Assessment of zinc nutritional status in rural China

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Zinc nutriture was assessed in 6500 adults aged 35-64 years old in 65 mostly rural counties (two communes per county) in China on the basis of plasma zinc levels and dietary zinc intakes. In addition, the use of plasma albumin and red blood cell superoxide dismutase (SOD) for assessing zinc nutritional status was evaluated. Plasma levels of zinc and albumin were highly correlated between sexes ($p<0.001$) and between neighbouring communes in the same county ($p<0.005$), indicating a high degree of data reliability as assessed by this measure of "within county" homogeneity. Zinc deficiency, defined as plasma zinc values less than 70 μg/dL, was not observed for the populations in any of the 65 counties included in the survey. Dietary zinc intake was estimated on the basis of the newly revised Chinese food composition tables in conjunction with a 3-day household dietary survey of approximately 2000 households in the same study. Average dietary zinc intake was 11.9 mg/day, with a wide variability (7.4-34.9 mg/day) across the sample of 65 counties. The average levels of plasma zinc and dietary zinc intake observed in this adult rural Chinese population were comparable to those reported in healthy U.S. subjects, suggesting that zinc deficiency may not be a cause for concern in rural Chinese adults. However, marginal zinc deficiency may be prevalent in some rural areas.

Introduction

Reports on the zinc status of populations in China have primarily been confined to studies of children and pregnant women. The clinical symptoms of zinc deficiency are not specific, and thus most of the evidence based on various biochemical assays is evaluated against some defined minimal threshold values and estimations of zinc intake compared with the RDA. Among the various available biochemical measures, plasma zinc is frequently used to reflect zinc nutritional status[1]. The results of a recent survey conducted in Beijing showed that children aged 1 to 6 years with signs and/or symptoms of pica (47 subjects), anorexia (91 subjects) and poor growth (75 subjects) had significantly lower values of zinc in hair and plasma than well-nourished children and responded to zinc supplementation with observed improvement of growth and disappearance of pica and anorexia[2]. A similar survey conducted in Tianjin yielded comparable results[3]. The results of another survey of pregnant women conducted in Beijing showed that 20.2% of the 126 women in the second trimester and 25.7% of the 85 women in the third trimester, had plasma zinc values below 70μg/dL[4].

As a part of a 1983 ecological study of diet, lifestyle and disease characteristics in 65 counties in the People's Republic of China[5], various indicators of zinc nutritional status were specifically investigated in order to assess and document the zinc status of the adult rural population in China. Zinc intakes, however, have not been previously estimated due to a lack of information on the zinc content of Chinese foods. Further the overall zinc status of the adult Chinese population has not been previously documented and analysed and this study provides a set of comprehensive biochemical indicators and estimates of dietary intakes to evaluate zinc nutritional status for a representative sample of adult Chinese males and females.

The main purpose of this report is to provide a descriptive account of zinc status in rural China on the basis of several measures and indicators thereby establishing an essential baseline point of reference for future research.

Methods

The methods and procedures used in this study have been described in detail by Chen et al[5] and only a brief summary of the methodology relevant for purposes of this report is provided here.

Subjects

A multi-stage random sampling procedure was used to select the counties and subjects surveyed in this large study. Sixty-five mostly rural counties were selected to maximise the full range of cancer mortality rates for seven of the most prevalent cancers in China[6]. These counties were geographically dispersed across the nation, being located in 24 provinces and autonomous regions. Two communes were randomly selected in each county and within each commune 50 adults (25 males and 25 females), equally divided between each of four age groups (35-44, 45-54 and 55-64 years), were randomly selected to participate in the survey. Thus, the total number of participating subjects was 6500 adults, approximately 3250 males and 3250 females,

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Table 1. Biochemical indicators of zinc nutritional status in 65 rural counties in China[a]

Variable	N[b]	Mean ± SD	Median	Range	Between Sex Correlations[c]	Between Commune Correlations[d]
Plasma zinc (mg/dL)						
Males	63	0.12 ± 0.04	0.10	0.06-0.21	0.87*	0.76*
Females	63	0.12 ± 0.04	0.09	0.07-0.23		0.84*
Plasma albumin (g/dL)						
Males	63	3.0 ± 0.1	3.0	2.7-3.4	0.49*	0.41*
Females	63	3.1 ± 0.1	3.1	2.8-3.4		0.57*
Erythrocyte SOD (units/gHb)						
Males	63	13.7 ± 5.2	12.7	6.0-39.1	0.32**	0.09
Females	63	12.3 ± 4.6	12.0	5.7-28.0		0.22

a. Data shown are averages of county means, not averages of individual subjects: aliquots of individual samples were pooled by sex and commune, then assayed to yield sex and commune specific means; b. Number of counties on which calculations are based; c. Pearson product-moment correlation between males and females in commune I and II; d. Pearson product-moment correlation coefficient between sex-specific values in commune I and commune II.

