Zinc supplementation during lactation[1–3]

Nancy F Krebs

ABSTRACT The requirements for zinc during lactation are greater than those during pregnancy, especially during the early weeks postpartum. Therefore, lactation poses a significant threat to maternal zinc homeostasis, particularly in populations with chronically low dietary zinc intakes. The current knowledge of maternal zinc status in lactation, particularly in developing countries, is reviewed herein with emphasis on the effects of zinc supplementation trials. The studies that have examined the zinc status of breast-fed infants are also reviewed. *Am J Clin Nutr* 1998;68(suppl):509S–12S.

KEY WORDS Lactation, zinc requirements, dietary zinc, breast-fed infants, infant development, maternal adaptation, zinc homeostasis

INTRODUCTION

The requirements for zinc during lactation are quantitatively greater than those during pregnancy, especially during the early weeks postpartum (1, 2). Therefore, lactation poses a significant threat to maternal zinc homeostasis, particularly in populations with chronically low dietary zinc intakes. Whether any adverse consequences to either the mother or the infant result if the increase in demands is not met by increased dietary intake is as yet unknown. Also unknown is whether maternal zinc supplementation in such populations would result in any benefit.

Potential maternal benefits of zinc supplementation include improved lactation or subsequent reproductive performance, and maternal zinc status. The last of these assumes that, although difficult to assess, marginal suboptimal zinc status at any time is undesirable and likely to have functional consequences. The mechanism by which homeostasis is achieved and maintained by lactating women, as well as clarification of the limits of adaptation, are other issues of considerable interest. An understanding of maternal adaptation under different circumstances is critical to the development of appropriate public health policies.

Potential benefits of maternal zinc supplementation to infants include enhancement of either quantity or quality of human milk and optimization of infant growth, development, and immune function. Although breast-fed infants generally fare well in each of these areas, even in marginalized conditions, it is not known to what extent marginal zinc deficiency occurs and may compromise the health and development of breast-fed infants, especially after the first few months of life.

The purpose of this article is to review the current knowledge of maternal zinc status in lactation, particularly in developing countries, and the effects of zinc supplementation trials. Studies of zinc status in breast-fed infants are also reviewed.

MATERNAL ZINC REQUIREMENTS DURING LACTATION

A review of the magnitude of the demand for zinc during lactation sets the stage for further discussion. In the early weeks postpartum, excretion in the milk is ≈30–45 μmol (2–3 mg) Zn/d; this declines to ≈15 μmol (1 mg) Zn by 2–3 mo postpartum (2). Zinc concentrations decline dramatically over the first 3–5 mo of lactation, and even as the volume of milk output increases during the early weeks postpartum, actual zinc output in milk also declines significantly (2). On the assumption that it is desirable to match these extra losses with a corresponding increase in the absorption of exogenous zinc, such volume of output represents a large increase over the estimated normative zinc requirement for absorption of 1.0 mg/d for nonpregnant, nonlactating woman (3). The high zinc output is relatively short term, but output beyond 3 mo, ≤15 μmol/d (≤1 mg/d), remains substantially higher than the estimated normative requirement (3).

Evidence suggests that women generally increase their dietary zinc intake by at least a modest amount when lactating. Lactating women in the United States were reported to have zinc intakes significantly higher than nonpregnant, nonlactating women (2, 4). In a group of fully lactating women in Denver, mean intakes were 13 mg Zn/d between 2 wk and 7 mo postpartum, whereas nonlactating postpartum women had intakes of 9.3 mg/d over the same period. Such intakes are much less than the current US recommended dietary allowances for lactating women of 19 mg Zn/d for the first 6 mo postpartum (5), but are close to minimum intakes considered safe by the World Health Organization for diets of moderate availability (3). Data are much more limited for women in developing countries. As shown in **Figure 1**, several reports indicate dietary zinc intakes that are much lower than those typical of US women (2, 4, 6–8).

[1] From the Center for Human Nutrition, University of Colorado School of Medicine, Denver.

