluded studies on anthropometry that did not use the correct nutritional indicator a priori, a relatively high proportion of the included studies reached a high quality score. By far most of the data came from Asian and Latin American countries; there were much fewer data

TABLE 1. Quality criteria and associated scores

Criterion	Description	Score
Indicator and cutoff[a]	No definition reported	0
	Inappropriate indicator used[b]	1
	Inappropriate cutoff value used, but appropriate indicator	2
	Appropriate indicator and cutoff value used	3
Sample size if biochemical measurements are taken	Not reported	0
	$100 \leq n < 400$	1
	$400 \leq n$	2
Sample size if anthropometric measurements are taken	$100 \leq n < 400$ or not reported	0
	$400 \leq n < 800$	1
	$800 \leq n$	2
Year of study	< 1998 or not mentioned	0
	1998–2002	1
	≥ 2003	2

a. For studies on iron deficiency and iron-deficiency anemia, the score given for the indicator and cutoff criterion also takes into account whether the presence of inflammation was assessed by biochemical markers (no change in scoring), by clinical assessment only (subtraction of 1 point), or not at all (subtraction of 2 points).

b. Indicators and cutoffs that are considered appropriate are presented in **table 2**.

TABLE 2. Overview of indicators and cutoffs that are considered appropriate to assess malnutrition in school-aged children

Condition	Appropriate indicator	Appropriate cutoff value
Stunting[a]	Height-for-age	< –2 SD from median or < 3rd percentile of WHO growth reference or CDC growth charts
Underweight[a]	Weight-for-age	< –2 SD from median of WHO growth reference or CDC growth charts
Thinness[a]	BMI-for-age	< –2 SD from median or < 5th percentile of WHO growth reference or CDC growth charts
Overweight[a]	BMI-for-age	> + 1 SD from median or > 85th percentile of WHO growth reference or CDC growth charts > BMI value corrected to BMI = 25 in adults (IOTF)
Obesity[a]	BMI-for-age	> + 2 SD from median or > 95th percentile of WHO growth reference or CDC growth charts > BMI value corrected to BMI = 30 in adults (IOTF)
Anemia[b]	Hemoglobin	< 110 g/L in children < 5 yr < 115 g/L in children 5–11 yr < 120 g/L in children 12–14 yr and older girls < 130 g/L in boys ≥15 yr
Iron deficiency[b]	Serum or plasma ferritin	< 12 µg/L in children < 5 yr < 15 µg/L in children ≥ 5 yr
Iron-deficiency anemia[b]	Hemoglobin	< 110 g/L in children < 5 yr < 115 g/L in children 5–11 yr < 120 g/L in children 12–14 yr and older girls < 130 g/L in boys ≥ 15 yr
	AND	
	Serum or plasma ferritin	< 12 µg/L in children < 5 yr < 15 µg/L in children ≥ 5 yr
Iodine deficiency[b]	Urinary iodine	< 100 µg/L (< 0.79 µmol/L)
Zinc deficiency[c]	Serum or plasma zinc	< 65 µg/dl (9.9 µmol/L) in children < 10 yr < 70 µg/dl (< 10.7 µmol/L) in girls ≥ 10 yr < 74 µg/dl (11.3 µmol/L) in boys ≥ 10 yr
Vitamin A deficiency[b]	Serum or plasma retinol	< 20 µg/dl (< 0.70 µmol/L)

BMI, body mass index; CDC, Centers for Disease Control and Prevention; IOST, International Obesity Taskforce; IZiNCG, International Zinc Nutrition Consultative Group; WHO, World Health Organization

a. Anthropometric measures were evaluated based on WHO growth reference [8], CDC growth charts [22], or IOTF, criteria [23].

b. Iron deficiency and iron-deficiency anemia, vitamin A deficiency, and zinc deficiency were defined according to WHO criteria [12, 24].

c. Zinc deficiency was defined as suggested by IZiNCG, adapted according to time of day [25].

FIG. 1. Overview of reviewed world regions. The countries shown in light and dark gray were included in the search and review. Countries from which studies contributed data are in dark gray. Adapted from World Vector, GeoAtlas, 1997.

