Dietary selenium intake and selenium concentrations of plasma, erythrocytes, and breast milk in pregnant and postpartum lactating and nonlactating women1,3

Orville A Levander, PhD; Phylis B Moser, PhD; and Virginia C Morris, MS

ABSTRACT The selenium status of a group of 23 lactating and 13 nonlactating women was assessed from 37-wk gestation through 6-mo postpartum. The mean overall dietary Se intake of both groups of women was 80 ± 37 μg/d. Plasma and erythrocyte Se levels were lower in the lactating than in the nonlactating mothers both before and after parturition. Breast-milk Se concentrations fell from 20 μg/L (0.25 μmol/L) at 1-mo postpartum to 15 μg/L (0.19 μmol/L) at 3- and 6-mo postpartum. A weak (r = 0.38) but statistically significant (p < 0.025) relationship was observed between maternal plasma Se level and breast-milk Se concentration. The dietary Se intake of these lactating North American women appears sufficient to maintain satisfactory Se nutrure in their breast-fed infants during the first 6 mo of lactation. Am J Clin Nutr 1987;46:694-8.

KEY WORDS Selenium, lactation, breast milk, dietary intake, plasma, erythrocytes

Introduction

During the past 6 y, there has been remarkable progress in establishing adult human requirements for the essential trace element selenium (1). However, at this time the only nutritional standard for Se is the estimated safe and adequate daily dietary intake proposed in 1980 by the Food and Nutrition Board of the US National Research Council (2). Although this standard gives suggested ranges of intake for adults, children, and infants, it remains silent concerning possible increased nutritional needs during periods of physiological stress such as pregnancy (3) or lactation.

Recent work from Finland, a country with low-Se soils, suggests that maternal dietary Se intakes there may be insufficient to maintain breast-milk Se concentrations at levels consistent with the US estimated safe and adequate range for infants (4, 5). The study reported here examined the relationship between dietary Se intake and the Se concentration in blood and breast milk of North American women with the purpose of determining whether maternal Se intake in North America is adequate to maintain breast-milk Se concentrations for appropriate infant intake. This study was part of a larger investigation of the dietary intake and status of several nutrients consumed by postpartum lactating and nonlactating women (6-9).

Subjects and methods

Details of the experimental methods used in this study and the characteristics of the participating subjects were given previously (6) and only a brief description is presented here. Thirty-six healthy pregnant women aged 18-36 y were recruited for the study through a private obstetrics practice in the Annapolis, MD area. The women were of upper-middle-class socioeconomic status, were nulliparous or multiparous, and had no serious complications with their present or previous pregnancies. Thirteen women were recruited for the nonlactating group and 23 for the lactating group. The study procedures were approved by the Committee on Human Subjects at the University of Maryland and the USDA.

Duplicate-plate food and drink composites and dietary records were collected daily for 3 d at 37-wk gestation and at 1, 3, and 6 mo postpartum. The diet and beverage samples were homogenized and frozen for later Se analysis. On the third day of diet collection, fasting blood samples were drawn into citrated syringes. The blood samples were taken before and after delivery and processed as described (6). Umbilical cord samples were not

---

1 From the Vitamin and Mineral Nutrition Laboratory, Beltsville Human Nutrition Research Center, USDA-ARS, Beltsville, MD and the Department of Food, Nutrition, and Institution Administration, University of Maryland, College Park, MD.

2 A preliminary report of some aspects of this work has been presented: Levander OA, Moser VC, Moser PB. Dietary selenium (Se) intake and Se content of breast milk and plasma of lactating and nonlactating women. Fed Proc 1981;40:890(abstr).

3 Address reprint requests to Dr OA Levander, Beltsville Human Nutrition Research Center, US Department of Agriculture, Beltsville, MD 20705.

