Preplanned Studies

Prevalence of Micronutrient Deficiencies in Children and Adolescents Aged 3–17 Years — 14 PLADs, China, 2019–2021

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Summary

What is already known about this topic?

Micronutrient deficiencies in children represent a significant global health challenge. Currently, there are limited nationally representative reports on micronutrient deficiencies among Chinese children and adolescents.

What is added by this report?

This study presents nationally representative data on six micronutrient deficiencies. Among children and adolescents aged 3–17 years in China, the overall prevalence of vitamin A deficiency, marginal vitamin A deficiency, vitamin D deficiency, vitamin D insufficiency, iron deficiency, zinc deficiency, low selenium status, and copper deficiency were 0.3%, 12.1%, 23.9%, 41.2%, 10.9%, 3.3%, 7.1%, and 1.6%, respectively.

What are the implications for public health practice?

Among children and adolescents aged 3–17 years in China, vitamin D deficiency in adolescents (12–17 years), iron deficiency in adolescent girls (12–17 years), and low selenium status in rural areas emerge as the most prevalent micronutrient deficiencies requiring targeted interventions.

ABSTRACT

Introduction: Micronutrient deficiencies in children remains a significant global health challenge. This study presents the recent prevalence of micronutrient deficiencies among children and adolescents aged 3–17 years in China.

Methods: Using data from the National Nutrition and Health Systematic Survey for children aged 0–18 years in China (2019–2021), we analyzed the prevalence of six micronutrient deficiencies (vitamin A, vitamin D, iron, zinc, selenium, and copper) in children aged 3–17 years.

Results: A total of 9,121 children were included. The prevalence across age groups (3–5, 6–8, 9–11, 12–14, and 15–17 years) was 0.6%, 0.6%, 0.3%, 0.3%, and 0.1% for vitamin A deficiency; 18.8%, 22.2%, 13.9%, 7.8%, and 4.4% for marginal vitamin A deficiency; 4.5%, 9.8%, 17.6%, 36.3%, and 35.6% for vitamin D deficiency; 26.8%, 39.8%, 44.1%, 44.4%, and 40.9% for vitamin D insufficiency; 4.4%, 4.2%, 5.2%, 17.0%, and 18.3% for iron deficiency; 3.0%, 1.5%, 2.6%, 4.7%, and 4.4% for zinc deficiency; 5.7%, 5.7%, 7.7%, 9.0%, and 6.6% for low selenium status; and 1.1%, 1.6%, 1.9%, 1.2%, and 1.7% for copper deficiency, respectively.

Conclusions: Among children aged 3–17 years in China, vitamin D deficiency and iron deficiency emerge as the most prevalent micronutrient deficiencies.

Micronutrient deficiencies represent a significant public health concern among children aged 3–17 years, adversely affecting growth, immunity, and cognitive development. Despite the significance of this issue, comprehensive and current data on micronutrient deficiencies among Chinese children aged 3–17 years are limited. This study addresses this knowledge gap by characterizing the prevalence of vitamin A, vitamin D, iron, zinc, selenium, and copper deficiency in this age group using recent, nationally representative data from China.

This study was part of a cross-sectional National Nutrition and Health Systematic Survey for children aged 0–18 years conducted between 2019 and 2021 across 14 provincial-level administrative divisions (PLADs) in China. The project employed a multi-stage stratified randomized cluster sampling method, with two PLADs randomly selected from each of the seven regions in China. One urban district and one rural county were randomly sampled from each PLAD, totaling 28 survey counties/districts. At each survey site, 132 children aged 3–5 years and 196 children aged 6–17 years were selected for each age group, with gender balance required throughout. Among the sampled children from each site, 10 children aged 3–5 years and 30 children aged 6–17 years were randomly cluster sampled from each age group for blood collection (*1*).

