Dietary Phytate Reduction Improves Zinc Absorption in Malawian Children Recovering from Tuberculosis but Not in Well Children

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ABSTRACT High dietary phytate content that compromises zinc nutriture is thought to be a major problem among children of the developing world. Zinc stable isotope techniques permit the quantitative assessment of the effect of phytate reduction on zinc homeostasis. We tested the hypothesis that zinc absorption would be increased in Malawian children fed a reduced-phytate corn-plus-soy diet compared with a standard high phytate diet. Twenty-three children hospitalized in Blantyre, Malawi, were enrolled. Children were selected from those recovering from tuberculosis and from well children (those with minor injuries, those awaiting elective surgery or healthy siblings). Children received a diet of corn-plus-soy porridge (either low phytate or high phytate) for a period of 3–7 d and then participated in a zinc stable isotope study. The study included the administration of oral and intravenous zinc stable isotopes and 7-d collections of urine and stool. The diet was maintained throughout the duration of specimen collection. Zinc isotopic enrichments in urine and stool were measured, and zinc fractional absorption, total zinc absorption, endogenous fecal zinc, net zinc retention and size of the exchangeable zinc pool were calculated. Among the 14 children recovering from tuberculosis, dietary phytate reduction resulted in higher fractional absorption (0.41 ± 0.14 versus 0.24 ± 0.08, mean ± SD, P < 0.05) and total zinc absorption (169 ± 55 versus 100 ± 46 μg/(kg · d), P < 0.05). No effect of phytate reduction was seen in the well children (n = 9). Phytate reduction did not decrease the absolute endogenous fecal zinc, but it did decrease it relative to total absorbed zinc. These preliminary results indicate that phytate reduction may be beneficial in improving zinc nutriture in groups with increased zinc requirements who consume a cereal-based diet. J. Nutr. 130: 2959–2964, 2000.

KEY WORDS: • zinc • stable isotopes • phytate • zinc homeostasis • Africa • children

Corn is the major staple used for infant and child feeding in Malawi (Ferguson et al. 1993). Due to the high content of phytic acid (myoinositol hexaphosphate) in corn, the bioavailability of zinc is thought to be restricted. Phytic acid is the most potent inhibitor of zinc absorption in animal and human studies, particularly when the molar ratio of phytate to zinc is >15, because it can form insoluble complexes with zinc in the gastrointestinal tract (Bindra et al. 1986, Sandstrom and Lönnerald 1989). In addition, substantial quantities of endogenous zinc enter the lumen of the small intestine postprandially; the reabsorption of this secreted zinc is necessary to maintain homeostasis (Wastney et al. 1986). Dietary phytate may also form complexes with this endogenous secreted zinc and inhibit its reabsorption (Lönnerald et al. 1989).

In rural Malawi, the high phytate diet is associated with compromised zinc status (Ferguson et al. 1989, Huddle et al. 1998). This is unfortunate because zinc deficiency during childhood contributes to impaired growth, immunity and cognitive function and increased severity and incidence of diarrheal, malarial and respiratory infections (Black 1998, Zinc Investigators’ Collaborative Group 1999).

The development of analytical techniques for measuring stable isotope ratios of zinc in biological samples allows the processes of zinc absorption and conservation by the intestine to be examined individually and quantitatively (Jackson et al. 1988, Krebs et al. 1995). These techniques can provide measurements of the impact of high dietary phytate on the absorption of exogenous dietary zinc and on the intestinal conservation of endogenous zinc. This study tested the hypothesis that children who consume a phytate-reduced corn-plus-soy diet will have greater absorption of zinc and greater intestinal conservation of endogenous zinc than children who consume a standard high phytate diet.

SUBJECTS AND METHODS

Study children. Children aged 3–13 y who were hospitalized for tuberculosis treatment or due to minor trauma or were awaiting an elective orthopedic procedure or healthy siblings of inpatients at the Queen Elizabeth Central Hospital in Blantyre, Malawi, were eligible for this study. The rationale for choosing these children was that they...
were all relatively healthy, and thus their zinc homeostasis would probably represent that of normal Malawian children. Conducting the study in the hospital allowed for strict dietary control and complete specimen collection. In Malawi, children are hospitalized for the treatment of tuberculosis for many weeks; the regimen used at the time of this study was inpatient treatment for 60 d with streptomycin, rifampicin, pyrazinamide and isoniazid. During the latter part of their hospitalization, these children were active and rapidly gaining weight. Other well children, with either congenital deformities or minor injuries, were waiting in the hospital many days for an orthopedic consultation. These children were ambulatory and had no acute disability. The principal investigator, who was a pediatrician, enrolled only children with a normal upper respiratory, chest, abdominal and dermatologic physical examination. All children who were enrolled met the criteria listed in Table 1.

