Zinc intake of US preschool children exceeds new dietary reference intakes[1–3]

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ABSTRACT

Background: The recent dietary reference intakes publication provides updated information on the physiologic and dietary requirements for zinc and proposes new tolerable upper intake levels.

Objective: We analyzed dietary intake data of US preschool children to determine the prevalence of inadequate and excessive intakes of zinc.

Design: Diets of 7474 nonbreastfeeding preschool children in the Continuing Survey of Food Intakes by Individuals (1994–1996 and 1998) were analyzed for the intakes of zinc and other dietary components, and factors associated with zinc intake were examined.

Results: The mean intakes of zinc by children aged < 1 y, 1–3 y, and 4–5 y were 6.6, 7.6, and 9.1 mg/d, respectively. Less than 1% of children had usual zinc intakes below the adequate intake or estimated average requirement. The percentages of children with intakes exceeding the tolerable upper intake level were 92% (0–6 mo), 86% (7–12 mo), 51% (1–3 y), and 3% (4–5 y). Controlling for age and energy intake, zinc intake was greater in 1998 than in 1994 ($P < 0.0001$) and was positively associated with participation in the Women, Infants, and Children Program ($P < 0.001$) and with the lowest income category ($P < 0.001$).

Conclusions: Preschool children in the United States have dietary zinc intakes that exceed the new dietary reference intakes. Zinc intakes increased during the 4 y of the study. The present level of intake does not seem to pose a health problem, but if zinc intake continues to increase because of the greater availability of zinc-fortified foods in the US food supply, the amount of zinc consumed by children may become excessive. *Am J Clin Nutr* 2003;78:1011–7.

KEY WORDS Zinc, copper, phytate, dietary intake, preschool children, Continuing Survey of Food Intakes by Individuals, CSFII, dietary reference intakes, DRIs

INTRODUCTION

In 2001, the Food and Nutrition Board of the Institute of Medicine released new dietary reference intakes (DRIs) for zinc (1). The DRIs contain a set of 4 nutrient reference values for various applications: the estimated average requirement (EAR), the recommended dietary allowance (RDA), adequate intake (AI), and the tolerable upper intake level (UL). The new RDA is calculated as 2 SDs greater than the EAR, which is the nutrient intake level that meets the requirements of 50% of healthy individuals in an age and sex group. The EAR is used to assess the adequacy of intake by populations. The RDA specifies the intake level that meets the requirements of nearly all (97–98%) persons in the population group, and it is used as a dietary intake goal for individual persons. The new zinc RDAs for preschool children are substantially lower than the previous ones (**Table 1**; 2). For infants aged 0–6 mo, an AI for zinc, rather than an EAR, has been established. The AI is based on the maternal zinc supply to the infant who is fed human milk exclusively. For older infants and young children, an EAR is based on factorial analysis, and endogenous zinc losses are estimated by extrapolation from measured values for adults or younger infants.

The UL is the highest average level of daily intake that is likely to pose no risk of adverse health effects to almost all persons in the general population. Possible adverse effects of high zinc intake include lower copper status (3), impaired immune responses (4), and alterations in lipoprotein metabolism (5). The UL of 4 mg for infants was based on a study in which infants consumed 4.5 mg Zn/d from a zinc-fortified formula, and no adverse effects on serum copper or cholesterol were found (6). The UL values for children were derived from the UL for infants with adjustment for body weight.

In the assessment of the dietary intake of zinc, other dietary factors that may interact with zinc should be examined. Phytate, a component of plant-based foods, interferes with the absorption of dietary zinc (7). Foods that are high in phytate, such as whole-grain breakfast cereals, peanut butter, and soy-based infant formula, are consumed by many children in the United States. A diet with a phytate-to-zinc ratio < 5 provides zinc with a high degree of availability, whereas a phytate:zinc > 15 results in relatively poor absorption of zinc (8). Children consuming a diet that provides marginal zinc intake may not absorb an adequate amount of zinc if they are also consuming foods high in phytate. Dietary intake of copper is also impor-

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TABLE 1
US dietary zinc and copper recommendations for children[1]