TABLE 3. Mean (± SD) prevalence (%) of malnutrition in school-aged children, by WHO region, weighted for quality score

Condition[a]	Africa	South-East Asia	Latin America	Eastern Mediterranean	Western Pacific
Stunting	22 ± 16	29 ± 18	16 ± 14	24 ± 15	28 ± 22
Underweight	21 ± 15	39 ± 17	8 ± 9	32 ± 14[b]	28 ± 20
Thinness	36 ± 21	34 ± 26	6 ± 8	13 ± 15	14 ± 10
Overweight, including obesity	7 ± 5	13 ± 9	26 ± 12	18 ± 11	17 ± 12
Anemia	29 ± 25	32 ± 23	25 ± 14	24 ± 15	31 ± 16
Iron deficiency	29 ± 16	20 ± 14	14 ± 12	23 ± 9[b]	6 ± 9
Iron-deficiency anemia	19 ± 10	4 ± 2	9 ± 7	15 ± 8[b]	19 ± 22[b]
Iodine deficiency	33 ± 28	33 ± 23	14 ± 21	25 ± 23	43 ± 26
Vitamin A deficiency	32 ± 26	17 ± 22[b]	9 ± 7	7 ± 12[b]	20 ± 13
Zinc deficiency	54 ± 18[b]	29 ± 29[b]	49 ± 28[b]	11 ± 0[c]	49 ± 46[b]

a. Stunting is defined as low height-for-age, underweight as low weight-for-age, thinness as low body mass index (BMI)-for-age, overweight or obesity as high BMI-for-age, anemia as low hemoglobin, iron deficiency as low serum or plasma ferritin, iron-deficiency anemia as low hemoglobin and low serum or plasma ferritin, iodine deficiency as low urinary iodine, vitamin A deficiency as low serum or plasma retinol, and zinc deficiency as low serum or plasma zinc (for complete definitions with appropriate cutoff values, see **table 2**).

b. Average prevalence is based on only three or fewer available studies.

c. Prevalence is based on only one available study.

on schoolchildren from Africa and the Eastern Mediterranean. **Figure 2** gives an overview of the number and quality of studies found reporting on over- and undernutrition.

Stunting (low height-for-age) in school-aged children was assessed in 105 studies in developing countries and countries in transition. Of these, 46 studies were of high quality, including 18 national surveys. The WHO classification of the public health significance of stunting refers to children below 5 years of age; a stunting prevalence above 20% is considered a public health issue for young children in community settings [26]. Since there are no corresponding definitions for older children, the definitions mentioned above were used to evaluate the situation of stunting in schoolchildren. According to this definition, 20 of the 46 high-quality studies found stunting prevalence to be a public health issue across the reviewed regions. The average prevalence of stunting was between 20% and 30% in all regions except Latin America. Within regions, stunting prevalence varied substantially between countries. The median prevalence among the high-quality studies was 18%, with an IQR of 7% to 25% (**fig. 3**). Especially high prevalences, between 30% and 74%, were found in national surveys from Guatemala [27], North Korea [28], Madagascar [29], Malawi [30], and Vietnam [31]. A high prevalence of stunting was reported most frequently in rural populations of countries in Asia, such as India [32, 33], Nepal [34], and Laos [35].

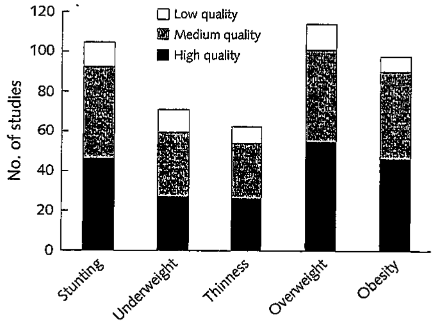

FIG. 2. Overview of number and quality of available studies reporting on over- and undernutrition in school-aged children in developing countries and countries in transition

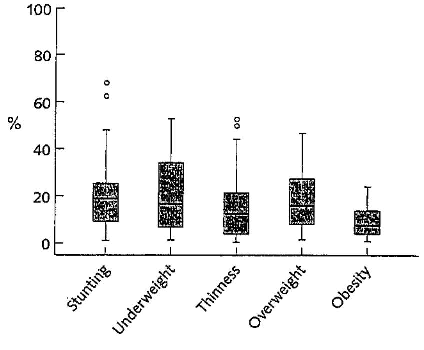

FIG. 3. Median and IQR prevalence of over- and undernutrition in school-aged children in developing countries and countries in transition, as reported by high-quality studies. Stunting is defined as low height-for-age, underweight as low weight-for-age, thinness as low body mass index (BMI)-for age, and overweight or obesity as high BMI-for-age. (Error bars show the inner fences (values ≤1.5 times the IQR from the upper or lower quartile) and circles show outliers)

Seventy-one studies reported on underweight (low weight-for-age) in school-aged children. Most studies were of high or medium quality, assessing underweight according to the WHO/Centers for Disease Control and Prevention (CDC) definitions [8, 22]. The median prevalence of underweight among the 27 high-quality studies was 17%, with an IQR of 7% to 34% (**fig 3**). The highest mean prevalence was in South-East Asia (39%), and the lowest was in Latin America (8%). All of the nine high-quality studies on populations from Latin America, including four national surveys from Brazil [36], Colombia [37], Nicaragua [38], and the Dominican Republic [39], reported prevalences below 9%. In South-East Asia, the Western Pacific Region, and Africa, underweight prevalence varied substantially from below 10% in parts of countries such as Sri Lanka [40], Laos [35], China [41], South Africa [42], and Kenya [43] to 40% or 50%, as observed in a national study from Madagascar [29] and among children from poor rural families across India [32, 44] and northern Vietnam [45]. For the Eastern Mediterranean Region, only two studies of medium quality were available, which reported prevalence rates of underweight of 25% in Pakistan [46] and 49% in Yemen [47].