Informed consent was solicited from the caretakers. The study was approved by the College of Medicine Research Committee (University of Malawi), University of Otago Human Ethics Committee and the Human Studies Committee (Washington University, St. Louis, MO).

Children were weighed regularly with an electronic scale accurate to the nearest 200 g, and their height was measured with a stadiometer accurate to the nearest 2 mm.

A blood sample was obtained at the time of isotope administration and used to measure the concentrations of plasma zinc (Smith et al. 1979), serum C-reactive protein and α1-antitrypsin (Rose et al. 1986). The acute-phase proteins were used to assess the status of inflammatory processes in the children. Care was taken to use standard trace element–free materials and methods for the measurement of plasma zinc.

Diets. The diet was corn-plus-soy porridge served five times each day. The porridge was prepared from a mixture of 80% unrefined white corn flour and 20% soybean flour, with vegetable oil and sugar added. Water was added to form a 20% slurry. In addition to the porridge, a sugar-based drink and a fruit or nut snack were provided daily. The menus were identical for both diets, except for the phytate reduction of the porridge. The nutrient and antinutrient contents of the diets are shown in Table 2.

Children were randomly assigned to either the standard diet or the phytate-reduced diet. For at least 3 d before the metabolic study, the children received their assigned diet to ensure acceptance of the test diet and to ensure that they had a good appetite. Complete weighed food records were maintained during this period to quantify each child’s intake. Nutrient composition data were derived from the International Mini List (University of California at Berkeley). The zinc content of the diet was determined by saving and analyzing weighed aliquots of porridge according to standard methods (Bindra et al. 1986, Scythes et al. 1982), and the phytate content was determined according to a modified method of Lehrfield (1989). The dietary zinc intake on the day of isotope administration was used to calculate total absorbed zinc (TAZ). If the dietary zinc intake on the day of isotope administration was <80% of the mean daily zinc intake for the 3-d period proximate to this day, then the 3-d zinc intake was used to calculate TAZ.

Metabolic study. Stable isotopes 67Zn and 70Zn (Martin Marietta Energy Systems, Oak Ridge, TN) were prepared for human administration according to standard sterile techniques (Krebs et al. 1996). On d 1 of the metabolic zinc study, children received a precisely measured intravenous dose of ~750 μg of 70Zn. During the five meals on d 1, an oral dose of 67Zn was consumed with the food. The total dose of 67Zn was 20% of the total zinc intake estimated from the weighed dietary records of the previous 48 h (1.5–2.5 mg 67Zn; Sian et al. 1996). A brilliant blue fecal marker was administered 72 h after administration of the 70Zn and again precisely 4 d later. All stools between markers were collected. Children defecated into zinc-free plastic bags. Three times daily on d 3–8, a clean-void midstream urine sample was collected into a zinc-free plastic container. Specimens were frozen and transported unprocessed to the laboratories in Denver, CO, for analyses.

A 24-h urine collection was completed for most of the children, beginning 48 h after the administration of isotopes. The specimens were analyzed for total urinary zinc losses.

Sample analyses. The zinc concentration and ratio of zinc isotopes were measured for each individual fecal and urine sample as described by Peirce et al. (1987) and Friel et al. (1992). Briefly, samples were reduced to ash, and total zinc was determined with flame atomic absorption spectrometry. Zinc was separated from other inorganic constituents with ion-exchange chromatography (Turnlund et al. 1982). Zinc isotopic ratios were determined with fast atom bombardment–induced secondary ion-mass spectrometry on a double-focusing mass spectrometer equipped with an Ion Tech atom gun (Peirce et al. 1987).

Isotopic enrichments were calculated from measured isotopic ratios using curves determined from the measurement of standard zinc isotope solutions. Adjustments were made to isotopic enrichment data to correct for the presence of the other zinc isotopes. For each isotope used, enrichment was defined as the total zinc in the sample from an isotopically enriched source divided by the total amount of zinc in the sample.