	Zinc					Copper				
		2001[3]					2001[3]			
	1989 RDA[2]	AI	EAR	RDA	UL	1989 RDA[2]	AI	EAR	RDA	UL
	mg					*μg*				
Infants										
0–6 mo	5	2	—	—	4	—	200	—	—	—
7–12 mo	5	—	2.5	3	5	—	220	—	—	—
Children										
1–3 y	10	—	2.5	3	7	—	—	260	340	1000
4–8 y	10	—	4	5	12	—	—	340	440	3000

[1] RDA, recommended dietary allowance; AI, adequate intake; EAR, estimated average requirement; UL, tolerable upper intake level.
[2] *See* reference 2.
[3] *See* reference 1.

tant because of the effect of excess dietary zinc on copper status.

The current study was undertaken to reassess the adequacy of zinc intakes of US preschool children in light of the new DRIs. The specific goals were *1*) to assess the prevalence of both inadequate and potentially excessive zinc intakes, *2*) to describe zinc intakes in relation to the phytate and copper contents of the diet, *3*) to describe food sources of zinc for these children, and *4*) to examine demographic and socioeconomic variables associated with zinc intake.

SUBJECTS AND METHODS

The analyses in this report are based on dietary intake data obtained during the 1994–1996 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII), a nationwide survey conducted periodically by the US Department of Agriculture (9). The CSFII sampling scheme is a stratified, clustered, multistage probability design with oversampling of low-income households. For our analyses, we selected children < 6 y old who were not breastfeeding and for whom there were complete dietary intake data from 2 d, which resulted in a sample of 7474 children (**Figure 1**). Sampling weights from the CSFII data set were used to account for the sampling design of the survey. The CSFII data set without individual indentifying information is available publicly.

The CSFII collected dietary intake data via in-home interviews of the caretakers of the children. Two 24-h recalls were obtained on nonconsecutive days 3–10 d apart. For the dietary recalls, a multiple-pass approach was used. On the first pass, the respondent was asked to recall, without interruption by the interviewer, all foods consumed during the previous day. On the second pass, the interviewer asked for details and amounts of each food consumed throughout the day. Measuring guides, such as cups, spoons, and food pictures, were used to help the respondents specify accurate portion sizes.

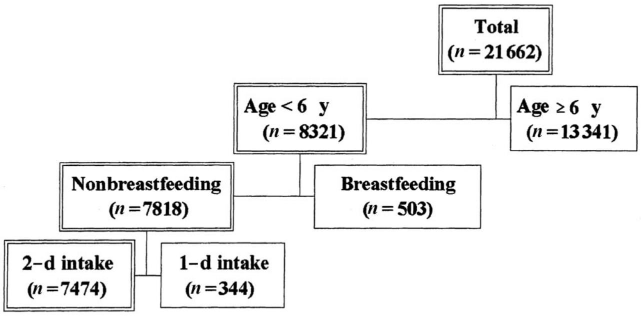

FIGURE 1. Flow chart of subjects from the Continuing Survey of Food Intakes by Individuals from 1994–1996 and 1998 included in the current study.

Intakes of energy, zinc, and copper were calculated with the use of nutrient values provided in the data set. Although information was available on whether the children took a micronutrient supplement and, if so, on the frequency of use, the nutrient values presented here are from food only, because the data files did not contain quantitative information on the nutrient contents of the supplements. Values for the phytate content of all foods were obtained by using the NUTRIENT DATA SYSTEM FOR RESEARCH software (10).

To determine the percentage of children with inadequate zinc intake, the "usual" zinc intakes were obtained and the EAR cutoffs were used, as described by the Institute of Medicine (11). The distribution of zinc intakes was skewed, and thus the zinc intake values were transformed, by using the natural logarithm (ln). To calculate the distribution of usual intakes, the within-person and between-person variations in intake were obtained by using the two 24-h intakes for each child. The adjusted (usual) zinc intake for each child was calculated by using the equation

$$[(\text{Subject's mean} - \text{group mean}) \times \text{SD}_{\text{between-person}}/\text{SD}_{\text{observed}}] + \text{group mean} \quad (1)$$

The proportions of children with intakes below the EAR for each of the age groups for which an EAR for zinc exists were calculated by counting the number of children with zinc intake below the EAR and dividing by the total number of children in that age group. Likewise, the proportions of children with intakes above the UL were calculated by counting the number of children with zinc intakes above the UL and dividing by the total number of children in that age group.

