Original Article

Dietary intake of zinc in the population of Jiangsu Province, China

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Objectives: To evaluate dietary zinc and other divalent minerals intake among the population of Jiangsu Province. Methods: 3,867 subjects aged 4-89 years were representatively sampled in two urban and six rural areas of Jiangsu Province. Dietary intake was assessed using 24-hour recalls on three consecutive days. Insufficient zinc intake was calculated based on the Chinese Dietary Reference Intakes. Results: Overall, the percentage of subjects with insufficient intake of zinc was 22.9%, with a declining trend with age. Except for the group ≥50 years, mean zinc intake of all other groups were below the age- and sex- specific Recommended Nutrition Intakes (RNI). Approximately 2/3rds of the subjects ≤17 years of age had insufficient zinc intakes. Compared with the age group below 11 years, risk of insufficient zinc intake increased in the adolescents aged 11-17 years (OR: 2.10, 95% CI: 1.86-2.36), but decreased in adults aged 18-49 years and ≥50 years (OR: 0.76, 95% CI: 0.66-0.8; OR:0.55, 95%CI: 0.47-0.64). Mean intake of iron, copper, magnesium and selenium met the Chinese DRIs respectively, except for selenium in females. The prevalence of insufficient intake of copper, magnesium and selenium was 37.2%, 22.8% and 29.3%, respectively, while the overall prevalence of insufficient iron intake was only 3.4%. Conclusion: Dietary zinc intake of the Jiangsu Province population does not generally meet the Chinese RNI. Children and adolescents in particular have a higher risk of insufficient zinc intake.

Key Words: zinc, minerals, dietary intake, Jiangsu Province, China

INTRODUCTION

Zinc is an essential trace element and is required for the activity of approximately 300 enzymes involved in most of the major metabolic pathways. Consequently, zinc is necessary for a wide range of biochemical, immunological and clinical functions.[1,2] Adverse health consequences of zinc deficiency are: growth retardation, delayed sexual and bone maturation, skin lesions, diarrhea, impaired appetite, increased susceptibility to infections mediated via defects in the immune system, and the appearance of behavioral change, especially in infants, toddlers and children, pregnant women, and elders.[3-6]

Insufficient dietary zinc intake is one of the causes of zinc deficiency, which is in isolation or in combination with other factors, such as increased requirements, malabsorption, increased losses, and impaired utilization.[1] Dietary factors can influence zinc absorption. Phytate and dietary calcium inhibit zinc absorption, whereas protein and amino acids may have a positive effect on zinc bioavailability.[7] In addition, the fractional absorption of zinc deceases with increasing amount of zinc intake.[1] Moreover, other divalent minerals, such as copper, iron, magnesium and selenium, may compete with zinc for absorption. Dietary reference intakes (DRIs) are developed as nutrient reference standards which provide guidance for maintaining and enhancing adequate nutritional status.[8] The Chinese DRIs has been developed by the Chinese Nutrition Association in 2000.[9] Average phytate intakes in China is higher than that in western countries, which negatively affects the absorption of zinc, particularly when the molar ratio of phytate to zinc is above 15.[10-12] Ma et al.[13] showed higher proportions of zinc inadequacy in a Chinese population consuming a diet with a higher phytate content, but they assessed the prevalence of zinc intake in accordance with the normative requirement of the WHO.[3]

In Jiangsu Province, the average soil zinc concentration is lower than the national average level.[14] Consumption of plants growing on such soils might result in low zinc content of the diet.[15] The 2002 China National Nutrition and

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Health Survey was implemented in 2002, and Jiangsu Province was involved as a part of the survey. Based on the survey, our study aimed (1) to evaluate dietary zinc intake in a representative sample in Jiangsu Province; (2) to investigate demographic factors related to zinc intake; (3) to assess the intake of other nutrient intakes, including iron, copper, magnesium and selenium among the population.