* $p<0.001$; ** $p<0.05$; SOD refers to superoxide dismutase.

aged 35-64 years. A large amount of information was collected for the sampled units from various integrated surveys including blood and urine samples, comprehensive questionnaire data for individual survey subjects and a three day household dietary survey for selected households in the sample.

Laboratory Methods

Ten millilitres of fasting intravenous blood was drawn from each subject between 6:00-12:00AM in a trace-element-free heparinised vacutainer (Becton-Dickinson Inc, Rutherford, NJ, USA). Fractions of blood were separated and stored at -15° to -20°C in local laboratories. Samples were then thawed and portions of each individual sample were combined into sex- and commune-specific pools and stored at -30°C in Beijing (Institute of Nutrition and Food Hygiene, Chinese Academy of Preventive Medicine). Plasma albumin was determined by the method of Doumas et al[7]. Plasma zinc and copper were analysed using a Jarrel Ash Inductively Coupled Argon Plasma Atomic Emission Spectrometer (ICP). Erythrocyte superoxide dismutase (SOD) activities were determined in red blood cell haemolysates by the method of Misra and Fridovich[8]. The data are expressed in appropriate enzyme units.

Dietary Zinc Intake

In each of the 65 counties, 30 households (15 households in each of two villages, in one of the two communes) were selected for the dietary survey. Food consumption was measured over a period of three successive days with one surveyor being responsible for 4-6 households. The survey procedures were the same as those used in a nationwide nutrition survey of dietary practices conducted in 280 counties in 1982[9]. Nutrient intakes were estimated using the Chinese Food Composition Tables[10] and the results were standardised on the basis of a "reference man" defined as an adult male, 19-59 years of age, 65kg body weight and undertaking light physical work[5]. Thus food consumption and nutrient intakes were reported as average intake[5] per reference man for the 30 households in each county. The zinc content of various Chinese foods was not available in 1983 and has only become available with the compilation of the recently revised Chinese food composition tables[11]. Thus the food consumption data obtained in 1983 were reanalysed using these more recent and comprehensive food composition tables to yield dietary zinc intakes for the adult Chinese population. Average daily zinc intakes per reference man were calculated using the zinc content of foods listed in the revised Chinese food composition tables[11].

Statistical Analyses

Descriptive statistics including means, standard deviations and ranges of average county values by sex were computed for all relevant biochemical indicators of zinc status, and dietary intakes of zinc. On the basis of the dietary zinc intake data, the sample was grouped into high (≥10mg/d) and low (< 10mg/d) categories of zinc consumption and the t-statistic was used to test if plasma zinc, plasma albumin, SOD levels and dietary zinc intakes from animal foods were significantly different in the two groups. Pearson product-moment correlation coefficients were used to examine the univariate relationship between the values of various biochemical indicators of zinc status by sex and commune. All probability levels of significance reported and examined here are two-sided.

Results

Average values of selected biochemical indicators of zinc status for adult males and females are presented in Table 1. Plasma zinc levels were 120>μg/dL for both males and females. No differences by sex were observed for any of the three indicators shown. Except for SOD, no differences were found between the two communes in each county indicating within county homogeneity and confirming data reliability for these indicators. The minimum value of 70μg/dL for plasma zinc proposed by Smith et al[12] was used to assess zinc deficiency in this population of Chinese rural adults. Average plasma zinc values were not less than 70μg/dL for any of the 65 survey counties, suggesting that zinc deficiency in Chinese adults is not a cause for concern on the basis of accepted criteria. Correlation coefficients between the various indicators of zinc status examined here are shown in Table 2 and the results showed no significant associations among the various indicators.