The contributions of individual foods to zinc and copper intakes were calculated by summing the amount of zinc or copper consumed from each food by all subjects in each age group and dividing by the total intake from all foods for all subjects in the respective age group. Sampling weights were used in the calculation.

Zinc-fortified foods were identified from the database by examining the ingredient list on the product label for added zinc. Zinc-fortified foods consumed by these children included breakfast cereals, infant formula, fortified beverages (eg, meal replacement or instant breakfast beverages), and fortified cereal bars. The amount of added zinc in food could not be separated from the amount of zinc occurring naturally in the product, and thus the total zinc content of zinc-fortified foods is used to represent zinc from fortified foods. Mean daily zinc intakes from fortified foods were obtained for each subject.

Factors associated with zinc intake were assessed with the use of a multivariate modeling procedure (PROC SURVEYREG, release 8; SAS Institute Inc, Cary, NC) that takes into account the complex sampling design of CSFII. The sampling weights were used to adjust for variations in the probability of selection and for differential nonresponse rates. Adjustment was also made to account for the clustering design, by using the appropriate variables provided in the data set. The ln of zinc intake was the dependent variable, and the independent variables were age, sex, region of the country, degree of urbanization (according to the US Census Bureau Metropolitan Statistical Area standards), ethnic origin, income, participation in food assistance programs, use of vitamin or mineral supplements or both, the year of the survey, and the education level and employment status of male and female heads of households. All independent variables were entered into the model, and nonsignificant variables were removed one variable at a time with the use of a backwards, stepwise method. If removal of a nonsignificant variable did not change the coefficient of the variables remaining in the model, the nonsignificant variable was eliminated.

RESULTS

Characteristics of the 7474 children in the study are presented in **Table 2**. CSFII intentionally oversampled low-income households. By applying appropriate weighting factors supplied in the data set, the frequencies provided in the table are representative of the US population of nonbreastfeeding children of these ages.

The ratios of within-person to between-person SDs of zinc intake were 0.75, 1.03, 1.47, and 1.70 for children aged 0–6 mo, 7–12 mo, 1–3 y, and 4–5 y, respectively. After adjustment of zinc intakes to remove within-person variation and thereby to obtain estimates of usual intakes, < 1% of the children had inadequate zinc intakes in relation to the EAR and < 1% of infants aged 0–6 mo had intakes below the AI (**Figure 2**). Notably, 92% of 0–6 mo-old infants, 86% of 7–12 mo-old infants, 51% of 1–3 y-old children, and 3% of 4–5 y-old children had usual intakes greater than the UL. The UL for zinc includes intake from both food and supplements. Because CSFII data do not include nutrient intake from supplements, these figures may underestimate the percentages of children with intakes greater than the UL.

Energy and zinc intakes increased with age, but the zinc density (mg zinc/1000 kcal) of the children's diets decreased (**Table 3**). Phytate intakes increased with age, as did the molar ratios of phytate to zinc. Children with diets in the lowest quartile of zinc density had higher phytate intakes and higher phytate:zinc than did children in the highest quartile of zinc density **(Table 4)**. Most of the children in the highest quartile of zinc density had phytate:zinc < 5. Less than 1% of children had inadequate copper intakes in relation to the EAR. Only one infant had a copper intake below the AI. Four percent of 1–3 y-old children and none of the 4–5-y-old children had copper intakes above the UL. The children's median ratios of zinc to copper were close to the < 10:1 ratio of the requirements (EAR) for zinc and copper (Table 3). There was a positive correlation between dietary zinc and copper intake ($r = 0.61$, $P < 0.0001$). However, copper intakes did not differ significantly across quartiles of zinc density, and zinc:copper increased with increasing zinc density (Table 4). One-half of the children in the highest quartile of zinc density were also in the highest quartile of zinc:copper intakes.