MATERIALS AND METHODS

Sample

In 2002, China launched a national representative cross-sectional study on nutrition and health. A multistage cluster sampling method was used for subject selection. The data presented in this article are based on a sub-sample from Jiangsu Province, one of the economically booming areas in East-China, with a population of 73.6 million. Two urban cities (Nanjing, Xuzhou) and 6 rural areas (Jiangyin, Taicang, Suining, Jurong, Sihong, Haimen) were randomly selected based on geographic characteristics and economic development, and then three townships/sub-districts were randomly selected from each city or rural area. Two villages/neighborhood committees were randomly selected from the selected townships or sub-districts. Thirty households were randomly selected from each of the selected villages or neighborhoods for dietary intake assessment. The six counties and two cities represented a geographically and economically diverse population with a gross domestic product ranging from 3,221 Yuan/capita/year (US$403) to 35,169 Yuan/capita/year (US$4,396; mean US$1,993, SD 1,510; Jiangsu Bureau of Statistics, 2002). Nanjing, Jurong, Taicang and Jiangyin are in the South. The south has a higher gross domestic product than the north (24,702 vs. 7,183 Yuan). All members in the households were invited to take part in the study. Written consent was obtained from all the participants or their parents/guardians. Because of the small sample of toddlers below 4 years, we just included subjects above 4 years and altogether 3,867 subjects have been included in the present analysis.

Dietary intake assessment

Information on food intake was collected using the 24-hour dietary recall method for three consecutive days (two weekdays and one following weekend day) during September and November. Participants were interviewed in their homes by trained health workers from the local Center for Disease Control and Prevention using a pre-coded questionnaire. Interviews took approximately two hours to complete. Interviews for subjects below 18 years were completed by their parents/guardians. Energy and nutrient intake was calculated using the data from dietary recall in conjunction with the Chinese Food Composition Table published in 2002.[16]

Other information

Socio-demographic information, health habits such as cigarette smoking and physical activity, and other life-style factors were included in the questionnaire. Socio-economic status (SES) was assessed by the question 'What was your family's income per person in 2001?' The response categories for the question were less than 800, 800–1,999, 2,000–4,999, 5,000–9,999, 10,000–19,999 and more than 20,000 Yuan. Socio-economic status was constructed from income, 'low' being less than 1,999 Yuan, 'medium' being 2,000–4,999 Yuan and 'high' being more than 5,000 Yuan. Age groups were categorized as < 11years, 11-17 years, 18-49 years and ≥ 50 years.

Statistical analysis

Values of dietary energy or nutrient intake are expressed as mean and standard deviation (SD) mg/day. Using age- and gender- specific values from the Chinese DRIs (Table 1), insufficient and adequate nutrient intake in specific population groups were determined as below 66% and 77% of the RNI or AI respectively.[9,17] T-test, ANOVA with Tukey's post hoc comparisons and chi-squared test was used to compare the differences in nutrient intake and categorical variables between different gender and age groups, respectively. Poisson regression was used to determine the association between socio-demographic factors including residence, age, socioeconomic status, region and education and insufficient zinc intake. Poisson regression models were fitted by using SAS software (SAS Institute, Inc., Cary, North Carolina). Other analyses were performed using SPSS 12.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $\alpha = 0.05$.

RESULTS

Table 2 shows the characteristics of the sample. A total of 3,867 subjects (1,834 male and 2,043 female), with balanced distribution in gender, age, region and socio-

Table 1. Chinese Dietary Recommendations †

	RNI		AI	
	Male	Female	Male	Female
Zinc (mg/d)				
4-6 yrs	12			
7-10 yrs	13.5			
11-13	18	15		
14-18	19	15.5		
18-49	15	11.5		
50^+	11.5			
Iron (mg/d)				
4-10 yrs			12	
11-13			16	18
14-18			20	25
18-49			15	20
50^+			15	
Copper (mg/d)				
4-6 yrs			1.0	
7-10 yrs			1.2	
11-13			1.8	
14^+			2.0	
Selenium (mg/d)				
4-6 yrs	25			
7-10 yrs	35			
11-13	45			
14^+	50			
Magnesium (mg/d)				
4-6 yrs			150	
7-10 yrs			250	
11^+			350	

† Data is original from reference 9.