Morning fasting venous blood samples were collected from all participants. Serum retinol concentrations were measured using high-performance liquid chromatography (HPLC, Agilent Inc., USA). Serum 25(OH)D_2 and 25(OH)D_3 concentrations were determined via high-performance liquid chromatography-mass spectrometry (HPLC-MS, AB SCIEX, USA). Serum ferritin concentrations were measured using electrochemiluminescence immunoassay (cobas e 601, Roche Diagnostics, Mannheim, Germany). Plasma zinc and copper concentrations, along with whole-blood selenium levels, were analyzed using inductively coupled plasma mass spectrometry (ICP-MS, Agilent, 7700x, USA). Quality control samples for each micronutrient at both low and high concentrations were analyzed in each run. The inter-run coefficients of variation (CVs) for retinol, 25(OH)D_2, 25(OH)D_3, ferritin, zinc, selenium, and copper were 2.85%, 2.99%, 3.16%, 4.98%, 1.93%, 2.00%, and 1.78% for the low concentrations, and 2.90%, 2.90%, 2.91%, 5.84%, 1.63%, 2.52%, and 1.57% for the high concentrations, respectively. To control for inflammation-induced alterations in micronutrient concentrations, children with C-reactive protein (CRP) levels exceeding 5 mg/L were excluded from the analysis.

Vitamin A deficiency (VAD) and marginal vitamin A deficiency (mVAD) were defined by serum retinol concentration <0.2 mg/L and 0.2–0.3 mg/L, respectively (*2*). Vitamin D deficiency (VDD) and vitamin D insufficiency (VDI) were defined by serum 25(OH)D concentration <12 ng/mL and 12–20 ng/mL, respectively (*3*). Iron deficiency criteria were age-dependent: serum ferritin <12 μg/L for children under 5 years and <25 μg/L for children 5 years or older (*4*). Zinc deficiency was determined using age- and sex-specific thresholds: serum zinc <0.65 mg/L for children <10 years, <0.7 mg/L for girls ≥10 years, and <0.74 mg/L for boys ≥10 years (*5*). Low selenium status was defined as serum selenium <70 μg/L (*6*). Copper deficiency thresholds were age-stratified: serum copper <750 μg/L for children <10.3 years, <640 μg/L for children 10.3–12.5 years, and <570 μg/L for children >12.5 years (*7*).

Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA). Categorical variables were presented as percentages, and gender differences were compared using chi-squared tests. The prevalence of micronutrient deficiencies and their 95% confidence intervals (*CIs*) were calculated for defined age groups. Chi-squared tests were used to assess differences in deficiency prevalence across age groups, between genders within the same age and regional groups, and between urban and rural areas within the same age and gender strata. Statistical significance was set at P<0.05.

This study included 9,121 children aged 3–17 years, comprising 4,587 boys (50.3%) and 4,234 urban residents (46.4%). The age distribution was: 646 (7.1%) aged 3–5 years, 2,020 (22.1%) aged 6–8 years, 2,028 (22.2%) aged 9–11 years, 2,113 (23.2%) aged 12–14 years, and 2,314 (25.4%) aged 15–17 years (Table 1).

The overall prevalence of mVAD was 12.1% among children aged 3–17 years in China. mVAD prevalence was significantly higher in younger children aged 3–5 years (18.8%) and 6–8 years (22.2%) compared to those aged 9–11 years (13.9%), 12–14 years (7.8%), and 15–17 years (4.4%). While no significant difference was observed between the 3–5 and 6–8 years age groups (P>0.05), all other age group comparisons revealed statistically significant differences (all P<0.05). Among adolescents aged 15–17 years, girls in rural settings demonstrated significantly higher mVAD prevalence than boys (P<0.05). Additionally, mVAD prevalence was significantly higher in rural areas than in urban areas for children aged 6–11 years, regardless of gender (all P<0.05) (Table 2).