The high zinc intakes by infants are due primarily to the consumption of zinc-fortified infant formula, which accounted

TABLE 2
Descriptive characteristics of 7474 children by weighted frequencies[1]

Characteristics	Frequency
	n (%)
Age (y)	
< 1	898 (12)
1–3	3908 (52)
4–5	2668 (36)
Ethnic or racial group	
White	4556 (61)
Black	1248 (17)
Hispanic	1231 (16)
Asian or Pacific Islander	217 (3)
American Indian or Alaskan Native	53 (1)
Other	169 (2)
Region of the United States	
Northeast	1407 (19)
Midwest	1752 (23)
South	2554 (34)
West	1761 (24)
Degree of urbanization[2]	
Central city	2481 (33)
Outside central city	3536 (47)
Non-MSA	1457 (20)
Income category (% of poverty index)	
0–130%	2363 (31)
131–350%	3226 (43)
> 350%	1885 (25)
Food assistance program participation	
WIC Program	1489 (20)
Food Stamps Program	1782 (24)
School Breakfast Program (free)	164 (19)[3]
School Lunch Program (free)	236 (27)[3]
Vitamin or mineral supplement use[4]	
Any vitamin or mineral supplement (or both)	
Daily or almost daily	2555 (34)
Every so often	890 (12)
Multivitamin with iron or other minerals	1516 (20)
Zinc supplement	3 (< 1)

[1] Frequencies weighted to adjust for sampling design so that they are representative of the US population. MSA, Metropolitan Statistical Area; WIC, Supplemental Food Program for Women, Infants, and Children.

[2] According to the Census Bureau's MSA standards.

[3] The denominator for the percentages is the number of children aged 5 y who attend school ($n = 876$).

[4] These categories of use are not mutually exclusive.

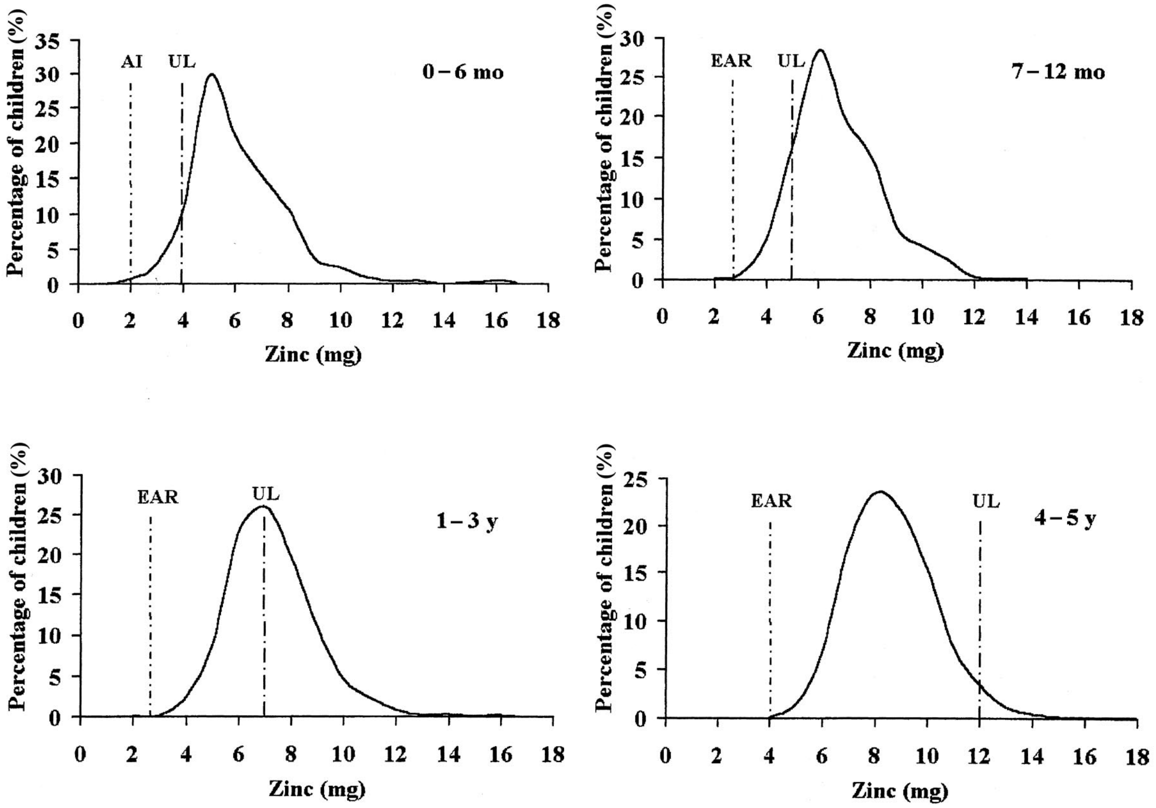

FIGURE 2. Distribution of usual zinc intakes by age group. Intakes are adjusted to obtain an estimate of usual intake according methods described by the dietary reference intakes committee (11). The adequate intake (AI) or estimated average requirement (EAR) and tolerable upper intake level (UL) are depicted for each age group.

