Micronutrients deficiency and associated socio-demographic factors in Chinese children

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Background: **Although the prevalence of malnutrition has decreased, micronutrient deficiency still exists among children. While iron level has been studied, limited information on serum levels of zinc in Chinese children is available. This study aims to describe the status of micronutrients and its association with sociodemographic factors, and to assess associated risk factors.**

Methods: **A cross-sectional study was performed on 1375 Chinese preschool children. Venous blood samples were collected and analyzed for zinc and iron by atomic absorption spectrophotometry. Sociodemographic information was obtained from self-administered questionnaires given to the parents.**

Results: **The high prevalence of low serum zinc (38.2%) and iron (24.3%) was found. Children from rural preschools had the lowest zinc levels, whereas those from urban preschools had the lowest iron levels. Children living in small houses had the highest prevalence of low serum zinc (47.1%), and children from small families (≤3 persons) had a higher prevalence of low serum zinc than those from large families (41.8% *vs.* 34.1%).**

Conclusions: **Our findings in the recent socioeconomic development of China suggest the need for continuous monitoring of nutritional factors and highlight the importance of public health implication in preschool children even in developed regions.**

World J Pediatr 2011;7(3):217-223

Key words: **iron; micronutrient deficiency; socio-demographic factors; zinc**

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doi:10.1007/s12519-011-0317-1

Original article

Introduction

Iron and zinc play important roles in children's health. Zinc is a component of enzymes that affect growth in infancy and childhood, sexual maturation, neuromotor development, and immunity. Mental function is improved by zinc's promotion of normal brain development and physiology.[1,2] Iron also has an important mental function by serving as a co-enzyme involving in the production and release of neurotransmitters,[1,3] and by influencing cognitive function[4] and behavioral disorders such as attention deficit hyperactivity disorder (ADHD).[5] Iron deficiency anemia has been linked with long-term cardiovascular problems,[6,7] obesity,[8] and hyperglycemia.[9] Zinc deficiency has been implicated in hyperglycemia,[10] diabetes,[11] and cardiovascular disease.[12] Furthermore, we previously reported that early micronutrient deficiency (zinc and iron) was linked to later cognitive deficit[13] and increased externalizing behavior outcomes in children.[14]

In developing countries, iron and zinc deficiency is common.[15,16] Over 90% of affected individuals live in developing countries and approximately one-tenth of the worldwide population suffers from iron deficiency.[17] Zinc deficiency in children continues to be a nutritional problem in both developing and developed countries.[18] Sociodemographic factors are related to food intake and infection risk as well as zinc and iron deficiency in developing countries.[19]

Iron and zinc deficiency used to be common in China, but over the past two to three decades reports on iron and zinc status have been mixed due to the socioeconomic reform and rapid economic development that has taken place since 1979. The availability[20] and affordability[21] of foods have increased dramatically during the past three decades. As a result of this increased output and access to food, the prevalence of malnutrition has decreased, while over-nutrition has increased.[22,23] Specific to micronutrients such as iron and zinc, studies show that iron deficiency is less prevalent than zinc deficiency among Chinese children.[24,25] Although the prevalence of anemia has decreased in China, it still exists among children.[22,26] While iron status has been studied, limited systematic information on serum levels of zinc in Chinese children is available.

Based on a large cohort study in an economically booming area in China, we described the status of serum iron and zinc and the associations with sociodemographic factors. The purposes of this study are to describe iron and zinc status among representative communities of Chinese children and to assess risk factors associated with low iron and zinc status.