Average dietary zinc intakes for Chinese rural adults are shown in Table 3. The mean dietary intake for the 65 survey counties was 11.9±3.46mg per day per reference man. However, there was a dramatic geographic variation in

values among the survey counties. Huian county (in Fujian province) had the lowest zinc intake of 7.4mg/day (49% of the Chinese RDA of 15mg/day), while the highest intake of 34.9mg/day (233% of the Chinese RDA) was reported in Tuoli county (in Xinjiang autonomous region). Shong county (in Henan province) and Jianhu county (in Jiangsu province) had the second and third highest zinc intake of 15.6mg/day (104% of the Chinese RDA) and 15.4mg/day (103% of the Chinese RDA), respectively. Of the 65 counties, 13 counties had dietary zinc intake levels less then 10mg/day. No significant differences in dietary zinc intake from meat, poultry, fish and other seafood and in three biochemical indicators between counties with dietary zinc intake <10mg/day and counties with ≥10mg/day, were found ($p>0.05$). In this population, average dietary zinc intake from cereals and starchy tubers was 10.0±2.1mg/day accounting for 83.8% of the mean dietary zinc intake and the average dietary zinc intake from meat, poultry, fish and other seafood was 0.6±0.5mg/day accounting for 5.8% of the mean dietary zinc intake.

The above analysis was replicated excluding the outlier county of Tuoli in Xinjiang province and no significant changes in the average values of the three biochemical indicators used in Table 3 was found. However, the average dietary zinc intake was slightly lower (11.6±1.9mg/day) as a result of excluding this county.

Table 2. Matrix of correlation coefficients for various indicators of zinc nutritional status in 65 rural counties in China.

Variable	Plasma albumin	SOD	Dietary zinc intake
Plasma zinc	0.127	0.113	-0.029
Plasma albumin	--	-0.117	-0.052
SOD	--	--	-0.139

$p>0.05$ for all coefficients shown

The difference in zinc intake among the 65 counties was mainly due to the variation in total food intake across counties. For example, subjects in Huian county consumed less food overall (527.0g/day plant food intake and 66.1g/day animal food intake) than the subjects in Shong county (1533.6g/day plant food intake and 15.6g/day animal food intake) and Jianhu county (1410.6g/day plant food intake and 15.4g/day for animal food intake) and thus had lower levels of dietary zinc intake (7.4mg/day) than reported for Shong county (15.6mg/day) and Jianhu county (15.4mg/day). Furthermore, high animal food intake resulted in high dietary zinc intake if counties had similar total food intakes. For example, the population of Tuoli county is primarily an ethnic minority of herdspeople who consume a large amount of animal foods (1081.8g/day for animal foods) and have an exceptionally high dietary zinc intake (34.9mg/day) in sharp contrast to the Han population in Shong county and Jianhu county where zinc intake is much lower despite similar amounts of total food intake in all three counties (total food intakes are 1549.2g/day for Shong, 1426.0g/day for Jianhu and 1478.2g/day for Tuoli county respectively).

Discussion

The results of this study represent the first nationwide description and evaluation of zinc nutritional status for rural Chinese adults. These 65 counties (2.7% of the total of 2400 counties in China; 1.6% of the total population) were located in 24 provinces and autonomous regions, and thus survey subjects were widely dispersed throughout the populated areas of mainland China providing a representative sample of the rural Chinese population. As described by Chen et al[5], the average nutrient intakes reported for these 65 counties were very similar to those reported in the national nutrition survey carried out in 1982[9]. Diverse regional dietary patterns were observed across the survey counties, as indicated by the large differences in the consumption amounts and varieties of various foods including cereals, pickled vegetables and alcohol, and in the wide variations of nutrient intakes. This variation is determined largely by the great diversity in food resources, food habits, and cultural practices across China and this nutritional diversity provides a distinct advantage for assessing the overall zinc status of this population.

A variety of biochemical measures were used to assess zinc nutriture of the populations in the 65 survey counties. On average, plasma zinc was 0.12±0.04mg/dL for rural Chinese adults. In addition, plasma albumin and erythrocyte SOD were examined to evaluate zinc nutritional status. Plasma albumin has been suggested as an index for assessing zinc status as approximately 66% zinc is loosely bound to albumin and, as such, albumin appears to be involved in the transportation of zinc in plasma. In the results of this analysis, plasma albumin levels did not correlate significantly with plasma zinc levels and dietary zinc intake. Zinc is essential for stabilising the structure of the enzyme protein superoxide dismutase (SOD). Burke et al[13] reported that lipid peroxidation in tissues increased in zinc-deficient animals, confirming the findings of Sullivan et al[14]. However, in this population study, no significant association was observed between levels of SOD, plasma zinc and plasma albumin. Further studies on the applicability of plasma albumin and SOD for assessing zinc status are needed for meaningful interpretation of the results. In addition, plasma albumin levels remained relatively constant across counties with widely varying dietary zinc intakes (Table 3).