Table 2. Descriptive characteristics[†‡]

	Male	Female
Total	1824	2043
Age group(years)		
<11	154	174
11-17	194	191
18-49	884	1033
≥50	592	645
Residence		
Urban	458	495
Rural	1366	1548
Region		
South	919	1001
North	905	1042
Education		
Primary	527	947
Junior high school	638	508
High school	243	188
University	68	33
Socio-economic status		
Low	620	697
Medium	562	670
High	624	657

economic conditions, were involved in the study. Males had a higher education than females. As expected, energy and nutrient intakes in males were significantly higher than those in females.

The average mean of zinc intake was 8.1 ± 2.7, 10.3 ± 3.1, 12.3 ± 3.7, and 11.6 ± 3.7 mg/d for age groups of 4-11 years, 11-17 years, 18-29 years, and above 50 years, respectively. Except for the group above 50 years, zinc intake in other groups was below the age- and sex- specific recommended RNI values (Table 1). Energy and zinc intake increased with age, for both males and females. The average mean intake of iron, copper and magnesium met the recommended daily intake for corresponding nutrients and age group, while selenium was below the recommended values in females. There were no differences in intake in terms of iron, copper, magnesium and selenium among different age groups, except for copper and selenium in males (Table 3).

The percentage of insufficient intake of zinc was 22.9%, with a declining trend with age. Subjects below 18 years old had a higher prevalence of insufficient zinc intake, while subjects above 18 years had a higher prevalence of adequate zinc intake. The prevalence of insufficient intake of copper, magnesium and selenium was

Table 3. Dietary intake of energy and selected nutrients by gender and age groups[†‡]

	Age group (yrs)			
	<11	11-17	18-49	50$^+$
Male				
Energy (1000kcal/d)	1.7(0.5)^a	2.3(0.6)^b	2.7(0.7)^d	2.5(0.7)^c
Zinc (mg/d)	8.5(2.8)^a	11.2(3.1)^b	13.7(3.8)^d	12.7(3.8)^c
Iron (mg/d)	17.7(6.3)^a	24.2(8.5)^b	28.6(10.6)^d	26.9(13.1)^c
Copper (mg/d)	1.9(2.7)^a	2.2(0.8)^a	2.5(1.0)^c	2.4(1.1)^b
Magnesium (mg/d)	239.7(105.4)^a	232.3(124.7)^a	369.9(148.8)^c	345.6(144.8)^b
Selenium (mg/d)	36.5(17.6)^a	44.0(19.2)^b	50.7(19.9)^c	46.5(21.0)^b
Female				
Energy (1000kcal/d)	1.6(0.5)^a	1.9(0.5)^b	2.1(0.6)^c	2.1(0.6)^d
Zinc(mg/d)	7.7(2.6)^a	9.5(2.8)^b	11.2(3.2)^d	10.5(3.3)^c
Iron(mg/d)	16.3(5.7)^a	20.6(7.4)^b	23.9(9.5)^c	22.4(9.8)^b
Copper (mg/d)	1.6(1.2)^a	1.8(0.8)^a	2.2(0.9)^b	2.1(1.0)^b
Magnesium (mg/d)	222.9(80.2)^a	264.2(121.8)^b	311.1(130.7)^d	292.3(127.5)^c
Selenium (mg/d)	31.6(15.5)^a	34.7(13.8)^a	41.5(17.6)^b	38.9(17.9)^c

[†]Data is presented as mean (SD).
[‡]Differences in intake of energy and selected nutrients between age groups by gender were analysed by ANOVA and Tukey's post hoc comparisons. Values in the same row with different superscript letters are significantly different.

Table 4. Prevalence of insufficient and adequate intake of selected nutrients according to Chinese dietary recommendations[†‡]

	Age group (yrs)				
	<11	11-17	18-49	50$^+$	*p* value
Insufficient intake					
Zinc (%)	64.6	64.9	13.9	12.6	<0.001
Iron (%)	2.1	8.8	3.7	1.5	<0.001
Copper (%)	2.7	24.7	40.7	44.9	<0.001
Magnesium (%)	11.0	34.5	20.9	25.2	0.006
Selenium (%)	5.2	36.9	27.1	36.6	<0.001
Adequate intake					
Zinc (%)	19.2	16.9	73.4	76.5	<0.001
Iron (%)	94.2	83.6	92.5.	96.5	<0.001
Copper (%)	94.5	75.1	82.2	77.8	<0.001
Magnesium (%)	78.6	50.6	64.2	57.1	<0.001
Selenium (%)	92.4	48.6	58.6	50.5	<0.001

[†]Data is presented as prevalence. Insufficiency and adequacy of nutrient intake in specific population groups was determined as below 2/3 and above 77% of the 2001 RNI or AI of the age- and gender- specific values, respectively.