for 77% of the zinc intake (**Table 5**). Milk and ready-to-eat (RTE) breakfast cereals were the highest contributors of zinc for children aged 1–3 y and 4–5 y, respectively. Milk contains less zinc per serving than do some of the other foods lower on the list, but milk was a major contributor of zinc to the children's diets because of the high volumes that they consumed. RTE breakfast cereals were consumed by 64% of all children in the study, and 78% of these cereals were fortified with zinc. Infant formula was also the main contributor of copper to the diets of infants. Fruit juice was the highest contributor of copper to the diets of 1–3-y-old children, and potatoes provided the largest amount of copper to 4–5-y-old children.

Overall, 24% of the mean daily zinc intake of all children was obtained from zinc-fortified foods, primarily infant formula and RTE breakfast cereal. Sixty-eight percent of children consumed at least one zinc-fortified food, and among these children, zinc-fortified foods provided 35% of their mean daily zinc intake. Fortified foods provided a much greater proportion of zinc to infants than they provided to children in the other age groups (**Table 6**). The percentage of zinc consumed from zinc-fortified foods doubled from 14% for children surveyed in 1994 to 28% for children surveyed in 1998 ($P < 0.0001$) (**Figure 3**). There were no differences between any of the survey years in the amount of zinc consumed from foods not fortified with zinc.

The results of multiple regression analysis showed that, after control for age and energy intake, participation in the Supplemental Food Program for Women, Infants, and Children (WIC) was positively associated with zinc (ln) intake ($P < 0.001$)

TABLE 3

Intakes of energy, zinc, copper, and phytate and dietary zinc densities and ratios by age group[1]

	<1 y (n = 898)	1–3 y (n = 3908)	4–5 y (n = 2668)
Energy (kcal/d)	852 ± 277 (794)	1381 ± 442 (1326)	1667 ± 485 (1601)
Zinc (mg/d)	6.6 ± 2.3 (6.1)	7.6 ± 3.3 (7.0)	9.1 ± 3.7 (8.5)
Copper (μg/d)	670 ± 212 (634)	709 ± 293 (665)	852 ± 337 (803)
Phytate (mg/d)	166 ± 167 (108)	390 ± 231 (342)	501 ± 271 (448)
Zinc density (mg/1000 kcal)	7.9 ± 1.6 (7.8)	5.6 ± 1.8 (5.2)	5.5 ± 1.7 (5.3)
Molar ratio of phytate to zinc	2.6 ± 2.4 (1.7)	5.3 ± 2.8 (4.8)	5.7 ± 2.8 (5.1)
Molar ratio of zinc to copper	9.8 ± 2.5 (9.3)	11.0 ± 4.0 (10.3)	10.9 ± 3.8 (10.3)

[1] $\bar{x}$ ± SD; median in parentheses. ANOVA F test for difference between age groups, $P < 0.0001$.

TABLE 4
Phytate and copper intakes by quartiles (Q) of zinc density[1]

	Zinc density				
	Q1 (n = 1870)	Q2 (n = 1868)	Q3 (n = 1869)	Q4 (n = 1867)	P^2
Zinc intake (mg/d)	5.9 ± 2.1[3]	7.5 ± 2.5	8.5 ± 2.9	10.1 ± 4.4	< 0.0001
Phytate intake (mg/d)	413 ± 236	430 ± 258	407 ± 238	360 ± 292	< 0.0001
Molar ratio of phytate to zinc	6.9 ± 3.2	5.6 ± 2.6	4.7 ± 2.1	3.3 ± 2.3	< 0.0001
Phytate:zinc category (no. of children)					
< 5	557	862	1186	1474	< 0.0001
5–15	1266	998	681	392	
> 15	47	8	2	1	
Copper intake (μg/d)	745 ± 280	769 ± 304	753 ± 305	754 ± 340	0.0758
Molar ratio of zinc to copper	8.0 ± 2.0	10.0 ± 2.4	11.7 ± 3.2	13.6 ± 4.4	< 0.0001
Quartiles of zinc:copper (no. of children)					
Q1 (< 8.2)	1044	402	232	191	< 0.0001
Q2 (8.3–10.2)	573	703	358	233	
Q3 (10.3–12.6)	214	531	643	482	
Q4 (> 12.6)	39	231	637	960	