Calculations. For the determinations of fractional absorption (FAZ), the ratio of the urinary isotopic enrichment of the intravenously administered 72Zn to the orally administered 67Zn was used in the following equation (Friel et al. 1992):

\[
FAZ = \frac{\text{Enrichment (oral/intravenous)}}{\text{Dose (intravenous/oral)}} \times \frac{\text{Dose (intravenous/oral)}}{3 \times \text{Dose (intravenous/oral)}}
\]

Ten urine specimens that were obtained during study d 3–8 were

TABLE 1

<table>
<thead>
<tr>
<th>Eligibility criteria for study children</th>
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<tbody>
<tr>
<td>Children received ≥7 d of drug therapy if hospitalized for tuberculosis.</td>
</tr>
<tr>
<td>Children were clinically improving (respiratory status was improving; new infiltrates were not developing on chest radiographs, were not anorexic and did not have altered mental status).</td>
</tr>
<tr>
<td>Children with tuberculosis were gaining weight in the hospital, and the other children were not losing weight.</td>
</tr>
<tr>
<td>Children had no diarrhea (&gt;3 watery stools/d) for 3 d.</td>
</tr>
<tr>
<td>Children were afebrile for ≥1 wk.</td>
</tr>
<tr>
<td>Children were consuming the standard Malawian hospital diet and were not breast fed.</td>
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<tr>
<td>Children were ambulatory.</td>
</tr>
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TABLE 2

<table>
<thead>
<tr>
<th>Composition of standard high and reduced-phytate diets</th>
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<tr>
<td>Standard high diet phyate</td>
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<tr>
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<tr>
<td>Energy, kJ/100 g porridge</td>
</tr>
<tr>
<td>Protein, g/100 g porridge</td>
</tr>
<tr>
<td>Iron, mg/100 g porridge</td>
</tr>
<tr>
<td>Zinc, mg/100 g porridge</td>
</tr>
<tr>
<td>Phytate, mg IP6/100 g porridge</td>
</tr>
<tr>
<td>Phytate/zinc molar ratio</td>
</tr>
<tr>
<td>(Calcium × phytate)/zinc molar ratio</td>
</tr>
</tbody>
</table>

FAZ, endogenous fecal zinc; EZP, pool of zinc exchangeable in 2 d; FAZ, fractional absorption of zinc; TAZ, total absorbed zinc.

3 Abbreviations used: EFZ, endogenous fecal zinc; EZP, pool of zinc exchangeable in 2 d; FAZ, fractional absorption of zinc; TAZ, total absorbed zinc.
Plasma zinc,3 mg/(kg D)

Dietary zinc intake, Dietary energy intake, and plasma within a 2-d period (EZP, in mg) was estimated by dividing C-reactive protein,4 Z

Weight-for-age,6 Height-for-age,6 Age, y (male, female) 2, 3 3, 1 2, 4 4, 4

Net absorbed zinc, mg/(kg D)

Fractional absorption of zinc

Total absorbed zinc, mg/(kg D)

Net absorbed zinc, mg/(kg D)

ANCOVA of zinc absorption in well and recovering children fed standard or reduced-phytate diets1,2

<table>
<thead>
<tr>
<th>P-value</th>
<th>Diet (reduced vs high phytate)</th>
<th>Group (recovering vs well)</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fractional absorption of zinc</td>
<td>0.025</td>
<td>0.076</td>
<td>0.35</td>
</tr>
<tr>
<td>Total absorbed zinc, mg/(kg D)</td>
<td>0.113</td>
<td>0.045</td>
<td>0.29</td>
</tr>
<tr>
<td>Net absorbed zinc, mg/(kg D)</td>
<td>0.400</td>
<td>0.032</td>
<td>0.25</td>
</tr>
</tbody>
</table>

1 Two-factor ANOVA models were used to determine the effects of diet and group on measures of zinc homeostasis.
2 Data presented are P-values for main effects and the r² of the model.
3 Plasma zinc measurements available for nine recovering children and three well children.

RESULTS

Twenty-three children who met the criteria in Table 1 were enrolled in October/November 1997 and May 1998. Eight other children completed the zinc stable isotope study but were excluded from the analyses because they had a markedly elevated C-reactive protein concentration (>80 mg/L), indicating coincident systemic infection, or were not fully ambulatory. The children were compliant with the diet; weighed records of all meals were kept. There was no difference in dietary zinc intake between the children receiving the high or reduced-phytate diet. One child lost stool samples, and thus stool data were obtained. Two children missed meals on the day of isotope administration, and thus 3-d dietary intakes were used to calculate TAZ. Children receiving a reduced-phytate diet had a greater FAZ (0.35 ± 0.14 versus 0.24 ± 0.07, P < 0.05) and TAZ [148 ± 61 versus 100 ± 41 μg/(kg D), P < 0.05].