The overall prevalence of VDD among children aged 3–17 years in China was 23.9%. VDD prevalence was significantly higher in adolescents aged 12–14 years (36.3%) and 15–17 years (35.6%) compared to younger children aged 3–5 years (4.5%), 6–8 years (9.8%), and 9–11 years (17.6%). While no significant difference was observed between the 12–14 and 15–17 years age groups (P>0.05), all other age group

TABLE 1. Demographic characteristics of children aged 3–17 years by gender [*n* (%)].

Characteristics	Total (*n*=9,121)	Boys (*n*=4,587)	Girls (*n*=4,534)	χ^2	*P*
Region					
Urban	4,234 (46.4)	2,133 (46.5)	2,101 (46.3)	0.024	0.877
Rural	4,887 (53.6)	2,454 (53.5)	2,433 (53.7)		
Age group (years)					
3–5	646 (7.1)	329 (7.2)	317 (7.0)	0.849	0.932
6–8	2,020 (22.1)	1,028 (22.4)	992 (21.9)		
9–11	2,028 (22.2)	1,008 (22.0)	1,020 (22.5)		
12–14	2,113 (23.2)	1,054 (23.0)	1,059 (23.4)		
15–17	2,314 (25.4)	1,168 (25.5)	1,146 (25.3)		

comparisons revealed statistically significant differences (all P<0.05). Among children aged 6–17 years in urban areas and children aged 9–17 years in rural areas, girls exhibited significantly higher VDD prevalence than boys (all P<0.05). No significant urban-rural differences in VDD prevalence were observed across any age group regardless of gender (all P>0.05) (Table 2).

The overall VDI prevalence was 41.2% among children aged 3–17 years in China. VDI prevalence was higher in children aged 9–11 years (44.1%) and 12–14 years (44.4%) compared to those aged 3–5 years (26.8%), 6–8 years (39.8%), and 15–17 years (40.9%). No significant differences were found between the 9–11 and 12–14 years age groups (P>0.05), or between the 6–8 and 15–17 years age groups (P>0.05); however, all other age group comparisons revealed statistically significant differences (all P<0.05). In rural settings, girls demonstrated significantly higher VDI prevalence than boys (P<0.05) in the 6–8 years age group, while showing significantly lower VDI prevalence than boys (P<0.05) in the 12–14 years age group. VDI prevalence was significantly higher in urban areas than in rural areas for girls aged 12–17 years (all P>0.05) (Table 2).

Iron deficiency affected 10.9% of children aged 3–17 years in China, with significantly higher prevalence in adolescents aged 12–17 years compared to children aged 3–11 years (all P<0.05). Among adolescents aged 12–17 years, girls demonstrated significantly higher iron deficiency rates than boys in both urban and rural settings (all P<0.05). Among children aged 3–5 years, boys exhibited significantly higher iron deficiency rates than girls in rural areas (P<0.05). The prevalence of iron deficiency was higher in rural areas than in urban areas for boys aged 3–5 years (P<0.05). For girls aged 12–14 years, iron deficiency was more prevalent in urban areas, while for girls aged 15–17 years, it was more prevalent in rural areas (all P<0.05) (Table 2).

The prevalence of low selenium status among children aged 3–17 years in China was 7.1%. Children aged 9–14 years demonstrated significantly higher prevalence rates compared to those aged 3–8 years (all P<0.05). Among children aged 12–14 years in urban areas, the prevalence of low selenium status was significantly higher in boys than girls (P<0.05). A consistent pattern emerged, showing significantly higher prevalence rates in rural areas compared to urban areas across all age groups, regardless of gender (all P<0.05) (Table 2).

In this study, among children aged 3–17 years in China, the overall prevalence of VAD, zinc deficiency and copper deficiency were 0.3%, 3.3% and 1.6%, respectively.

DISCUSSION

This study provides current, nationally representative data on micronutrient deficiencies among children aged 3–17 years in China. Our findings highlight primary public health concerns requiring targeted interventions: vitamin D deficiency in adolescents (12–17 years), iron deficiency in adolescent girls (12–17 years), and low selenium status in rural areas.