[1] Q1, ≤ 4.55 mg; Q2, 4.56–5.45 mg; Q3, 5.46–6.78 mg; Q4, > 6.78 mg.
[2] All values by general linear model, except phytate:zinc category and quartiles of zinc:copper (Mantel-Haenszel chi-square).
[3] $\bar{x}$ ± SD.

(**Table 7**). The lowest income category was positively associated with zinc intake, even after we controlled for WIC participation ($P < 0.0003$). Children surveyed in 1998 consumed more zinc than did children surveyed in 1994 ($P < 0.0001$). Age was negatively associated with zinc intake in the model because of control for energy intake—ie, the younger children's diets had greater zinc density that did the diets of the children in the other age groups. Participation in school breakfast and lunch programs was also positively associated with zinc intake, but these variables only applied to children who were 5 y of age and in school, so they were not included in the model. To determine whether the consumption of certain foods contributed to higher zinc intake among WIC participants, separate models were obtained by using zinc intake from individual foods as the dependent variables. After control for age and energy intake, WIC participation was positively asso-

TABLE 5
Major food sources of zinc and copper by age group[1]

	< 1 y		1–3 y		4–5 y	
Rank	Food item	Percentage of mineral intake	Food item	Percentage of mineral intake	Food item	Percentage of mineral intake
		%		%		%
Zinc						
1	Infant formula	76.8	Milk	19.5	RTE cereal	18.2
2	Milk	3.9	RTE cereal	16.3	Milk	14.4
3	Infant cereal	3.7	Beef	11.1	Beef	13.5
4	RTE cereal	1.8	Poultry	4.8	Poultry	5.1
5	Beef	1.8	Deli meats	4.8	Deli meats	5.1
6	Poultry	1.6	Cheese	3.3	Cheese	3.5
7	Vegetables	1.3	Eggs	2.1	White bread	2.3
8	Eggs	0.6	Vegetables	1.9	Pork	2.2
9	Deli meats	0.6	Potato	1.7	Pizza	1.9
10	Infant vegetables	0.6	Pork	1.7	Potato	1.9
Copper						
1	Infant formula	69.1	Fruit juice	8.4	Potato	7.6
2	Infant cereal	5.8	Fruit	7.6	Fruit	6.3
3	Vegetables	3.4	Potato	7.1	Fruit juice	5.5
4	Fruit juice	3.1	Milk	5.9	RTE cereal	5.4
5	Potato	1.6	Vegetables	5.2	Beef	5.2
6	Fruit	1.4	RTE cereal	4.9	Vegetables	5.1
7	Poultry	1.3	Beef	4.6	Milk	4.8
8	Infant fruit	1.0	Poultry	3.6	White bread	4.8
9	Milk	1.0	Fruit drink	3.6	Fruit drink	4.0
10	Beef	0.8	White bread	3.5	Poultry	3.8

[1] RTE, ready-to-eat.

TABLE 6
Contribution of zinc intake from fortified foods by age group

	< 1 y (n = 898)	1–3 y (n = 3908)	4–5 y (n = 2668)
Children consuming zinc-fortified food(s) [n (%)]	876 (98)	2557 (65)	1667 (62)
Percentage of total zinc intake from zinc-fortified foods (%)[2]	82 ± 24[1]	16 ± 18	16 ± 17
Percentage of total zinc intake from zinc-fortified foods among consumers of zinc-fortified foods (%)[2]	84 ± 21	24 ± 17	25 ± 15

[1] $\bar{x}$ ± SD.