All of the FAZ values of >0.29 were found in children recovering from tuberculosis. The group effect (recovering from tuberculosis or other well children) was as important as the phytate content of the diet (Table 3). Because of the dichotomy between the two groups of children, the data are presented separately for both diet and group. The demographic characteristics of the children recovering from tuberculosis (hereafter referred to as recovering children) and the other children (hereafter referred to as well children) are presented in Table 4. For TAZ, FAZ and EFZ, only diet was found to be predictive in the multiple stepwise regression model for the recovering children. Inclusion of the anthropometric indices only improved the model from r² = 0.30 to r² = 0.38.

TABLE 3

Demographic, anthropometric and biochemical characteristics of the recovering and well Malawian children studied who consumed high or low phytate diets1

<table>
<thead>
<tr>
<th></th>
<th>Well children</th>
<th>Recovering children</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (male, female)</td>
<td>2, 3</td>
<td>2, 4</td>
</tr>
<tr>
<td>Age, y</td>
<td>9.9 ± 2.1</td>
<td>5.6 ± 2.4</td>
</tr>
<tr>
<td>Weight-for-age, Z-score</td>
<td>−1.40 ± 0.84</td>
<td>−1.41 ± 0.90</td>
</tr>
<tr>
<td>Height-for-age, Z-score</td>
<td>−2.15 ± 1.37</td>
<td>−2.84 ± 0.66</td>
</tr>
<tr>
<td>Weight-for-height, Z-score</td>
<td>0.10 ± 0.62</td>
<td>0.60 ± 0.70</td>
</tr>
<tr>
<td>Dietary energy intake, kJ/(kg D)</td>
<td>321 ± 109</td>
<td>369 ± 151</td>
</tr>
<tr>
<td>Dietary zinc intake, mg/(kg D)</td>
<td>0.37 ± 0.13</td>
<td>0.42 ± 0.18</td>
</tr>
<tr>
<td>Plasma zinc, μmol/L</td>
<td>14.2 ± 1.5</td>
<td>12.7 ± 1.5</td>
</tr>
<tr>
<td>C-reactive protein, mg/L</td>
<td>1.0 (2)</td>
<td>2.3 (10)</td>
</tr>
<tr>
<td>α1-Antitrypsin, g/L</td>
<td>2.1 ± 0.7</td>
<td>2.3 ± 1.4</td>
</tr>
</tbody>
</table>

1 Values are means ± SD.
2 Significantly lower than all other groups.
3 Plasma zinc measurements available for nine recovering children and three well children.
4 C-reactive protein are medians (25%, 75%).
Although diet was significant (P < 0.05) in the model, weight-for-age Z-score (WAZ), height-for-age Z-score (HAZ) and weight-for-height Z-score (WHZ) were not (P > 0.3). The correlation coefficients between WAZ, HAZ or WHZ and FAZ or TAZ were not significant.

Among the recovering children, phytate reduction resulted in greater FAZ and TAZ (Table 5, Figs. 1, 2). FAZ was greater among boys than among girls regardless of diet (0.43 ± 0.13 versus 0.27 ± 0.12, P < 0.05). Recovering children gained 0.18 kg during the 7 d metabolic study.

The nine well children included five children who were awaiting elective surgery (two for congenital deformities and three with frozen elbows due to previous fractures), two children with previous lower leg fractures who were ambulating well with external fixation, one ambulatory child with an ankle sprain and one healthy sibling. Among the well children, phytate reduction did not result in higher FAZ or TAZ values (Table 5, Figs. 1, 2). Although the statistical power of the comparisons between these small groups of well children is too low to say they are truly the same, there was only a 5% chance that FAZ varied by ≥0.03 between the high and reduced-phytate diets.

Well children gained 0.18 kg during the 7 d of metabolic collections, a change in body mass of <1%, and significantly less than gained by the recovering children (P = 0.01). No child lost weight during the 7-d period.

For the well children, TAZ and EFZ were directly correlated (r = 0.81, P < 0.01), and there was no significant difference in this correlation with phytate reduction. For the recovering children who consumed the high phytate diet, TAZ and EFZ tended to be directly correlated (r = 0.81, P = 0.09); however, this positive correlation was not seen in the recovering children who consumed a low phytate diet (r = −0.19, P = 0.7). TAZ was directly correlated with percent-age weight gain (r = 0.44, P < 0.05).