Vitamin D deficiency and insufficiency remain a significant public health concern among children aged 3–17 years in China, with a particularly high deficiency prevalence in adolescents aged 12–17 years. Our results show that the prevalence of VDD and VDI in children aged 3–5 years (4.5% and 26.8%) has

TABLE 2. Prevalence of micronutrient deficiencies in children aged 3–17 years stratified by gender and region (%, 95% *CI*).

Characteristics		Age (years)	Vitamin A deficiency	Vitamin A marginal deficiency	Vitamin D deficiency	Vitamin D insufficiency	Iron deficiency	Zinc deficiency	Low selenium Status	Copper deficiency
Total		3–5	0.6 (0.2, 1.6)	18.8 (15.8, 22.1)*	4.5 (3.0, 6.5)*	26.8 (23.2, 30.6)*	4.4 (2.7, 6.8)*	3.0 (1.8, 4.7)*	5.7 (4.0, 7.8)*	1.1 (0.5, 2.3)
		6–8	0.6 (0.3, 1.0)	22.2 (20.4, 24.2)*	9.8 (8.5, 11.2)†	39.8 (37.6, 42.1)†	4.2 (3.4, 5.2)*	1.5 (1.0, 2.1)†	5.7 (4.7, 6.8)*	1.6 (1.1, 2.3)
		9–11	0.3 (0.1, 0.7)	13.9 (12.4, 15.5)†	17.6 (15.9, 19.4)§	44.1 (41.9, 46.4)§	5.2 (4.3, 6.3)*	2.6 (2.0, 3.5)†	7.7 (6.5, 9.0)†,§	1.9 (1.4, 2.7)
		12–14	0.3 (0.1, 0.7)	7.8 (6.5, 8.9)§	36.3 (34.1, 38.5)¶	44.4 (42.2, 46.7)§	17.0 (15.4, 18.7)†	4.7 (3.8, 5.7)*	9.0 (7.8, 10.4)†	1.2 (0.7, 1.7)
		15–17	0.1 (0, 0.3)	4.4 (3.6, 5.3)¶	35.6 (33.6, 37.7)¶	40.9 (38.9, 43.0)†	18.3 (16.6, 20.1)†	4.4 (3.6, 5.3)*	6.6 (5.6, 7.7)*,§	1.7 (0.1, 2.4)
Boys	Urban	3–5	0.6 (0, 3.5)	19.2 (13.4, 26.3)	1.4 (0.2, 4.9)	21.4 (15.0, 29.0)	2.1 (0.3, 7.5)††	3.7 (1.4, 7.8)	0.6 (0, 3.4)††	1.2 (0.2, 4.3)
		6–8	0.7 (0.2, 2.1)	16.5 (13.0, 20.4)††	6.4 (4.2, 9.2)**	37.9 (33.2, 42.9)	5.0 (3.2, 7.5)	1.7 (0.7, 3.5)	2.5 (1.2, 4.5)††	1.2 (0.4, 2.9)
		9–11	0.3 (0, 1.4)	11.0 (8.1, 14.5)††	10.3 (7.5, 13.7)**	44.4 (39.5, 49.6)	5.5 (3.5, 8.1)	2.4 (1.1, 4.4)	3.1 (1.6, 5.4)††	1.3 (0.4, 3.0)
		12–14	0.2 (0, 1.3)	7.5 (5.2, 10.4)	29.1 (24.8, 33.7)**	48.5 (43.6, 53.3)	8.7 (6.4, 11.6)**	0.7 (0.1, 2.0)**,††	3.9 (2.3, 6.2)**,††	1.1 (0.4, 2.6)
		15–17	0 (0, 0)	3.6 (2.3, 5.5)	29.0 (25.2, 32.9)**	41.9 (37.8, 46.1)	7.6 (5.3, 10.5)**	2.8 (1.6, 4.5)**	2.6 (1.5, 4.3)††	2.8 (1.6, 4.5)**