It is generally accepted that plasma zinc as an indicator of zinc nutritional status does not correlate well with dietary zinc intake. In this study, there was no significant association between plasma zinc and dietary zinc ($r=0.029$, $p>0.05$; Table 2). For example, dietary zinc intakes in

Table 3. Dietary intakes and biochemical indicators of zinc nutritional status of 65 rural Chinese counties in China by high (≥10 mg/day) and low (< 10mg/day) levels of dietary zinc intake.

Dietary Zinc Intake (mg/day)	Number of Counties	Dietary Zinc intake (mg/day)	Dietary Zinc intake from animal foods (mg/day)	Plasma Zinc(mg/dL)	Plasma albumin (g/dL)	SOD (units/gHb)
Low (<10)	13	8.85 ± 0.68	0.62 ± 0.48	0.12 ± 0.03	3.05 ± 0.12	15.42 ± 5.34
High (≥10)	52	12.68 ± 3.45	0.55 ± 0.54	0.12 ± 0.04	3.08 ± 0.12	12.38 ± 3.39

Shong and Jianhu counties (15.4mg/day) were much higher than these in Huian county (7.4mg/day). Consistent with these levels of dietary zinc intake, plasma zinc for Shong county (0.160mg/dL) was much higher than that for Huian county (0.135mg/dL). However, plasma zinc for Jianhu county (0.098 mg/dL) was much lower than that for Huian county. The lack of association between dietary zinc intake and plasma zinc may be attributed to the minimal variation in plasma zinc levels due to the homeostatic regulation of plasma/serum zinc levels[15].

Diagnosis of zinc deficiency is hampered by the lack of a simple, specific and sensitive biochemical index of zinc status. Plasma/serum zinc is still the most widely used indicator of zinc status, especially in assessing longer term zinc status. In persons with severe zinc deficiency, plasma/serum zinc values are usually low[16]. Analyses of the Second National Health and Nutrition Examination Survey (NHANES II) in the US reveal a fasting mean serum zinc concentration of 95±14μg/dL for 3511 male and female adults[12]. The average intake of 11.9mg/day per reference man in rural China was also similar to the average level of 14.4mg/day for American men and 8.9mg/day for American women aged 35 to 50[17]. In addition, none of the Chinese counties in this sample had plasma zinc less than 70μg/dL, suggesting that severe zinc deficiency may not be a nutritional problem in rural China. Moreover, if adaptation to lower intakes provide for more efficient utilisation, as is the case for many other nutrients, deficiency would be even less likely to be a problem. However, plasma samples in this study were pooled by sex and commune, limiting the variation observed in the sample. Thus the values of plasma zinc obtained do not represent individual levels and thus, restrict conclusions on the variability of the distribution, especially the extreme cases. The possibility that plasma zinc levels may be less then 70μg/dL in some individuals, that is, marginal zinc deficiency in a small proportion of subjects, cannot be excluded.

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摘要

根据血浆锌和膳食锌摄入量，作者对中国65个县（每个县两个乡）中6500名35至64岁成年人的锌营养状况进行了评价。另外，对血浆白蛋白和红细胞超氧化物歧化酶（SOD）用于评价锌营养状况的意义进行了探讨。血浆锌和血浆白蛋白水平在男、女之间和同一县的相邻两个乡之间呈显著正相关，表明在各个县收集的资料是相对一致的及数据的可靠性。此次研究没有发现65个县中的一个县的成年人平均血浆锌水平低于 70ug/dl（常用的锌缺乏标准）。采用连续3天称重和记录食物消耗法对大约2000 户居民进行了膳食调查，用新版的中国食物成份表对膳食锌摄入量进行了估算。65个县膳食锌摄入量的范围为7.4毫克/天至34.9毫克/天，平均摄入量为 11.9毫克/天。此次调查的中国农村成年人的平均血浆锌水平和膳食锌摄入量与美国的健康成年人水平相一致，提示中国农村成年人中不存在明显的锌缺乏，但可能存在边缘性的锌缺乏。

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