Methods

Study design and samples

In this cross-sectional study, the subjects were drawn from The Jintan Child Study which consists of a preschool cohort of 1656 children accounting for 24.3% of all children in this age-range in Jintan city. The cohort comprised 55.5% boys, 44.5% girls, and 99.8% Han ethnicity, which was a representative sample based on data from a recent population census.[27] Between Fall 2004 and Spring 2005, all children (aged 3-5 years old) attending the following four preschools in Jintan consented to participate in our study: Jianshe (city), Huacheng (suburb), Xuebu, and Huashan (rural). Among the original group of 1656 children, complete data were available for 1375 children. We did not find significant difference in demographic factors between the two groups with completed and non-completed data (for example, no gender difference in the two groups with χ^2=0.77, P=0.381). We recently published the Jintan Cohort Profile, which contains detailed information on the subjects, recruitment, and setting.[27] Institutional Review Board (IRB) approval was obtained from the University of Pennsylvania and the ethical committee for research at Jintan Hospital in China. Furthermore, we held several focus group meetings, involving the Jintan research advisory board (pediatricians, school teachers, principals, representative parents of subjects, and researchers), in order to prepare the instruments of measurement and to formulate culturally relevant explanations of the data obtained.

Measures

Collection and analyses of blood samples

Blood specimens were collected in Autum 2004 and Spring 2005 by trained pediatric nurses using a strict research protocol to avoid lead contamination. Approximately 0.5 mL of venous blood was collected in a lead-free EDTA tube for zinc and iron analysis. Samples were frozen and shipped to the Child Development Center, Nanjing Medical University, Nanjing, China for analysis. Specimens remained frozen at -20ºC until analysis. Whole blood concentrations of iron and zinc were determined by atomic absorption spectrophotometry (BH model 5.100 manufactured by Beijing Bohu Innovative Electronic Technology Corporation), with duplicate readings taken with an integration time of two seconds. The reliability and validity of the analysis and the detailed analytic procedure have been described previously.[28]

Sociodemographic information

Sociodemographic information obtained from the questionnaire included gender, age, parental education, parental occupation, living conditions, house size, family size, and home location (city, suburb, rural). Parents filled out the sociodemographic questionnaire during their meeting at the pre-schools at the end of the school year when blood samples were collected, including the parents' occupation that they had held for the longest period in their lives. While this questionnaire was self-administered, research assistants were on-site to assist parents filling out the forms.

We did not ask for data on household income because it is often not the best indicator of socioeconomic status (SES) since the use of household income does not address the fact that family members may have unequal access to household income[29,30] and it may not adequately represent the standard of living of retired persons.[31] In addition, since we speculated that current income may be associated with recent health, a comparison of income and health status may therefore be subject to issues of reverse causation. In particular, China is experiencing rapid socioeconomic changes which have resulted in the instability of income and salary distribution. In a focus group held in preparation for this research, the Jintan research advisor board suggested that data on income not be collected because reported annual income may not reflect actual income, which may include additional financial bonuses and benefits. Furthermore, people in China still consider income to be private information and are reluctant to report it.[32]

Therefore, we asked for information on house size to indirectly indicate socioeconomic status. We also gathered data on family size. Although more than half of the families in our data set contained 3 persons (56.5%) (2 parents and 1 child), the rest contained more than 3 family members, including grandparents or additional children. Although the majority of families had only one child due to the one-child policy that still exists in China, there were a few families that had more than one child.

Data analysis

Descriptive statistics (means, standard deviations) were provided for Zn and Fe levels according to sociodemographic factors. Additionally, frequencies and percentages were provided for low zinc and iron status defined by levels of serum zinc <76.5 μg/dL and serum iron <7.5 μg/dL, respectively, within the various sociodemographic subgroups. These cutoffs were taken from the middle of the normal range. The Chi-square test and two-sample *t* test or ANOVA as appropriate was used to compare zinc and iron distributions by subgroup levels defined by sociodemographic factors. Multiple logistic regression models were used to regress dichotomized outcomes (low Zn and low Fe, separately) on sociodemographic factors, including family size, gender, education of parents, current living place (city, suburb, rural), and house size. Parameters for these subsets are listed in Table 1. The logistic regression models were adjusted for school cluster. The association between Zn and Fe levels was examined using a linear regression model. Statistical significance was taken at the two-sided $P<0.05$ level. All of the analyses were performed using STATA software.[33]