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[3] Reprints not available. Address correspondence to NF Krebs, Center for Human Nutrition, University of Colorado School of Medicine, 4200 East Ninth Avenue, Box C225 Denver, CO 80262. E-mail: nancy.krebs@uchsc.edu.

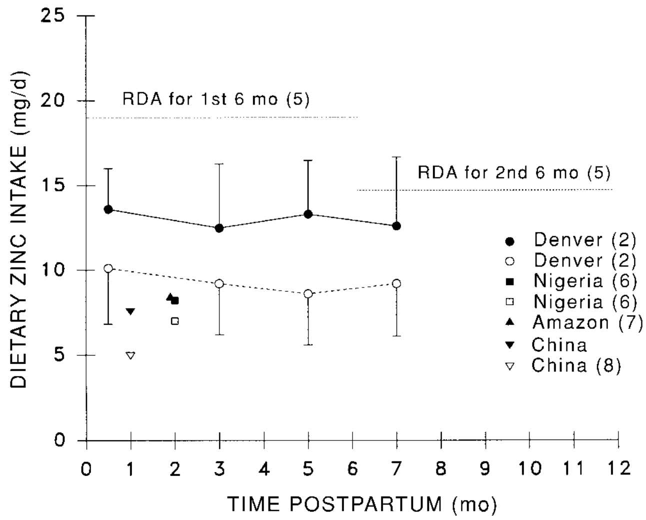

FIGURE 1. Comparison of dietary zinc intakes for lactating (solid symbols) and nonlactating (open symbols) women in the United States and developing countries. Intake for lactating women in China is from S Lei and NF Krebs, unpublished observations, 1996.

Comparisons of lactating and nonlactating women in the same setting are available in only a few instances, but it appears that zinc intakes are somewhat higher during lactation. For example, low-income, lactating Nigerian and Chinese women had ≈15% and ≈50% higher zinc intakes, respectively, than nonlactating women (6, 8; S Lei and NF Krebs, unpublished data, 1996). Nevertheless, the range of reported intakes is broad, with many populations consuming only ≈60% that of typical of US intakes, which are somewhat lower than recommended intakes (3, 5). It is at such marginal intakes that investigations are critical.

Is absorption efficiency increased in lactating women in addition to the modest increase in dietary zinc intake? Studies in rats suggest that in lactating dams, efficiency of absorption of dietary zinc is increased (9), but data for lactating women are still limited. Moser-Veillon et al (10) recently reported mean fractional absorption of zinc of ≈0.35 in US lactating women consuming only 8 mg Zn/d from mixed diets, whereas that of nonlactating postpartum women with the same zinc intake was ≈0.20. If a similar increase in fractional absorption is realized by lactating women consuming higher intakes, such as 10–12 mg Zn/d, the increase in absorbed zinc would be substantial relative to the output in milk. In populations routinely consuming <8 mg Zn/d, and with fractional absorption averaging ≈0.30 in nonlactating women (8), it is unknown whether lactation would result in a further increase in fractional absorption. The potential enhancing effect of lactation on absorption may also be limited in women whose diets include inhibitors of zinc absorption such as phytate.

Other means of maternal adaptation to the added demands for zinc during lactation include conservation of endogenous losses from the intestine and the kidney, mobilization and redistribution of body zinc pools, and, potentially, reducing losses in the milk. Much more information is needed on all of these aspects of adaptation, especially in populations with chronically marginal zinc intakes. In a recent study of nonpregnant, nonlactating women in rural China whose habitual zinc intake was ≈5 mg/d, conservation of intestinal endogenous zinc was found to be critical to maintaining zinc balance, whereas fractional absorption of dietary zinc did not differ from that of a group of urban Chinese women with higher habitual zinc intakes (8).