In general, levels of underweight were substantially higher when all studies were considered, not only those of high quality. Prevalences between 63% and 66% were reported in school-aged children from Nigeria [48] and Vietnam [31] and children of a indigenous community in Sri Lanka [49].

The prevalence of thinness (low body mass index [BMI]-for-age) in school-aged children was described in 62 of the reviewed studies. All studies used BMI as an indicator for thinness, but the cutoff values that were applied to define thinness varied and were sometimes inaccurate according to the recommendations. Twenty-six studies were of high quality; most of them assessed more than 1,000 subjects. The average prevalence of thinness was around 35% in both Africa and South-East Asia and was less than 15% in all other regions. As for underweight, the prevalence of thinness was lowest in Latin America. All but one of the nine high-quality studies (among which were two national studies from Brazil and Chile) reported a prevalence below 4%. The exception is a national survey from the Dominican Republic, which reported a prevalence of 14%. In South-East Asia, Africa, and the Western Pacific, the prevalence varied between countries. Especially high levels of thinness, between 35% and 50%, were reported in national studies from Sri Lanka [50], Vietnam [51], Madagascar [29], and Uganda [52]. For the Eastern Mediterranean region, only two high-quality studies were found, which reported prevalences of 1% in Kuwait [53] and 14% in Iran [54].

The levels of thinness were higher when all studies were considered, not only those of high quality. The most severe prevalences (77% to 90%) were observed in poor school-aged children from eastern India [55], Bangladesh [56], and rural South Africa [57].

A large number of studies, 135 in total, investigated overweight and obesity in school-aged children in developing countries and countries in transition. The vast majority of the reviewed studies used an appropriate definition to identify overweight and obesity; most of the studies applied international growth curves as a reference. China, Taiwan, and Korea used their population-specific (national) growth reference curves. Close to 45% of the studies on overweight and obesity were of high quality.

The high-quality studies reported median prevalences of overweight and obesity of 16% (IQR, 8% to 27%) and 8% (IQR, 4% to 14%), respectively. The burden of overweight and obesity is remarkably higher in Latin America than in other regions. In Africa, South-East Asia, the Western Pacific, and the Eastern Mediterranean, the prevalences of overweight and obesity were generally below the median. Most of the Latin American studies reported prevalences above the median, between 20% and 35% for overweight and between 10% and 20% for obesity. Many of the Latin American studies focused on children living in urban areas, where they are more likely to be in positive energy balance due to urban lifestyles and environments. The highest burdens of overweight (40% to 47%) and obesity (23% to 24%) were reported in studies on urban schoolchildren in Mexico [58, 59]. There were also nationally representative data from recent surveys in Mexico [60] and Brazil [36] that reported high prevalences of overweight (22% to 26%) in school-aged children. National surveys in Mexico [60] and Chile [61] reported prevalences of obesity of 9% and 21%, respectively. These survey data show that overnutrition is not restricted to urban populations but more widely affects children in Latin America.

When all studies are considered, there is greater variation in prevalence data than among high-quality studies only, and the highest levels of overweight and obesity are still found in Latin America and the lowest in Africa. In addition, several medium-quality studies reported high prevalence of overweight (22% to 25%) and obesity (12% to 21%) in schoolchildren from urban families in India [62, 63] and China [64–66].

Micronutrient deficiencies

Most of the reviewed studies on malnutrition in school-aged children reported on anemia and iodine deficiency. The amount of data available on deficiencies of iron, vitamin A, and zinc was substantially lower. For deficiencies of B vitamins, vitamins C, D, E, and K, and copper, selenium, magnesium, phosphorus, and calcium, fewer than 10 studies could be found on each nutrient. Considering the amount of available data, we report only on the prevalence of anemia and of deficiencies of iron, iodine, vitamin A, and zinc.

Figure 4 gives an overview of the number and quality of studies found reporting on micronutrient deficiencies. **Table 3** gives the mean prevalence rates of iron, vitamin A, iodine, and zinc deficiency and of anemia, with and without iron deficiency, for each region, weighted according to the quality score of the contributing studies. Thirty-seven of the reviewed studies reported the prevalence of iron deficiency (low iron status), and 22 reported the prevalence of iron-deficiency anemia (low hemoglobin together with low iron status) among school-aged children. Most of these were medium- or low-quality studies that were conducted before 2003 and used inappropriate measures to define iron deficiency. The median of reported prevalences among all studies was 19% for iron deficiency and 12% for iron-deficiency anemia.