Seven recovering and seven well children completed 24-h urine collections. The urinary zinc excretion in the well children was almost twice that of the recovering children, but this difference was not significant (234 ± 149 versus 128 ± 63, P

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**Table 5**

<table>
<thead>
<tr>
<th></th>
<th>Well children</th>
<th>Recovering children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High phytate</td>
<td>Reduced phytate</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td></td>
</tr>
<tr>
<td>Fractional absorption of zinc</td>
<td>0.24 ± 0.03</td>
<td>0.24 ± 0.02</td>
</tr>
<tr>
<td>Total absorbed zinc, mg/d</td>
<td>2.17 ± 0.41</td>
<td>1.59 ± 0.47</td>
</tr>
<tr>
<td>Total absorbed zinc, μg/(kg·d)</td>
<td>91.9 ± 40</td>
<td>105 ± 52</td>
</tr>
<tr>
<td>Endogenous fecal zinc, mg/d</td>
<td>1.54 ± 0.37</td>
<td>1.52 ± 0.16</td>
</tr>
<tr>
<td>Endogenous fecal zinc, μg/(kg·d)</td>
<td>66.4 ± 30.5</td>
<td>96.6 ± 25.3</td>
</tr>
<tr>
<td>Net absorbed zinc, mg/d</td>
<td>0.63 ± 0.40</td>
<td>0.07 ± 0.40</td>
</tr>
<tr>
<td>Net absorbed zinc, μg/(kg·d)</td>
<td>25 ± 20</td>
<td>8 ± 28</td>
</tr>
<tr>
<td>Pool of zinc exchangeable in 2 d, mg/kg</td>
<td>3.9 ± 0.5</td>
<td>4.1 ± 1.1</td>
</tr>
<tr>
<td>Urinary zinc, μg/d</td>
<td>319 ± 143</td>
<td>60 ± 12</td>
</tr>
<tr>
<td>Urinary zinc, μg/(kg·d)</td>
<td>12.7 ± 3.0</td>
<td>4.1 ± 1.0</td>
</tr>
<tr>
<td>Weight gain during metabolic study, g/d</td>
<td>280 ± 400</td>
<td>50 ± 100</td>
</tr>
<tr>
<td>Weight gain during metabolic study, % change in 7 d</td>
<td>1.2 ± 1.9</td>
<td>0.3 ± 0.6</td>
</tr>
</tbody>
</table>

^1 Values are mean ± SD.  ^2 Significantly greater than all other groups.

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**Figure 1**  Fractional zinc absorption in either well or recovering Malawian children receiving either a high or a low phytate diet. Well children were healthy, awaiting elective surgery or had recently had a minor injury, and recovering children had received chemotherapy for tuberculosis and were rapidly gaining weight. Data presented as mean ± SEM: high phytate, well, n = 5; low phytate, well, n = 4; high phytate, recovering, n = 6; low phytate, recovering, n = 8. *Significantly greater than the other 3 groups, P < 0.05.

**Figure 2**  A comparison of total absorbed zinc (TAZ) and endogenous fecal zinc (EFZ) in either well or recovering Malawian children receiving either a high or a low phytate diet. Well children were healthy, awaiting elective surgery or had recently had a minor injury, and recovering children had received chemotherapy for tuberculosis and were rapidly gaining weight. The net absorbed zinc is the difference between the TAZ and EFZ for each group. Data are mean ± SEM: high phytate, well, n = 5; low phytate, well, n = 4; high phytate, recovering, n = 6; low phytate, recovering, n = 8. *Significantly greater than the recovering high phytate group, P < 0.05.
Low phytate improves children's zinc absorption

DISCUSSION

Improving the bioavailability of zinc had different effects on zinc absorption in different groups of children. For the recovering children, dietary phytate reduction resulted in greater FAZ and TAZ. In contrast, among the well children, dietary phytate reduction had no effect on zinc absorption. These data also suggest that children who habitually consume a very high phytate diet may achieve an FAZ of 0.25.