	Rural	3–5	1.9 (0.4, 5.4)	22.6 (16.4, 29.9)	4.8 (1.9, 9.6)	31.3 (23.9, 39.5)	8.3 (4.2, 14.3)**,††	2.5 (0.7, 6.3)	10.7 (6.4, 16.6)††	1.3 (0.2, 4.5)
		6–8	0.7 (0.2, 1.8)	26.3 (22.7, 30.1)††	8.0 (5.9, 10.6)	36.5 (32.5, 40.6)**	4.9 (3.2, 7.1)	1.1 (0.4, 2.5)	7.9 (5.8, 10.5)††	1.0 (0.3, 2.2)**
		9–11	0.4 (0, 1.3)	17.8 (14.7, 21.2)††	12.8 (10.1, 15.9)**	40.5 (36.4, 44.8)	4.0 (2.5, 6.0)	1.1 (0.4, 2.4)**	12.7 (10.0, 15.7)††	2.2 (1.2, 3.8)
		12–14	0.5 (0.1, 1.6)	10.1 (7.7, 13)	28.5 (24.7, 32.6)**	44.8 (40.6, 49.2)**	10.9 (8.4, 13.7)**	5.1 (3.4, 7.3)**,††	13.9 (11.1, 17.2)††	1.8 (0.9, 3.3)
		15–17	0.2 (0, 1.0)	2.1 (1.1, 3.6)**	26.8 (23.2, 30.7)**	40.9 (36.8, 45.1)	6.1 (4.2, 8.5)**	2.5 (1.4, 4.1)**	9.6 (7.3, 12.4)††	2.8 (1.6, 4.6)**
Girls	Urban	3–5	0 (0, 0)	16.7 (11.1, 23.6)	4.2 (1.6, 9.0)	22.5 (16.0, 30.3)	4.5 (1.2, 11.1)	4.5 (1.9, 9.1)	1.3 (0.2, 4.6)††	0.7 (0, 3.6)
		6–8	0 (0, 0)	14.9 (11.5, 18.8)††	13.5 (10.3, 17.4)**	43.0 (38.0, 48.1)	3.1 (1.6, 5.2)	2.4 (1.1, 4.5)	2.6 (1.3, 4.7)††	1.6 (0.6, 3.4)
		9–11	0.3 (0, 1.4)	9.6 (6.9, 12.9)††	23.9 (19.7, 28.4)**	47.7 (42.7, 52.8)	5.5 (3.5, 8.0)	4.4 (2.6, 6.9)	1.8 (0.7, 3.6)††	1.8 (0.7, 3.7)
		12–14	0.2 (0, 1.3)	5.7 (3.7, 8.2)	43.3 (38.5, 48.2)**	47.4 (42.5, 52.3)††	27.0 (23.1, 31.1)**,††	3.8 (2.3, 6.1)**,††	1.4 (0.5, 3.1)**,††	0.5 (0, 1.6)
		15–17	0 (0, 0)	5.3 (3.6, 7.5)	44.2 (39.9, 48.5)**	44.2 (39.9, 48.5)††	27.0 (22.8, 31.5)**,††	5.2 (3.5, 7.4)**	1.8 (0.9, 3.3)††	0.5 (0.1, 1.6)**
	Rural	3–5	0 (0.2, 1.9)	16.7 (11.2, 23.5)	7.6 (3.9, 13.2)	31.7 (24.3, 40.0)	2.2 (0.5, 6.4)**	1.3 (0.2, 4.6)	10.3 (6, 16.1)††	1.3 (0.2, 4.6)
		6–8	0.7 (0, 1.3)	27.7 (24.0, 31.7)††	11.4 (8.9, 14.5)	42.6 (38.4, 46.9)**	3.9 (2.4, 5.9)	1.0 (0.3, 2.2)	7.9 (5.8, 10.5)††	2.7 (1.5, 4.5)**
		9–11	0.4 (0, 1.0)	15.1 (12.2, 18.3)††	22.9 (19.5, 26.6)**	44.9 (40.7, 49.1)	6.1 (4.3, 8.5)	3.1 (1.8, 4.9)**	10.0 (7.6, 12.7)††	2.2 (1.1, 3.8)
		12–14	0.2 (0, 1.0)	7.0 (5.0, 9.4)	44.1 (39.9, 48.4)**	38.6 (34.5, 42.8)**,††	21.5 (18.2, 25.2)**,††	8.1 (5.9, 10.6)**,††	14.2 (11.3, 17.4)††	1.1 (0.4, 2.3)
		15–17	0.2 (0, 1.0)	6.6 (4.7, 9.0)**	43.1 (38.9, 47.4)**	36.8 (32.7, 41.0)††	33.1 (29.1, 37.3)**,††	7.2 (5.2, 9.7)**	12.5 (9.8, 15.6)††	0.7 (0.2, 1.8)**