The prevalence rates of iron deficiency and iron-deficiency anemia varied between regions, being mainly below the global median in Latin America (0.5% to 15%) and above the median in Africa. The highest regional prevalence of iron deficiency was found in Africa (29%), and the highest country prevalence of iron deficiency and iron deficiency anemia was from Côte d'Ivoire, where 59% of rural schoolchildren were iron deficient and 36% had iron-deficiency anemia [67]. The regional average prevalence of iron deficiency in South-East Asia was 20%. The range of prevalences of iron deficiency and iron-deficiency anemia reported by high-quality studies alone was narrower—with a maximum prevalence of iron deficiency of 31%—than that reported by all studies on iron deficiency and iron-deficiency anemia. We found only four studies on iron deficiency from the Western Pacific Region and three from the Eastern Mediterranean Region that qualified for this review, which reported prevalences between 1% and 30%.

Many more of the reviewed studies ($n = 79$) investigated the prevalence of anemia (low hemoglobin) among school-aged children. Among these, there were 33 high-quality studies from Africa, Latin America, South-East Asia, and the Western Pacific; many investigated a large sample of more than 1,000 children. The median prevalence of anemia from these high-quality studies was 22% (IQR, 12% to 37%). For the Eastern Mediterranean Region, only medium- and low-quality studies of anemia in school-aged children could be found.

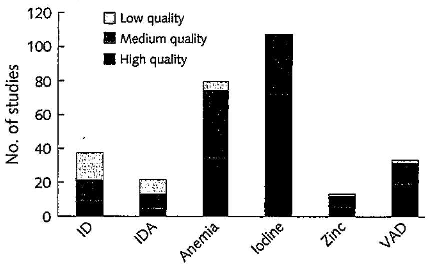

FIG. 4. Overview of number and quality of available studies reporting on micronutrient deficiencies and anemia in school-aged children in developing countries and countries in transition. ID, iron deficiency; IDA, iron-deficiency anemia; VAD, vitamin A deficiency

WHO classifies anemia as a "mild," "moderate," or "severe" public health issue when its prevalence exceeds 5%, 20%, or 40%, respectively [24]. According to this definition, over half of the high-quality studies on anemia reported moderate or severe prevalences of anemia. The data from 32 of 33 studies indicate that anemia is at least a mild public health problem in schoolchildren across developing countries and countries in transition. Recent national studies from Thailand [68], the Philippines [69], Nicaragua [38], and Colombia [37] observed a national average anemia prevalence of 23% to 38%. In the Africa Region, national surveys from Rwanda [70] and Ethiopia [71] reported low prevalences of anemia, 4% and 6%, respectively. Yet, the average regional prevalence was 30%, and studies from regions in Côte d'Ivoire [72], Kenya [73], and Mali [74] with more than 500 participants found anemia prevalences of 40% or higher. The reported anemia prevalence was generally somewhat higher when all studies were taken into account than when high-quality studies only were considered. In rural areas of the Philippines [75], Vietnam [76], and Cambodia [77], anemia prevalence rates from 35% to as high as 65% were routinely reported. Such high levels of anemia were also observed in samples from South-East Asia, rural regions of Nepal [78], and rural and urban areas of India [79, 80].

Iodine status was the most frequently investigated nutritional variable and was included in 107 studies. The majority of these studies, including 24 nationally representative surveys, accurately assessed iodine deficiency and were of high quality. The prevalence of iodine deficiency varied tremendously, not only within regions but also within countries. In India, 21 different high-quality studies conducted in various districts of the country found prevalence rates ranging from 2% in West Bengal [81] to 86% in Bhubaneswar in eastern India [82]. The median prevalence for all high-quality studies was 23%, with an IQR of 10% to 44%. Especially high prevalences (60% to 90%) were observed in multiple African, Asian, and Eastern Mediterranean countries. Such high prevalences were not limited to children of poor families or disadvantaged districts of a country, but also affected children on a nationwide basis [83–88]. Data from Latin America were more homogeneous, with a recent survey in 13 Latin American countries by Pretell et al. indicating the prevalence

of low urinary iodine to be generally below 10% [89]. However, subnational studies from Guatemala [89], Bolivia [89], and Mexico [90] that reported prevalence of iodine deficiency at 84%, 39%, and 38%, respectively show that iodine deficiency is still common in some communities in Latin America. The results were not markedly different when all studies were taken into account compared with high-quality studies only.