Results

Table 1 provides mean values for zinc and iron among preschool children, aged 3 to 5 years, within sociodemographic subgroups. The mean serum zinc levels were 82.2 (SD 13.4) μg/dL in boys and 82.9 (SD 13.4) μg/dL in girls. Both boys and girls had the same level of serum iron (8.1 μg/dL). Overall, the prevalence of low zinc and iron was 38.2% and 24.3%, respectively. There was a significant difference in the mean serum zinc and iron levels by preschool location. Children from rural preschools had the lowest level of serum zinc, but those from the city preschools had the lowest level of serum iron. Family size was positively associated with serum zinc level, but not with iron. Children living in a small house (<80 m^2) had the highest prevalence of low serum zinc (47.1%), and children from small families (≤3 persons) had a higher prevalence of low serum zinc than those from large families (41.8% *vs.* 34.1%, P=0.006). Furthermore, the education level of parents was classified into three categories: low education in those who had only completed junior high school or less (48.1% of mothers, 39.0% of fathers), medium education in those who had some high school or other vocational training (31.6% of mothers, 33.6% of fathers), and high education in those who had finished high school or beyond (20.3% of mothers, 27.4% of fathers).

The coexistence of low serum zinc and iron was

Table 1. Descriptive estimates of zinc and iron by socio-demographic factors among preschool children aged 3-5 years in Jiangsu, China (*n*=1375)

Variables	*n*	Zn (μg/dL)					Fe (μg/dL)				
		mean	SD	$P^‡$	Low Zn (%)*	$P^‡$	Mean	SD	$P^‡$	Low Fe (%)†	$P^‡$
Gender											
Male	760	82.2	13.4	0.358	38.4	0.888	8.1	0.8	0.683	24.5	0.916
Female	615	82.9	13.4		38.0		8.1	0.8		24.2	
Mother's education											
Low (≤9 y)	625	82.8	13.5	0.828	37.4	0.747	8.1	0.8	0.997	25.3	0.761
Medium (9-12 y)	411	82.4	13.1		38.4		8.1	0.8		23.4	
High (>12 y)	264	82.3	13.9		40.2		8.1	0.8		23.9	
Father's education											
Low (≤9 y)	506	83.1	13.4	0.503	37.0	0.614	8.2	0.8	0.581	25.5	0.667
Medium (9-12 y)	435	82.1	13.0		38.4		8.1	0.8		24.4	
High (>12 y)	355	82.5	14.1		40.3		8.1	0.8		22.8	
House size (m^2)											
<80	227	81.4	13.3	0.434	47.1	0.019	8.1	0.8	0.635	26.0	0.654
≥80 & <100	464	82.5	13.1		36.2		8.2	0.8		22.0	
≥100 & <120	174	83.3	13.6		34.5		8.2	0.8		24.7	
≥120	392	83.1	13.9		36.5		8.1	0.8		24.5	
Family size (persons/family)											
>3	548	83.3	12.6	0.056	34.1	0.006	8.2	0.8	0.194	22.8	0.265
≤3	713	81.9	13.9		41.8		8.1	0.8		25.5	
Location											
City	543	81.0	15.0	<0.001	46.0	<0.001	8.1	0.9	<0.001	30.2	<0.001
Suburb	547	85.3	11.2		25.4		8.2	0.8		16.6	
Rural	285	79.9	13.0		48.1		8.1	0.8		28.1	

*: Low zinc was defined as serum zinc <76.5 μg/dL; †: Low iron was defined as serum iron <7.5 μg/dL; ‡: For continuous variables, *P* value represents an ANOVA test; for categorical variables, it is from a Chi-square test.

seen in 17.0% of the children (Fig. 1). While the low serum zinc was more common than the low serum iron, over 7% of the children had a low iron but normal zinc level. Only about half of the children had both normal zinc and iron levels. No gender differences were observed in the prevalence of low zinc and iron levels. Serum zinc was positively correlated with serum iron (*r*=0.29) but after excluding extreme zinc values of <50 μg/dL or >150 μg/dL, *r*=0.33 (*P*<0.001, Fig. 2).