[2] ANOVA F test for difference between age groups, $P < 0.0001$.

ciated with zinc intake from infant formula ($P < 0.001$), beef ($P < 0.01$), and poultry ($P < 0.05$). RTE cereal was a major source of zinc for both WIC participants and nonparticipants, and thus there was no association with program participation.

DISCUSSION

The present study assessed the adequacy of zinc intakes in US children according to newly released DRIs. Less than 1% of the children had inadequate intakes based on the EAR (or based on AI for infants aged 0–6 mo), and a substantial percentage of children consumed higher amounts of zinc than the recently proposed UL. The new DRIs are lower than the previous (1989) version of the RDA. Before the publication of the new DRIs, there was concern that children in the United States were not consuming enough zinc. By using dietary intake data from the third National Health and Nutrition Examination Survey (NHANES III, 1988–1994), Briefel et al (12) found that 81% of 1–3-y-old and 48% of 4–6-y-old children had inadequate zinc intakes, which they defined as < 77% of the 1989 RDA. The mean zinc intakes in children in NHANES III were 6.4 mg/d for 1–3-y-olds and 7.7 mg/d for 4–6-y-olds. These intakes are adequate if compared with the current EAR or RDA, but they are lower than the zinc intakes measured by the CSFII (1994–1996 and 1998), which was used for the current study.

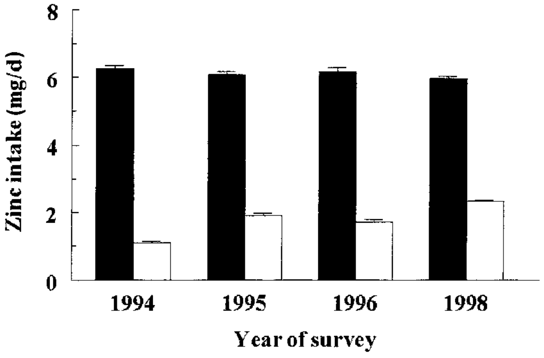

FIGURE 3. Contribution of nonfortified (■) and zinc-fortified (□) foods to mean daily zinc intakes. $n = 1199$ in 1994, 1191 in 1995, 1193 in 1996, and 3891 in 1998. There was a significant difference in zinc intake from fortified foods between all years (ANOVA; $P < 0.0001$), except between 1995 and 1996. There were no significant differences in zinc intake from nonfortified foods between years.

TABLE 7
Multiple regression model of factors associated with dietary zinc intake (natural logarithm)[1]

Dependent variables	Coefficient	P
Age (y)	−0.0110	0.0032
Energy intake (kcal/d)	0.0006	< 0.0001
WIC Program	0.0483	0.0009
Income category (% of poverty index)		
0–130%	0.0447	0.0003
131–350%	0.0279	0.0127
≥350% (reference group)	—	
Year of survey		
1994 (reference group)	0.0000	—
1995	0.0774	< 0.0001
1996	0.0654	< 0.0001
1998	0.0826	< 0.0001

[1] WIC Program, Supplemental Food Program for Women, Infants, and Children. $r^2 = 0.50$.

Children surveyed in 1998 had higher zinc intake than did those in the 1994 survey, and this was true for all age groups (data not shown). For children aged 1–5 y, the percentage of zinc intake from zinc-fortified foods increased over the time of this study, whereas the percentage of zinc intake from nonzinc-fortified foods remained the same. For infants, the percentage of zinc from fortified foods remained the same over time because zinc content of infant formula has not changed during this period. Berner et al (13) reported the contribution of fortified foods to total nutrient intakes among users of fortified foods from the previous CSFII (1989–1991). Among children who consumed at least one zinc-fortified food product, Berner et al found that fortified foods contributed 13% of total zinc intake for 1–3-y-old children and 17% of total zinc intake for 4–5-y-old children, compared with 24% and 25% of total zinc for 1–3-y-old and 4–5-y-old children, respectively, who consumed a zinc-fortified food in the present study. In the previous CSFII study (1989-1991), 18% of children aged 1–6 y consumed a food fortified with zinc; in the present study (CSFII 1994-1996 and 1998), 64% of children aged 1–5 y old did so.