Table 5. Prevalence of insufficient intake of selected nutrients by socioeconomic factors†‡

	Resident			Region			Socio-economic status				Education			
	Urban	Rural	*p*	South	North	*p*	Low	Medium	high	*p*	low	Medium	High	*p*
Zinc insufficiency	35.2	18.9	<.001	17.0	28.7	<.001	27.3	23.1	18.2	<.001	26.1	20.4	17.6	<.001
Iron insufficiency	6.6	2.3	<.001	3.6	3.2	0.482	1.8	4.7	3.7	0.008	2.4	4.3	4.8	0.001
Copper insufficiency	56.8	30.9	<.001	49.3	25.4	<.001	25.7	39.4	47.2	<.001	31.2	40.5	50.7	<.001
Magnesium insufficiency	39.8	17.2	<.001	30.7	14.9	<.001	14.4	25.0	29.4	<.001	21.4	21.6	30.4	<.001
Selenium insufficiency	27.0	30.0	0.72	30.6	27.9	0.067	35.9	29.2	22.6	<.001	33.9	26.4	19.9	<.001

†Data is presented as prevalence. Insufficiency of nutrient intake in specific population groups was determined as below 2/3 of the 2001 RNI or AI of the age- and gender- specific values.
‡ Prevalence of insufficient nutrients intake were analysed by chi-square test.
* Low, medium and high education is defined as primary school, junior high school, and high school and above, respectively.

Table 6. Poisson regression model for predictors of insufficient zinc intake†

Characteristics	Odds ratio (95%CI)	*p* value
Gender		
Female	1	
Male	1.45(1.31-1.60)	< 0.001
Age group		
< 11 yrs	1	
11-17 yrs	2.10 (1.86-2.36)	< 0.001
18-49 yrs	0.76 (0.66-0.86)	< 0.001
50^+ yrs	0.55 (0.47-0.64)	< 0.001
Residence		
South urban	1	
South rural	0.89 (0.73-1.07)	0.21
North urban	1.52 (1.26-1.84)	< 0.001
North rural	1.15 (0.94-1.39)	0.16
Socio-economic status		
Low	1	
Medium	0.91 (0.82-1.03)	0.15
High	0.78 (0.68-0.90)	< 0.001

†Adjusted by daily energy intake. Insufficiency of nutrient intake in specific population groups was determined as below 2/3 of the 2001 RNI or AI of the age- and gender- specific values.

37.2%, 22.8% and 29.3%, respectively. In contrast to zinc insufficiency, the prevalence of copper, magnesium and selenium insufficiency tended to increase, while the prevalence of adequate intake decreased with age. The prevalence of insufficient iron intake was the lowest (3.4%) as compared to the other nutrients, and all age groups had adequate iron intakes except ages 11-17 years. (Table 4).

The prevalence of insufficient intake of zinc, iron, copper and magnesium was higher in urban residents than in rural residents (p<0.001, respectively). Residents from the North had a higher prevalence of insufficient zinc intake than residents from the South, while insufficient intake of copper and magnesium was higher in the South (p<0.001, respectively). There were no differences in selenium intake between urban and rural areas, or between the South and the North (Table 5).

The prevalence of insufficient intake of zinc and selenium was lower in the high socio-economic status group compared with the lower socio-economic groups (p<0.001, respectively). In contrast, the prevalence of insufficient intake of iron, copper and magnesium increased with socio-economic status (p<0.01, respectively). Similarly, the prevalence of insufficient intake of zinc and selenium decreased with education, while insufficient intake of iron, copper and magnesium had a negative trend (p<0.01, respectively) (Table 5).