The multiple logistic regression adjusted model shows that a small family size was associated with a higher risk of low zinc and iron levels (Table 2). Compared with large families, small families had an odds ratio of low zinc level of 1.36 (95% CI 1.15-1.60). The odds of low iron level was 1.17 (95% CI 1.01-1.37). Mother's education was positively associated with the risk of low zinc level, as children of mothers with high education had a 33% increased risk of low zinc level, compared to children of mothers with less education. However, an association between mother's education and low iron level was not demonstrated. Living in a house larger than 80 m^2 was associated with a lower risk of low zinc level, but not low iron level.

In multivariate logistic regression adjusting for sociodemographic factors including family size, gender, mother's education, location, and house size, low zinc level was positively associated with low iron level (OR 5.61, 95% CI 3.85-8.16; data not shown). After adjusting for zinc level, none of the above sociodemographic factors was associated with the low level of iron. Furthermore, additional adjustment for children's age while adjusting for other covariates did not change the association in the model for zinc (*P*=0.777) or iron (*P*=0.587) deficiency.

Discussion

In this cross-sectional study, we found a significant prevalence of low serum zinc and iron in Chinese children. While low zinc was more common than low iron, the coexistence of low levels of both zinc

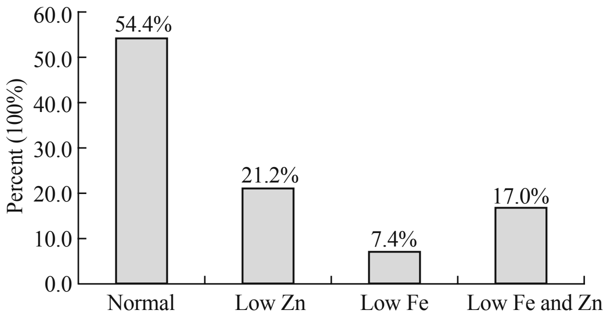

Fig. 1. Distribution of low Zn and Fe percent among children in Jiangsu China.

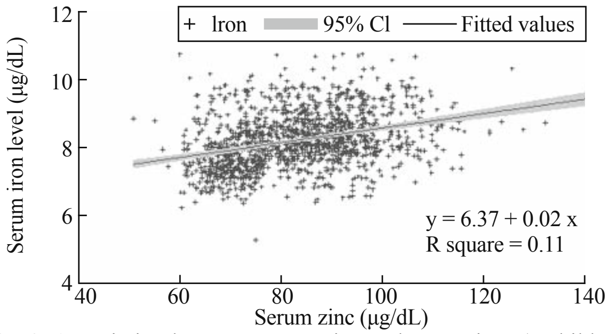

Fig. 2. Association between serum zinc and serum iron (5 children with Zn <50 and 2 children with Zn >150 were excluded).

Table 2. Odds ratio (95% CI) of low zinc and iron levels assessed by sociodemographic variables in multivariate logistic regression*

Variables	Low Zn†	*P*	Low Fe‡	*P*
Family size				
>3 persons/household	1 (reference)		1	
≤3 persons/household	1.36 (1.15-1.60)	<0.001	1.17 (1.01-1.37)	0.041
Genders				
Boys	1 (reference)		1	
Girls	0.95 (0.70-1.28)	0.722	0.93 (0.82-1.05)	0.247
Mother's Education				
Low (≤9 y)	1		1	
Medium (9-12 y)	1.14 (0.81-1.62)	0.454	0.93 (0.66-1.32)	0.693
High (>12 y)	1.33 (1.24-1.42)	<0.001	1.01 (0.48-2.10)	0.981
Location				
City	1		1	
Suburb	1.48 (0.83-2.64)	0.189	1.12 (0.52-2.43)	0.771
Rural	1.17 (0.64-2.16)	0.605	0.98 (0.54-1.77)	0.936
House size (m^2)				
<80	1		1	
≥80 & <100	0.66 (0.63-0.70)	<0.001	0.89 (0.58-1.36)	0.588
≥100 & <120	0.61 (0.46-0.81)	0.001	1.03 (0.86-1.23)	0.737
≥120	0.70 (0.56-0.87)	0.002	1.06 (0.73-1.55)	0.755

*: model adjusted for preschool clusters. †: Low zinc was defined as serum zinc <76.5 μg/dL. ‡: Low iron was defined as serum iron <7.5 μg/dL.

and iron was high. The low zinc level was associated with sociodemographic factors. Living in a small family or a small house and having a mother with high education were positively associated with low zinc levels. The low zinc level was highly associated with low iron level. There was no clear association between sociodemographic factors and low iron level.