Of the reviewed studies, 33 investigated vitamin A deficiency in school-aged children. Except for two studies, all were of medium or high quality. According to WHO definitions, a prevalence of vitamin A deficiency of 10% or greater among children under 5 years of age is considered a moderate public health issue, and a prevalence of 20% or greater is considered a severe public health issue [91]. Since there are no corresponding definitions for older children, the WHO definitions were used to evaluate the severity of vitamin A deficiency in schoolchildren. Of the 18 high-quality studies that were found across all reviewed regions, more than half reported a moderate or severe level of vitamin A deficiency. An exceptionally high prevalence (40% or more) of vitamin A deficiency was observed in a national study in the Philippines among 4,500 6- to 12-year-old children [69] and in a rural sample from Burkina Faso [92].

When all studies are considered, the reported prevalences of vitamin A deficiency are somewhat higher than when only high-quality studies are considered. The highest levels of vitamin A deficiency (50% to 90%) were observed among rural and urban poor African schoolchildren in Botswana [93], South Africa [94], and Kenya [14] and among urban schoolchildren in Hyderabad, India [95].

Among the reviewed studies, only 13 were found that assessed the prevalence of zinc deficiency in school-aged children, 5 of which received a high quality score. Most studies did not identify zinc deficiency using the exact age-dependent cutoff for low serum zinc, as suggested by the International Zinc Nutrition Consultative Group (IZiNCG) [25]. The median prevalence among all studies on zinc deficiency was 46%, with an IQR of 19% to 57%, covering most studies from African, Latin American, and South-East Asian countries. There were some outliers, however, and overall the prevalence of zinc deficiency ranged from only 1% in a sample of urban schoolchildren in Hyderabad, India [95], and rural children in Jiangsu Province, China [41], up to 80%, as observed in a sample of indigenous Tarahuma children in Chihuahua, Northern Mexico [90].

Discussion

This review aimed at giving an overview of the current data on the nutritional status of school-aged children in developing countries and countries in transition. Although there are plenty of data available on anemia, iodine deficiency, and the anthropometric status of school-aged children, high-quality data on iron, zinc, and vitamin A deficiency are limited. For vitamins B, C, D, E, and K and other minerals and trace elements, virtually no studies were found.

The available data show that malnutrition clearly is an issue in school-aged children all across developing countries and countries in transition. Nearly half of the high-quality surveys reported concerning levels (over 20%) of stunting across all reviewed regions. Underweight and thinness were most prominent in populations from South-East Asia and Africa. In school-aged children from Latin America, the prevalence of thinness and underweight was generally lower, less than 10%. Overnutrition was primarily present in Latin American countries, where about 20% to 35% of school-aged children were overweight and 10% to 20% were obese. In Africa, Asia, and the Eastern Mediterranean, the prevalence of overweight and obesity combined was generally below 15%. Overnutrition was mainly detected in urban populations from all the reviewed regions.

Both undernutrition and overnutrition during the school-aged years have detrimental impacts on the development and health of children. Stunting is associated with long-term consequences, including impaired intellectual achievement and school performance [6, 7] and small body size in adulthood [7]. In turn, small adult size translates into increased risk of obstetric complications during childbirth due to small pelvic size and reduced work capacity, which impacts economic productivity [8]. Low height-for-age in school-aged children and adolescents primarily reflects deficits in linear growth that occurred before the age of 3 years, deficits that cannot be recovered later in life [7, 8]. Therefore, stunting is not the priority indicator to use when planning nutrition interventions in this age group. However, data on height are easily collected, useful for tracking secular trends, and required in order to calculate BMI. Recent research suggests that improving the nutrition and health environment of school-aged children can make a small contribution to linear growth potential and may prevent the continuation of the stunting process in older children [17, 20, 96].

Underweight in young children is highly correlated with an increased risk of morbidity and mortality [8]. This relationship is clear in children under 5 years of age, since underweight is regularly recorded for growth monitoring purposes. It is plausible that being underweight confers some increased risk of morbidity on children older than 5 years as well, although the risk may be of much lesser magnitude. Underweight was commonly measured in the studies we retrieved. However, the indicators underweight and wasting (low weight-for-height) are not recommended for use in children over 10 years of age, since relative height cannot be distinguished from body mass, and the weight–height relationship changes dramatically with age and maturational status [8, 97].

Therefore, we reported the data retrieved on both underweight and thinness, since WHO recommends using thinness (BMI-for-age) instead to measure undernourishment in older children. Thinness has been adopted recently as a more appropriate indicator than underweight in older children. It is indicative of relatively recent nutritional deprivation, such as insufficient dietary intakes of energy, protein, or several micronutrients, impaired absorption, or excess nutrient losses [8]. Research has shown that low BMI in adults is related to increased morbidity, and adult and adolescent mothers who are overly thin are more likely to deliver babies of low birth weight [98]. Some consequences of being excessively thin during the school-aged years include delayed pubertal maturation and reduced muscular strength and work capacity [8]. Excessive thinness may also lead to reduced bone density later in life [8].