A Poisson regression was undertaken to assess the association of insufficient intake of zinc with demographic characteristics. Males have a higher risk for zinc insufficiency, with an odds ratio (OR) of 1.45 (95% CI: 1.31-1.60) compared to females (Table 6). There was a higher risk of insufficient intake of zinc in the age group of 11-17 years (OR: 2.10, 95% CI: 1.86-2.36), but a decreased risk in the age group of 18-49 years and older than 50 years (OR: 0.76, 95% CI: 0.66-0.8; 95%; OR: 0.55, 95%CI: 0.47-0.64), in comparison with that in the age group of children below 11 years. The risk was higher in the North than in the South, with the highest odds ratio in the Northern urban residents (OR: 1.52, 95% CI: 1.26-1.84). Subjects with a high socio-economic status showed a decreased risk for insufficient intake of zinc, as compared to subjects with a low socio-economic status.

DISCUSSION

Our study showed that daily dietary zinc intake was low according to the Chinese DRIs in the study population from Jiangsu Province, especially in children and adolescents. Males were more likely to suffer from dietary zinc insufficiency than females.

The Chinese DRIs includes four concepts: EAR, RNI, AI and UL. The EAR (estimated average requirement) estimates an intake that is to prevent deficiency in 50% of a population. The RNI (recommended dietary intake) is approximately 2 standard deviations above the EAR and should provide adequate intake for 97.5% of the population for a given micronutrient. The UL (upper safe level) provides recommendations on values to avoid the sequels of excessive intake.[9,18,19] In our study, we used a cut-off of 2/3 of the RNI to estimate insufficiency of zinc intake and intake of other micronutrients among the population of Jiangsu Province.

As a subgroup analysis of the Chinese Nutrition and Health Survey, the study has its strengths and limitations. Our sample included an economically and geographically diverse population from Jiangsu Province, and therefore can be considered to be representative for the Province as a whole.[20] For the dietary assessment, we used a 3-day 24 h dietary recall in conjunction with the updated Chinese Food Composition Table, which can be sufficient to describe the subject's usual intake of nutrients.[16,21] For assessment of dietary zinc insufficiency, we used the new Chinese DRIs, which has been specifically developed and updated for studies in China.[9] Odds ratios were calculated using the Poisson regression models, which provides a better estimation than odds ratio by logistic regression in cross-sectional studies.[22] A limitation is that we covered a few days within a short time frame for dietary intake assessment, and zinc insufficiency might have been either overestimated or underestimated in our study.[23] The recommended zinc intake by life stage from the Chinese DRIs are higher than the recommendations from IZiNCG and the WHO.[1,3] This difference may partly explain why the prevalence of insufficient zinc intake in our study was higher than that previously reported at the national level using the other recommendations. Moreover, since soil zinc is low in Jiangsu Province, the actual zinc content of foods may have been lower than that reported in the Food Composition Table, which may underestimate insufficient intake of zinc in the population.

In our study, the mean zinc intake in age- and gender-specific population groups was lower than the recommended values for each specific group, except in males above 50 yrs; this may be due to a higher energy intake and/or altered zinc metabolism.[24] About 58%-64% of children aged 4-18 yrs had low dietary zinc intake, although this was less than 20% among adults. Insufficient intake of zinc has also been reported in other developing and emerging countries, but also in some affluent countries. A National Food Consumption Survey in South Africa showed inadequate intake of zinc in all age groups, and 50-73% of children had an intake less than two-third of their RDA.[25] In a survey from the UK, the prevalence of inadequate zinc intake was reported to be 13% in young people aged 4-18 yrs, and higher prevalence was reported in girls aged 4-6 yrs (26.2%) and aged 11-14 yrs (34.5%), respectively. The UK reference nutrient intakes are lower than the Chinese recommendations.[26,27] From the ZENITH study in European countries, the percentage of subjects who had an intake below 2/3 of the European RDA for people older than 55 yrs was lower than 4%.[24] In Mexican-American- and Anglo-American preschool children, 33% and 38% of zinc insufficiency were reported according to the 1989 US recommended dietary allowance. In the US, young children aged 1-3 yrs (81.1%, adolescent females aged 12-19 yrs (56.8%) and persons aged above 71 yrs (57.5%) were at the greatest risk of inadequate zinc intake, based on a total intakes of > 77% of the 1989 recommended dietary allowance.[17] However, Arsenault et al.[28] reported only 1% of inadequate zinc intake among US preschool children based on the 2001 recommended dietary allowance. The new recommended dietary allowance has lower age- and gender- specific values than the previous one. Differences in the prevalence of insufficient zinc intake among different countries and studies is attributed to differences in sampling methods and different target populations, but also for an important part the differences between the dietary recommended values used.[29] Therefore, it is not clear to what extent the differences in dietary habits and zinc content of foods consumed in different countries may explain the variation.