Abbreviation: *CI*=confidence interval.

$^{*, \dagger, \S, \P}$ Values sharing the same superscript letter do not differ significantly (P>0.05), values with different superscript letters differ significantly (P<0.05) between age groups.

** Significant gender difference within the same age group and region (P<0.05).

†† Significant urban-rural difference within the same age group and gender (P<0.05).

improved compared with the prevalence reported in CNNHS 2010–2013 (8.9% and 43.0%) (*8*). However, the prevalence of VDD and VDI in children aged 6–17 years (25.3% and 42.3%) was similar to that reported in CNNHS 2015–2017 (18.6% and 43.3%) (*9*). The prevalence of VDD and VDI in our study population substantially exceeds that reported in NHANES 2017–2018 data (for children aged 5–11 years and 12–19 years, the prevalence of VDD was 1% and 7%, and the prevalence of VDI was 13% and 23%, respectively) (*10*).

Iron deficiency persists as a significant nutritional challenge, particularly among adolescent girls. The observed prevalence of iron deficiency in girls aged 12–17 years (27.1%) remains virtually unchanged from CNNHS 2015–2017 (27.6%) (*9*), indicating that current intervention strategies may be inadequate. This elevated prevalence likely stems from increased iron requirements during adolescence, primarily due to menstruation-associated iron losses. While NHANES 2011–2016 data showed that 15% to 22% of girls aged 12–18 years had serum ferritin levels below 15 μg/L (*11*), our findings indicate that the iron status among Chinese adolescent girls requires substantial improvement to reach levels comparable to their US counterparts.

Our findings demonstrate a substantial improvement in selenium status among rural Chinese children aged 6–17 years, with the prevalence of low selenium status (11.1%) showing marked reduction from historical levels of 43.8% in 2002 and 25.6% in 2012 (*12*). However, consistent with previous research (*13*), significant urban-rural disparities persist, with rural children continuing to exhibit a higher prevalence of low selenium status.

Addressing micronutrient deficiencies in children requires a multifaceted approach. For widespread deficiencies, food fortification or supplementation represents an effective intervention strategy. Encouraging increased meat consumption can help combat iron, zinc, and selenium deficiencies, while promoting outdoor activities can enhance vitamin D levels. A comprehensive combination of these strategies is crucial for effectively addressing nutrient inadequacies in children.

A major limitation of this study is the under-representation of children aged 3–5 years, who constituted only 7.1% (646 out of 9,121) of the study population. Additional research with enhanced representation of this age group is necessary to establish more generalizable findings.

In conclusion, vitamin D deficiency and iron deficiency were highly prevalent among Chinese children, particularly in school-aged children. Selenium status exhibited significant urban-rural disparities, with rural areas showing marked deficiency. Public health interventions should prioritize vitamin D and iron interventions for school-aged children, alongside targeted strategies to increase selenium levels in rural children.

Conflicts of interest: The authors declare no conflicts of interest.

Ethical statement: Approval from the Medical Ethical Review Committee at the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention (No. 2019-009). Written informed consent was obtained from the guardians of all participating children.

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