The high prevalence of poor iron level among children was consistent with findings in adults and adolescents.[34,35] However, in contrast to findings in adults, we did not find an association between sociodemographic factors and low iron level. In adults, income has been positively associated with anemia.[34] Results from Chinese national surveys show that this region together with Shanghai has the highest prevalence of iron-deficiency anemia in adults despite the highest economic resources.[36] Anemia has been associated with a high prevalence of *Helicobacter pylori* infection (60%), suggesting that infection and inflammation may partially contribute to anemia in adults.[34,37,38] The current study has provided information on iron level in children. The lack of association between sociodemographic factors and low iron level suggests that there is a common environmental factor inducing anemia in this region. Generally speaking, there are several possible nutritional reasons for low iron level in the Chinese population. First, Asians in general consume less red meat, which is a well-recognized source of iron, contributing to around 20% of iron intake, on average, in developed countries.[39] In addition, it is customary for the Chinese to prepare pots of tea from which the entire family drinks, and the tannic acid in this tea can inhibit iron absorption.[40] Phytates can also inhibit iron absorption and are found in vegetables, an important part of the Chinese diet.[41] Finally, the Chinese typically lack ascorbic acid in their diet that can enhance iron absorption.[40] Our study also indicates a higher prevalence of low iron level in city children. While the exact etiology is unknown, we speculate that city children have more access to processed food and consequently consume more food additives and preservatives in soft drinks, etc than do rural children.[19] These food additives and preservatives, such as phosphate, inhibit iron absorption.[42]

With respect to zinc, in our data 38% of the children had low zinc levels. Ours is the first report from this region showing a low level of zinc among children of this age group. The finding is supported by another study from this region, which shows that 64.6% of children aged <11 years old had insufficient zinc intake.[24] The association between low zinc level and small family size as well as high education level of mother could be due to these groups having developed a less traditional lifestyle that includes eating fast food, skipping breakfast, and not being breastfed.

The finding that living in a large house is related to a better zinc level could be due to the fact that a big house could reflect a better economic status and thus more intake of animal foods.[19] A mother who has a higher education level is more likely to have a demanding job that prevents her from spending time selecting food and cooking at home for her family.[43-45] In our Jintan focus group, the local advisory board suggests that smaller families are also more likely to eat out more as opposed to larger families who are more likely to cook at home. These two factors might contribute to the lifestyle of a family and thereby to the low zinc level of children. Studies show that the nutrient quality of fast food is low, and it is especially low in zinc.[46] Fast food is becoming an increasingly popular part of children's diets in China. A study of children in Beijing shows that roughly 97.5% of children ate at least one type of junk food in the month prior to the study and 15.9% had eaten all types of them (deep fried food, processed food, fast food, and more).[47] While a high SES is traditionally associated with better zinc level, children with higher SES backgrounds can afford the convenience of fast food, and studies show that children living in high-SES areas had more than twice as many outlets where takeaway or fast food could be purchased en route to school.[48]

Additionally, there are several environmental and dietary factors that are very likely contributors to low zinc level in China. Modern farming technology and crop intensification result in reduced soil zinc, particularly paddy soil: the main type of soil in the study location. Reduced soil zinc consequently reduces the zinc content of rice—a dietary staple in China.[49] In addition to the zinc-poor soils, low zinc level may be due in part to the use of low-zinc starchy roots and tubers as food staples, and an intake of phytate that is sufficient to negatively affect the bioavailability of dietary zinc.[50] Furthermore, as previously discussed, the Chinese consume less red meat.[39] The zinc in red meat is in a highly bioavailable form, making this food a very valuable source of this mineral.[39]

Finally, our results showed that serum zinc was highly correlated with serum iron, consistent with other published reports.[35,51] A strong positive association between low zinc levels and low iron levels as well as the much higher prevalence of low zinc levels points out the importance of considering low zinc level when dealing with iron status.