Addressing the health and nutrition issues of school-aged children is further complicated by the increase in childhood obesity in developing countries [51, 99-102]. Overnutrition during the school-aged years is associated with numerous immediate and long-term negative health outcomes. Research has shown that in schoolchildren, overweight or obesity leads to increased risks of high blood pressure, metabolic syndrome, non-insulin-dependent (type 2) diabetes, and psychological disorders [103]. Obesity is the greatest risk factor for the onset of type 2 diabetes in childhood, an increasingly prevalent chronic illness that, until recently, was not considered a pediatric condition [104]. The risk factors such as dyslipidemia and hyperinsulinemia that define the metabolic syndrome tend to track throughout the lifetime and are associated with cardiovascular disease in adulthood [9, 105, 106]. Without intervention or some change in individual lifestyle or environment, overweight and obese children are likely to remain in this condition in adolescence and adulthood and to struggle with the negative health and social consequences of being overweight or obese. The public health communities in developing countries and countries in transition should adopt a preventive approach in order to avoid an epidemic of childhood obesity such as the United States is experiencing currently.

In addition to the shortage or excess of macronutrients providing the necessary energy and building blocks for healthy growth, many school-aged children in developing countries suffer from micronutrient deficiencies, which negatively impact healthy development. Anemia appears to be a public health problem among schoolchildren in almost all of the reviewed countries, and prevalences of 20% to 30% were commonly observed for all vitamin and mineral deficiencies reviewed (**fig. 5**). Among the micronutrient deficiencies, the median reported prevalence rates of zinc and iodine deficiency were highest. But the range of observed iodine and zinc deficiency was large, and the prevalence rates varied tremendously within regions and countries. In Latin America the prevalence of iodine deficiency was generally lower than in other regions.

The limited data (five high-quality studies) available on zinc status suggest that there may be serious levels of deficiency in various parts of the world, with prevalences of 40% to 80% reported in more than half of the studies. However, the current lack of data restricts us from drawing solid conclusions and highlights the clear need for more comprehensive research on the micronutrient status of school-aged children.

Micronutrients play a role in various functions that are key to healthy development. Deficiencies during childhood can have acute and long-term consequences on the physical and mental health of children. Iron deficiency is one of the 10 leading risk factors contributing to the global burden of disease, mainly in Asia and Africa [107]. Iron-deficiency anemia can lead to reduced muscle function and work capacity [108, 109] and less explorative behavior in school-aged children [110]. Iron deficiency or iron-deficiency anemia is also consistently associated with impaired cognitive function and lower school performance in school-aged children [111–114]. As reviewed by Gera et al. [115], data from three randomized, controlled trials in anemic or iron-deficient school-aged children suggest beneficial effects on physical performance of oral iron supplementation at 30 to 200 mg per day [116–118]. Furthermore, there is some evidence that iron supplementation improves growth in anemic schoolchildren [119–121]. Oral iron supplementation (50 to 60 mg/day) in anemic [122, 123] and nonanemic iron-deficient [114, 124] children has also been shown to improve cognitive performance, such as verbal learning and memory [18, 111].

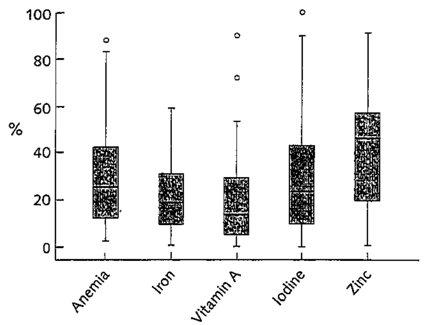

FIG. 5. Median and IQR prevalence of micronutrient deficiencies and anemia in school-aged children in developing countries and countries in transition, as reported by all studies. (Error bars show the inner fences (values ≤1.5 times the IQR from the upper or lower quartile) and circles show outliers)

Iodine deficiency is evidently associated with deficits in cognitive function as well. There is evidence from two meta-analyses showing that the intelligence quotients of young and school-aged children from iodine-deficient regions were 12.5 and 13.5 points lower, respectively, than those of children from iodine-sufficient regions [125, 126]. Some randomized, controlled intervention trials also showed that iodine deficiency in schoolchildren could be relieved and mental performance improved by oral supplementation with 400 to 540 mg of iodine via fortified oil [19, 127–129]. This suggests that some of the cognitive deficit resulting from iodine deficiency can still be recovered in school-aged children. Iodine-deficiency disorders have been brought under control in much of Latin America through the introduction and use of iodized salt [89, 130]. However, there is still progress to be made across African, Asian, and Eastern Mediterranean countries to establish and enforce universal salt iodization programs and diminish the prevalence of iodine deficiency. For example, in Sudan, Gambia, and Guinea-Bissau, less than 10% of households consume iodized salt [130].