The contributions to the mobilizable zinc pools from postpartum involution of the uterus and resorption of trabecular bone in the early weeks postpartum have not been quantified. Estimates suggest that these sources could provide up to 0.5 mg Zn/d, a modest but significant amount of zinc during the first 3 mo of lactation when zinc output in milk is highest (3). The effect of other dietary constituents on the systemic redistribution of zinc is also unknown. For example, dietary calcium intake, which is also frequently low in developing countries, may influence bone resorption during lactation (11). This might in turn influence zinc availability for secretion into milk.

From a practical viewpoint, the most important potential consequence is whether marginal maternal zinc intake affects zinc concentration in breast milk. The overall decline in human breast milk zinc concentrations as lactation progresses is physiologic and predictable. Numerous cross-sectional and limited longitudinal studies showed no consistent correlation between maternal dietary zinc intakes and milk zinc concentrations when maternal intakes are relatively high (2, 4, 12–14). Short-term supplementation with pharmacologic doses of zinc does not stop or reverse the physiologic decline in milk zinc concentrations (15). In a longitudinal supplementation study in Denver, lactating women whose average intake was 13 mg Zn/d showed no effect of an additional 15 mg Zn/d on milk zinc concentrations through 9 mo of lactation (2). Longitudinal data indicate that whereas there is fairly wide interindividual variability, an individual woman's milk zinc concentrations tend to be consistent across the course of lactation. In our recent supplementation study, the correlation was 0.55 ($P<0.001$) for milk zinc concentrations at 2 wk postpartum with those at 5 mo, when most subjects were still exclusively breast-feeding (2). Factors that account for an individual producing milk with relatively high or low zinc concentrations are unknown.

Much less studied is the effect of low maternal zinc intakes during lactation, the preceding pregnancy, or both on milk zinc concentrations. Data from animals on marginal zinc intakes suggest that zinc secretion in milk may be decreased (16, 17). In an earlier longitudinal supplementation trial of well-nourished Denver women with lower daily zinc intakes, daily supplementation with zinc resulted in a significantly slower rate of decline in milk zinc concentrations through 9 mo. Concentrations of the 2 groups were not different at the outset of the study but diverged by 5–7 mo postpartum (18). In other zinc supplementation trials in US women, 1 group reported an early positive effect on milk zinc concentrations (19), possibly indicating differences between groups at the outset, independent of the supplement, whereas another intervention study resulted in no effect (20). Zinc supplementation in lactating Finnish women was associated with a slower decline in milk zinc concentrations only with very high supplementation (21).

Data on milk zinc concentrations from women in developing countries were obtained primarily by using cross-sectional design methods and often with wide ranges of time over which sampling had been undertaken. Data from several developing countries and longitudinal data from well-nourished US women are compared in **Figure 2** (2, 19, 22–28). Unfortunately, exact calculations of dietary zinc intake have generally not been available for the women providing milk samples, but for all the populations included, intake was presumed to be low. Such compar-

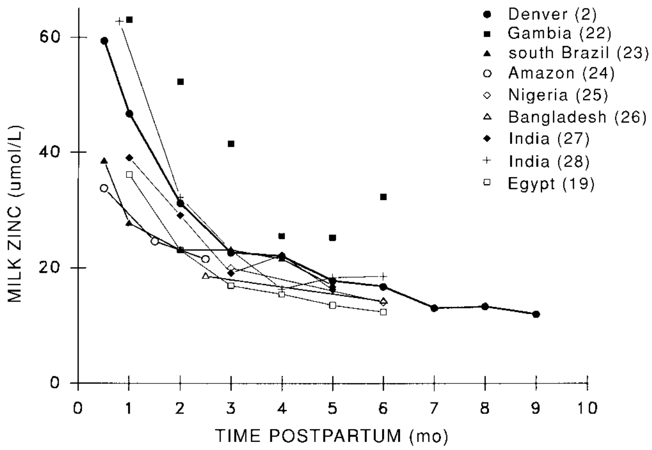

FIGURE 2. Comparison of milk zinc concentrations from lactating US women and women in developing countries. Connected symbols represent longitudinal or semilongitudinal data.

isons among studies with different methodologies must be interpreted cautiously, but the data indicate concentrations that are frequently lower than those of the US women at comparable times postpartum (19, 23–27, 29). Such observations support the hypothesis that low dietary zinc intake is associated with lower milk zinc concentrations.