There are several limitations to the study that should be acknowledged. First, we used serum iron instead of using serum ferritin and serum transferrin receptor as measures of iron deficiency, which may be better indicators of iron stores and therefore true iron level. Nevertheless, serum iron is an adequate measure of iron level. Second, we did not adjust for inflammation, which may have given rise to a false positive result for low iron level in some subjects. The prevalence of zinc deficiency may also be overestimated because of unknown inflammation and infections in children, which depress serum zinc concentrations. In future research, indicators of infection (C reactive protein, alpha 1-acid glycoprotein) should be measured and children with elevated levels of the infection status indicators should be excluded or serum zinc concentrations should be adjusted based on the effect of infection status indicators on serum zinc in the sample. Other limitations of the study includes that there were no data on family income or fast food consumption, both of which are variables which can contribute to better interpretation of the data and add to the overall values of the study. The reasons for not collecting family income data are mentioned earlier in the text, and a variable to measure fast food consumption can be potentially added to future follow-ups or studies of the same nature and format. Lastly, we acknowledge that there were other potential confounders that were not controlled in the logistic regression, e.g., dietary intakes (food frequency questionnaires or 7-day recall), hookworm, infection, anthropometry measures (BMI), and child age. We have addressed this and collected this information in other follow-up studies from this cohort.

Nursing implications exist at several different levels. First, nurses must recognize that a high prevalence of micronutrient deficiency still exists despite recent socioeconomic reform that has been taking place in developing countries. Low zinc and low iron levels have been related to many adverse health outcomes in children, including negative physical,[1,51] cognitive,[13] and behavioral outcomes.[14] Second, nurses can apply this knowledge to their practice by educating both children and families on the importance of eating well. Since small family size has been related to low serum zinc, perhaps due to an increased frequency of eating outside the home, it is particularly important for nurses to target this population. More specifically, nurses can educate children on avoiding fast food and eating a balanced diet. If children are aware of which foods are rich in iron (beef and liver) and zinc (wheat germ/bran, eggs, shellfish), they can make selections of healthier food when eating both inside and outside of the home.

In conclusion, this large cross-sectional study shows that poor iron and zinc levels are common in Chinese pre-school children despite recent socioeconomic reform in China. Low levels of zinc are significantly correlated with low levels of iron, and low zinc levels are associated with sociodemographic factors. These findings during the socioeconomic development of the region suggest the need for continued monitoring of nutritional factors and highlight the importance of this public health implication for preschool children.

Acknowledgements

Thanks are extended to the participating children and their families from Jintan City, and to the Jintan Cohort Study Group. This group consists of the Jintan Maternal Child Health Center, Jintan Hospital (Dr Liping Zhang, Yue Xian Ai and Liudi Han), Shanghai Jiaotong University (Dr Xiaoming Shen and Dr Chonghai Yan), China Southern Eastern University (Dr Guiju Sun and Honglei Peng), Nanjing Brain Hospital (Dr Tunong Chen) and The Chinese University of Hong Kong (Patrick W.L. Leung). We are very grateful to the Jintan city government and the Jintan Hospital for their support and assistance.

Funding: This study was funded by the National Institute of Environment Health Sciences (NIEHS, K01-ES015 877; R01-ES018858) US, UPenn CEET P30 ES013508, The Wacker Foundation US, Jintan City Government and Jintan Hospital, China.

Ethical approval: Institutional Review Board approval was obtained from the University of Pennsylvania and ethical committee for research at Jintan Hospital in China.

Competing interest: None declared.

Contributors: Liu J contributed to project conception, data collection, data interpretation, and manuscript preparation and revision. Ai YX contributed to data collection and interpretation. Aanlou H contrixbuted to data analysis and interpretation. Shi Z contributed to data analysis, interpretation and manuscript preparation. Dickerman B contributed to manuscript preparation. Compher C contributed to data interpretation and manuscript preparation.

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Received February 8, 2011
Accepted after revision June 20, 2011