Vitamin A deficiency increases susceptibility to infection and subsequently the risk of severe infection and mortality [131]. Meta-analyses of 12 trials have shown that vitamin A supplementation reduces mortality by 23% to 34% in children below 5 years of age in areas of endemic vitamin A deficiency [132–134]. Because of the generally higher mortality rate at younger ages, the magnitude of a beneficial effect of vitamin A supplementation, however, would probably be smaller in older children, and preventive high-dose vitamin A supplementation is not recommended for school-aged children.

A specific consequence of vitamin A deficiency is xerophthalmia, a severe eye disorder and a primary cause of childhood blindness, which is responsible for 350,000 cases of blinding in children worldwide every year [135]. The prevalence of severe corneal xerophthalmia usually peaks at 2 to 3 years of age, but the prevalence of mild xerophthalmia increases with age beyond 5 years, probably because vitamin A deficiency builds up over time due to a chronic shortage of the vitamin [136]. In addition to causing reduced immune competence and eye disease, vitamin A deficiency is likely to negatively influence iron status [137]. Intervention studies showed that vitamin A supplementation or fortification can contribute to anemia control efforts by increasing hemoglobin levels in preschool and school-aged children [138–140]. Although some studies also suggest a relationship between vitamin A status and child growth [137], several randomized, placebo-controlled intervention trials have failed to detect such a relationship [141].

Zinc deficiency is associated with inhibited growth and with impaired immune function and diarrhea, leading to recurrent infections [109]. There is evidence for a beneficial effect of zinc supplementation on the growth of undernourished children. A recent meta-analysis of 22 controlled intervention trials concluded that zinc supplementation can improve height and weight, with the greatest effect in children who were initially underweight or stunted [142]. The vast majority of trials were conducted in children under 5 years of age, but trials in school-aged children also reported benefits of zinc (10 to 40 mg/day), alone [143–145] or in addition to other micronutrients [146–148], on growth or body composition. The effects of zinc supplementation on immune function and infection rate were investigated almost exclusively in children under 5 years of age. These studies consistently showed reductions in the incidence of pneumonia and acute diarrhea [149, 150] and in overall mortality [151, 152]. Because the essential functions of zinc in resistance to disease are well known, it can be presumed that zinc supplementation of older zinc-deficient children will also be beneficial.

As reviewed by Black in 2003 [153], there is some evidence from observational and intervention studies in schoolchildren that zinc may benefit cognitive performance. However, the evidence is limited and inconsistent, and therefore more research is needed to be able to draw clear conclusions on the role of zinc in cognition.

Furthermore, zinc deficiency may negatively influence vitamin A absorption, transport, and utilization, especially in marginally nourished individuals, leading to secondary vitamin A deficiency [154]. This might suggest that zinc deficiency can limit the health effect of vitamin A supplementation alone in individuals with coexisting zinc and vitamin A deficiency. Supplementation of malnourished children with zinc, on the other hand, might improve not only zinc but also vitamin A status [154, 155].

In developing countries, micronutrient deficiencies generally do not occur in isolation but in combination with other deficiencies. That is because the main underlying cause of malnutrition is a poor-quality diet and lack of access to foods [156], especially animal foods, which are an important source of iron, zinc, vitamin A, vitamin B_{12}, and protein and are often unaffordable for a large part of the population in developing countries. As illustrated for zinc, iron, and vitamin A, micronutrients interact with each other, and these interactions can have consequences for the health and development of children. Multiple micronutrient supplementation and food fortification have been shown to have positive impacts on growth, cognitive outcomes, and nutritional status in school-aged children [15–17, 157, 158]; they may even be more effective than supplementation with a single nutrient [146, 147].

We acknowledge that nutrition interventions carried out in younger children are known to be more effective than nutrition interventions in school-aged children [5]. It has been shown that stunting can be prevented or reduced by nutritional supplementation of infants and toddlers, with higher gains in weight and/or length the younger the children; no effects on growth were reported for children over 3 years of age [159]. Evidence is still controversial on whether nutrition interventions in older children can induce catch-up growth [17, 20, 96], or whether they can only prevent the continuance of the stunting process [7, 8]. An early child development initiative in the Philippines, in which nutrition was part of a broader intervention program including health, education, and social services, reported a significant improvement in cognitive, social, motor, and language development and in short-term nutritional status of children, particularly in those children who received the intervention during the first 4 years of life [2]. Another comprehensive intervention program providing nutrition, healthcare, and educational components to underprivileged preschoolchildren in Colombia showed beneficial effects on cognitive function, which were greater in those children who started the treatment at a younger age than in those who started at an older age [3].

Because brain growth takes place mainly before the age of 6 years [160, 161] and younger children exhibit faster rates of change in psychosocial development than older children, nutrition interventions may have greater benefits on cognitive function in younger children than in older children [2]. Supplementation with, for example, vitamin A or zinc aimed to improve immune function might be more effective in younger children because of the generally higher mortality rate in younger than in older children [132].