The contribution of RTE cereal to the zinc intake of children has increased over time. In the previous CSFII study (1989–1991), the primary food sources of zinc for children 2–5 y old were milk (21%), beef (17%), and RTE cereal (11%; 14). In the present study, the primary food sources of zinc for children 2–5 y old were RTE cereal (18%), milk (16%), and beef (13%). In the present study, children in 1998 consumed the same amount, by weight, of RTE cereal as did children in 1994, but the mean amount of zinc consumed from RTE cereals increased from 0.8 mg/d in 1994 to 1.3 mg/d in 1998.

The finding of higher zinc intakes in children participating in food assistance programs agrees with previous reports. Rose et al (15) examined the effects of participation in the Food Stamp (FS) and WIC programs on nutrient intake of preschoolers in the 1989–1991 CSFII. Children in either or both of these programs had higher zinc intakes than did nonparticipants. Perez-Escamilla et al (16) found that inner-city preschoolers who were enrolled in both the WIC and FS programs had higher zinc intakes than did children enrolled only in WIC. The WIC food packages for infants and children include infant formula, milk, breakfast cereal, cheese, juice, peanut butter, beans, and eggs, which together provide 3.9–4.4 mg zinc/d (17). In the present study, zinc intake from infant formula was predicted by participation in WIC.

In this study, children in the lowest income category had higher zinc intakes, even after control for WIC participation, which suggests that some additional factor associated with low income contributed to higher zinc intake. When FS participation, but not income status, was in the model with WIC participation, FS participation and WIC participation were significant. When income was added to the model with WIC and FS, FS participation was no longer significant. This suggests that income status was probably responsible for the association of FS participation with zinc intake, but not for the association of WIC participation with zinc intake. In separate chi-square analyses, participation in the FS Program was more strongly associated with income status than was participation in WIC. Other variables that are often associated with income, such as parental education and single head of household, did not change the relation of income to zinc intake when added to the model.

Overall, 36% of children had diets containing zinc in excess of the UL. The UL published by the DRI committee includes both dietary zinc and zinc consumed as a micronutrient supplement, whereas the CSFII data describe zinc intake from foods only. If intakes in the present study had included nutrient intakes from supplements, the intakes of even more children would have exceeded the UL. In this population, 20% of the children were taking a multimineral supplement that may have contained zinc. Most children's multimineral supplements available in the market provide 15 mg Zn—or 7.5 mg if a half-tablet is consumed, as is advised for children < 4 y old. Therefore, children who consume a zinc-containing multimineral supplement receive more than the UL of zinc from the supplement alone. The UL of zinc is based on the adverse effects of zinc on copper metabolism. Despite the high zinc intakes of children in the present study, the children's diets contained adequate amounts of copper, and the mean zinc:copper of the diets was in the range of the molar ratios of the DRI values for zinc and copper. Thus, it may be less likely that high zinc intake produces adverse effects on copper metabolism under these circumstances. However, there were some children who had diets with high zinc density but whose zinc:copper was also high. More research is needed on possible adverse effects of these levels of zinc intake.

In setting the dietary requirement for zinc in children, a single percentage of fractional zinc absorption was assumed. If high zinc intakes are associated with consumption of inhibitors of zinc absorption, it may be less likely that zinc would induce adverse effects. Phytate is the major inhibitor of zinc absorption (7). In the present study, the children with diets in the highest quartile of zinc density had a mean phytate:zinc of only 3, and thus it is unlikely that phytate exerted an important effect on zinc absorption.

As a result of new dietary recommendations for zinc, the assessment of the adequacy of zinc intake now finds a high percentage of intakes above the recommended UL, rather than the previous finding of a high proportion of inadequacy. This may raise some concern, especially among those who misinterpret the purpose of the UL as indicating the level at which adverse effects may be seen. In fact, the UL is defined as the highest average daily intake likely to pose no risk of adverse health effects to almost all persons in the general population. There have been no recent reports of zinc toxicity in US children. It is unlikely that zinc intake from food is high enough to have a negative effect on health status. However, if zinc intake continues to increase because of the greater availability of zinc-fortified foods in the US food supply, the amount of zinc that children consume from foods may become excessive. Research is needed on the effect of current zinc intakes from both food and supplements on the copper status and immune function of US children. If no adverse effects are found, then the currently recommended UL should be increased.

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