A notable exception to the lower milk zinc concentrations in developing countries are the figures reported by Bates et al (22) from women in Gambia (Figure 2). The population was reportedly impoverished and diets were described as "almost entirely vegetable based with very little intake of meats or dairy products." The means reported by the investigators were not only higher than those of the US women, as shown in Figure 2, but were also higher than those of a concurrently studied group of middle-upper income women from Cambridge, United Kingdom. Appropriate precautions had been taken to avoid contamination and analytic procedures were identical, making artifactual differences seemingly unlikely (22). Similar results, ie, higher milk zinc concentrations associated with low zinc intakes, were observed in our laboratory from samples obtained from lactating women in China and India (28; S Lei and NF Krebs, unpublished observations, 1996). Contamination of samples at the time of collection is perhaps the most likely explanation. Until a better understanding of the mechanisms of zinc secretion in milk is available, however, the possibility of higher milk zinc concentrations associated with low zinc intake cannot be dismissed. Stress-mediated carrier proteins, including α_2-macroglobulin, were reported to be higher in postpartum women of low socioeconomic status than in those of higher socioeconomic status (30). Whether such differences could lead to a greater secretion of zinc by the mammary gland has not been investigated.

Longitudinal intervention trials in developing countries in which zinc intake is chronically low have not yet been conducted and are critically needed. Such carefully conducted trials will be essential to determine whether chronically low zinc intakes in lactating women are associated with lower milk zinc concentrations, output, or both. Ideally, evaluation of the effect of zinc intake and status during pregnancy should also be considered because this may have implications for maternal compensation during lactation. In addition to milk zinc concentrations, other outcome variables should be considered such as milk volume, immunologic factors in the milk, maternal zinc status, and maternal reproductive performance in subsequent pregnancies.

ZINC STATUS OF BREAST-FED INFANTS

There presently seems to be little reason for concern about term infants' zinc status during the first several months of life if milk supply is adequate. The young infant may be able to utilize zinc from hepatic zinc thionein for several weeks postpartum to supplement zinc derived from milk (31). Furthermore, the relatively high zinc concentrations in early breast milk provide a generous margin over predicted requirements (32). Studies of zinc homeostasis of normal exclusively breast-fed infants at 4–5 mo of age indicate positive net absorption similar to estimated requirements for growth (33).

The possibility of suboptimal zinc status in breast-fed infants after ≈6 mo of age was raised by several investigators (34–38). A longitudinal study of Danish infants found a significant decline in both serum zinc and erythrocyte metallothionein concentrations from 6 to 9 mo (35). In this study, serum zinc at 9 mo was positively associated with growth velocity between 6 and 9 mo. Two other longitudinal studies have reported inverse relations between serum zinc concentrations and growth velocity in breast-fed infants (21, 36).

The extent to which the well-documented slowing in growth midway through the first year of life is related to the zinc status of breast-fed infants is unknown. Results from supplementation trials suggest that at least some normal breast-fed infants may benefit from an increase in zinc intake by ≈6 mo (37, 39). These trials were undertaken in developed countries, although the group studied by Walravens et al (37) was from a low-income population. No controlled supplementation trials of breast-fed infants have been reported from high-risk populations in developing countries. Thus, data are too limited to estimate the actual prevalence of mild growth-limiting zinc deficiency; routine supplementation is not warranted on the basis of present evidence. In situations with potential increased losses of zinc, such as in acute gastroenteritis, development of deficiency is quite possible and supplementation should be considered. On a population basis, optimal choice of complementary foods is also critical during late infancy. Because exclusive breast-feeding is protective, especially in environments with poor sanitation, introduction of complementary foods should not be encouraged before 5–6 mo of age. At that time, however, choice of high-quality complementary foods that provide not only zinc but also iron, energy, and protein is likely to be beneficial.

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