However, as described before, targeted interventions in school-aged children have been shown to be effective in reversing or improving negative health consequences [15–17, 20, 157, 158]. As malnutrition occurring during school age can have detrimental effects on healthy growth and development [6, 7, 9, 10, 12, 13, 60], nutrition interventions in this age group can bring important benefits and have an impact on the future lives of these children. Poor nutritional status during this life stage can also negatively impact the future health and work capacity and quality of life of the next generation [162, 163].

For nutrition intervention programs, it is important to be aware of the nature of the prevailing problem in a country or region in order to target interventions accordingly. The type and degree of malnutrition vary tremendously between world regions, between countries within one region, and between districts of a single country. This may be due to various reasons, such as the socio-demographic and ecologic environment of the study population, for example, urban versus rural setting or mountainous versus coastal area. It is important to note that many of the reviewed studies were conducted in certain pockets of a country and may not be representative of schoolchildren nationwide. Therefore, the data presented in some of the studies need to be considered with caution and cannot necessarily be extrapolated to the whole nation or world region.

The quality of the studies and the methods used to assess micronutrient deficiencies varied. This may limit the validity and comparability of the data. By applying the quality score tool and comparing only data from studies of the same quality, we attempted to overcome this limitation. We recognize that by merging the prevalence data of various subgroups into a weighted average, as we did when different values for subgroups were provided within one study, we slightly compromise the validity of the data. However, because of the vast number of studies, we decided to limit the extent to which we presented the detailed outcomes of various subgroups in order to keep the overview interpretable.

We excluded data on children exposed to unique environmental conditions and children with overt suboptimal health conditions. However, particularly in developing countries, children are at high risk for infections due to poor sanitary conditions and reduced resistance to infection due to malnutrition [1, 164]. One can presume that those children who were excluded from our review belong to the most disadvantaged group and that their nutritional status may be exceptionally poor. Therefore, the presented prevalences may underestimate the true magnitude of malnutrition in school-aged children in developing and emerging regions. On the other hand, some of the prevalence rates, especially those for vitamin A and zinc deficiency, are derived from baseline data from intervention studies. Some of the study sites may have been selected because a high prevalence of nutritional deficiency was expected. This would lead to overestimation of malnutrition rates.

The comprehensiveness of this review may have been constrained by the difficulty of locating original reports of studies. For example, national nutrition or health surveys are not always publicly accessible. Often they are written in the local language and are not published in peer-reviewed journals. With the support of local nutritionists in our regional offices, we partially overcame this hurdle, but we could not avoid overlooking a survey if it was unfamiliar to the local nutritionists or was not publicly accessible. This will remain a common problem that many reviewers will encounter, and we would like to encourage researchers and ministries of health to publish their health surveys and circulate them in the public domain, for instance on websites or by distributing them to health institutes and organizations.

Conclusions

It is evident from this review that schoolchildren around the globe suffer from micronutrient deficiencies and malnutrition. Nutritional deprivation during the school-aged years can further constrain the physical and cognitive development of schoolchildren, possibly limiting their educational achievement and attenuating the impact of educational interventions for social development. Malnutrition during the school-aged years may even directly and indirectly compromise the health and survival of the future generation, as malnourished children approach adolescence and their reproductive years in a nutritionally and educationally disadvantaged position.

Despite the large number of studies included in this review, many were of low or moderate quality or were based on only a small subsample of the population. Very few studies assessed the status of any micronutrients other than iron and iodine. This confirms that schoolchildren are a group often omitted from public health research; in general, there is especially limited surveillance for micronutrient status. More national nutrition and health surveys that do not restrict their investigations to young children are necessary.

On the other end of the malnutrition spectrum is a high prevalence of overweight in certain regions, especially Latin America. Moreover, data from the national nutrition surveys in Mexico indicated a sharp increase in the prevalence of overweight in schoolchildren between 1999 and 2006 [60]. It is important, therefore, to track body weight and height in schoolchildren in developing countries and countries in transition, given the significant increase of overweight and obesity in Latin America and its associations with chronic diseases later in life.

Under- and overnutrition as well as micronutrient deficiencies occurring during school age are detrimental to the development of children; they negatively impact health, work capacity, and quality of life across the lifespan. Although nutrition intervention programs were shown to have most effect in younger children, nutrition interventions in school-aged children have important health benefits as well. They were shown to help reverse physical or mental health deficits, thereby improving children's chances for a better future. This review concludes that there is a need for nutrition intervention programs targeting school-aged children in addition to programs for younger children in developing countries and countries in transition in order to optimize children's physical and mental development. In addition, this review gives indications on which nutrition issues to tackle in which populations.

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