By distinguishing between well and recovering children, the sample size of each group was reduced, which limited the strength of the statistical comparisons between groups and introduced uncertainty as to whether anthropometric indices could also be related to zinc absorption. Because of the short period of time the children consumed the monotonous, low phytate diet and the rapid growth of the recovering children, caution should be exercised in extrapolating the findings to normal children on a reduced-phytate diet for a prolonged period of time. The recovering children received medications for the treatment of tuberculosis. Streptomycin, rifampicin and isoniazid have been investigated for their ability to chelate zinc and their effect on plasma zinc concentration, and no significant interactions were found (Cole et al. 1983, Elo and Uksila 1970). Any changes in zinc absorption produced by tuberculosis or its treatment would be seen in the recovering children receiving both low and high phytate diets, and comparisons between these two dietary groups are likely to remain valid. Stable isotope studies with 4-d stool collections require highly motivated, cooperative subjects and unfortunately cannot be conducted only with small groups of individuals. However, stable isotope techniques currently provide the most reliable quantitative human data on zinc homeostasis. Because of the limitations of this study, these data must be considered as preliminary.

Children recovering from tuberculosis are recovering from a wasting illness and are experiencing rapid catch-up growth. Indeed, the recovering children gained 6 g/(kg·d) during the metabolic study. Several investigators have noted that plasma zinc concentrations are lower in children with tuberculosis, and plasma zinc concentration increases gradually during treatment (Bogden et al. 1977, Sharda and Bhandari 1977, Sinha et al. 1985). Hair and tissue zinc contents have been found to be lower in patients with tuberculosis as well (Ly-senko et al. 1997, Zhang 1991). The plasma zinc concentration was lower in the recovering children than in the well children. Together, the rapid catch-up growth and compromised zinc status of tuberculosis suggest that these recovering children had increased requirements for zinc, and they improved their zinc absorption with phytate reduction. Boys are thought to have greater zinc requirements than girls (Castillo-Duran et al. 1994), and FAZ was higher among the boys studied here as well. This also supports the concept that the absorption efficiency of zinc varies with the physiologic zinc requirement. During periods of rapid growth, such as in utero, infancy and adolescence, as well as during pregnancy and lactation, increased zinc bioavailability may be particularly important, and phytate reduction may be beneficial.

The mean net zinc absorption among the well children was quite modest: 17 μg/(kg·d), or −375 μg/(child·d). Estimates of insensible losses from other investigators are 7 μg/(kg·d) (Johnson et al. 1993), and the measured urinary zinc losses were 9 μg/(kg·d) in the well children. Thus, the well children absorbed sufficient zinc to replace their losses but appeared to retain no zinc for growth. Why was this so? The well children consumed 0.41 mg zinc/(kg·d) compared with 0.50 mg/(kg·d), as found in a home-based dietary survey of 4- to 6-year-old Malawian children (Ferguson et al. 1989). It is possible that the children in the study consumed less food than they would have at home because the diet was so monotonous. The additional retained zinc provided by a higher dietary intake might have been sufficient to facilitate normal growth (World Health Organization 1996). Alternatively, the lack of zinc retained for growth in these nine well children could reflect an anomaly of this small sample size. This discrepancy makes it difficult to assume that these nine well children represent normal Malawian children. Further studies are in progress in normal Malawian children to further investigate zinc homeostasis.

Although EFZ did not decrease with phytate reduction among the recovering children, phytate reduction ameliorated the direct correlation between EFZ and its principal dietary correlate, TAZ, and thus potentiated increased zinc conservation. This indicates that although increased amounts of zinc were absorbed, corresponding amounts of endogenous zinc were not lost through the gastrointestinal tract, and the retained zinc was used for growth and replenishment of stores. The well children had substantial EFZ relative to TAZ that was unaffected acutely by phytate reduction. The observation that phytate reduction did not change zinc homeostasis in the well children indicates that zinc was probably not a limiting nutrient at the time of the metabolic study. Increased dietary zinc intake appears to compensate for the reduced bioavailability of the high phytate diet.

EFZ is thought to be a measure of zinc status, although an interpretation of values is not possible because of the paucity of normative data. Although no other data are available for a comparable age group, the EFZ in this study, considered on a body weight basis, was certainly not low in comparison with either adults (Miller et al. 1994) or infants (Krebs et al. 2000). The EZP from the Malawian children were measured only a few days after initiation of the diet and thus reflect their zinc status before enrollment rather than being an effect of the intervention.

This study provides evidence that dietary phytate reduction may be useful in improving zinc nutriture among populations who consume a cereal-based diet with increased physiologic zinc requirements. Studies that examine the long-term effects of phytate reduction on zinc homeostasis in a variety of nutritional and developmental states are needed to understand what role phytate reduction can play in improving zinc nutriture in the developing world.

LITERATURE CITED


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