Although zinc intake was low in our study, caution is warranted in predicting zinc status. The absorption of zinc depend not only on the amount but also on the quality of zinc ingested with the diet, and can be modified by chemical compositions of the zinc sources and the nutrient matrix.[7,30] Moreover, zinc absorption is increased in subjects with lower zinc status.[31]

We found that Northern and urban residents had a higher risk for dietary zinc insufficiency, compared to Southern and rural residents, respectively. This may be due to differences in socio-economic status and different food choices.[32] People from the North had a lower socio-economic status than those from the South. Nevertheless, it is surprising that city residents are more likely to have insufficient zinc intake than rural residents. This might partly be explained because rural residents consumed more energy than city residents. Moreover, although the quantity of zinc intake may be less in the cities, its bioavailability may be higher due to the higher quality of the diet. Our study also showed decreased risk for dietary zinc insufficiency with increased income, which was consistent with other reports.[26,32,33] The same trend was also seen with increasing education. Residents with a low socio-economic status or a low education level may spend more money for larger quantities of food that may have lower nutrient density at the expense of dietary quality.[34] A study by Thane et al.[26] did not support the association between low zinc intake and poor socio-economic conditions.

We also studied the intake of other divalent minerals besides zinc, and showed high risk for insufficient intakes of copper, magnesium and selenium, with low risks for insufficient intake of iron. However, Shi et al. reported in 2007 that 18.3% of men and 32.6% of woman above 20 yrs suffered from anemia in Jiangsu Province.[35] Magnesium intake was shown to be related to anemia in this study. Dietary intakes of iron, copper, magnesium and selenium had different distributions in age and gender specific groups, when compared to zinc intake. Differences in dietary sources may account for these differences.[29]

In conclusion, dietary zinc intake does not meet the Chinese DRIs, particularly in children and adolescents of Jiangsu Province. In addition, risk for insufficient zinc intake is more likely in the northern part of the Province, in city residents, and in residents with low socio-economic status. Moreover, intakes of copper, magnesium and selenium are low among specific age groups of this population. Relationships between dietary patterns and nutrients intakes should be further investigated, and dietary intervention strategies should be adapted in accordance with different areas and age groups.

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AUTHOR DISCLOSURES
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Original Article

Dietary intake of zinc in the population of Jiangsu Province, China

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中国江苏省居民膳食鋅摄入量的研究

目的：调查了解中国江苏省民眾食物中锌及其他二价元素摄入情况。方法：在江苏省 2 个城市和 6 个农村地区选择代表性的样本，共包括 3,867 名 4-89 岁的居民。以連續三天 24 小时饮食回顾法評估食物营养摄入，并根据中国膳食参考摄入量来定義锌摄入不足。结果：锌摄入量不足率为 22.9%，随着年龄的增长而下降。除 50 岁及以上的组别外，其他年龄组人群平均锌摄入量均低于相应年龄、性别的推荐摄入量。在 17 岁及以下的受訪者中，锌摄入量不足者约占 2/3。与 11 岁以下年龄组相比，锌摄入量不足的风险在 11-17 岁的青少年有所增加(OR: 2.10, 95% CI: 1.86-2.36)，而在成人 18-49 岁组和 50 岁及以上组别都下降(OR: 0.76, 95%CI: 0.66-0.8; OR: 0.55, 95%CI: 0.47-0.64)。在调查群体中，除了女性硒摄入量外，其余各组铁、铜、镁和硒的平均摄入量均达到中国膳食推荐摄入量。铜、镁和硒摄入不足率分别为 37.2%、22.8%及 29.3%，而铁摄入不足率仅为 3.4%。结论：江苏居民膳食锌摄入量不能达到中国膳食推荐摄入量，尤其是儿童和青少年的风险较高。

关键词：锌、礦物質、膳食摄入量、江苏省、中国