Received August 15, 1986.
Accepted for publication December 2, 1986.
Selenium in Diet and Breast Milk

Lactating women were analyzed by fluorometry of the diaminonaphthalene complex (10). Analytical quality control was maintained by the use of National Bureau of Standards (Gaithersburg, MD) Standard Reference Materials (NBS/SRM) as described earlier (11). Day-to-day variability in the technique was assessed by monitoring the values obtained for NBS/SRM #1577 bovine liver and #1567 wheat flour. Over a typical course of 10 analyses, the former gave a value of 1.10 ± 0.08 μg Se/g (13.9 ± 1.0 nmol/g) (±SD) and the latter 0.97 ± 0.06 μg Se/g (12.2 ± 0.8 nmol/g) (±SD) for coefficients of variation of 7.9 and 6.5%, respectively. The certified values of the liver and wheat are 1.1 ± 0.1 and 1.1 ± 0.2 μg Se/g (13.9 ± 1.3 and 13.9 ± 2.5 nmol/g), respectively. The wheat reference material contains ~10% water so that our analyzed value was 1.08 ± 0.07 μg Se/g (13.6 ± 0.88 nmol/g) (±SD) when corrected for moisture (CV = 6.5%). The detection limit of our analytical procedure is 10 ng.

The experiment was arranged in a completely random, repeated measures design. Dietary Se intake and blood Se concentration data were reported as least square means and these data were analyzed using general linear model procedures (12). Breast-milk Se data were reported as arithmetic means and were analyzed by Duncan's multiple range test (13). Correlation coefficients also were calculated.

Results

The mean daily dietary Se intakes of the lactating and nonlactating groups of women from 37-wk gestation to 6-mo postpartum are shown in Table 1. The lactating women consumed ~37% more Se than the nonlactating women when intake was averaged over all the time periods examined. This increased Se intake may be explained largely on the basis of the differences in energy intakes between these two groups because the lactating women consumed an average of 45% more calories than did the nonlactating women (6). The mean daily Se intake expressed on an energy basis was 47 and 45 μg Se/1000 kcal for the lactating and nonlactating groups, respectively. The lactating mothers also consumed an average of 54% more protein than those who did not lactate (6) and, because the Se in foods is associated largely with protein (14), increased protein intake could be yet another explanation for their higher Se intakes. Both the lactating and nonlactating mothers consumed less Se during the first 3 mo postpartum than during the final weeks of pregnancy. This again might be explained partially by the reduced postpartum energy intakes by both groups of these women.

The overall dietary Se intake of all the women who participated in this study was 80 ± 37 μg/d (mean ± SD for 423 individual 1-d diet composites). The large standard deviation associated with this mean value reflects the great diversity in the Se content of the 1-d composites collected by these women. The Se content of these composites ranged from 0.6 to 221 μg/d. About one-fifth of these daily composites contained <50 μg, the lower limit of the estimated safe and adequate daily dietary Se intake for adults (2). Only two of 423 single-day composites contained >200 μg, the upper limit of the adult estimated safe and adequate range.

The mean plasma and erythrocyte Se concentrations were lower in the lactating group than in the nonlactating group at all time periods tested (Table 2). Within a given group, plasma Se concentrations were lower during gestation than those postpartum but did not change as a function of duration of lactation. Erythrocyte Se levels did not change either as a function of pregnancy or duration of lactation.

The concentrations of Se in the breast milk of 10 lactating mothers giving samples at each collection period are shown in Table 3. The Se concentration decreased significantly by 3-mo postpartum but no further reduction was observed at 6 mo. The daily Se intake by infants aged 1, 3, and 6 mo was calculated on the basis of these concentrations and estimated breast milk volumes taken from Whitehead and Paul (15). In all cases, this calculated Se intake exceeded the lower limit of the safe and adequate range (2) for the 0–6-mo age group (10–40 μg/d).

There was no significant direct correlation between dietary Se intakes as estimated by analysis of 3-d pooled dietary composites and the Se content of maternal plasma, erythrocytes, or breast milk (data not shown). This was not unexpected, given the difficulty in attempting to estimate dietary Se intakes on the basis of such limited collections of dietary composites (16). Moreover, there was no significant correlation between erythrocyte and breast-milk Se levels or, as reported (17), plasma and breast milk Se levels when data were used only from mothers from whom complete sample collections were obtained (i.e., both plasma and milk samples at all time periods tested, n = 27) (data not shown). However, if all maternal plasma-milk data pairs were used (n = 43), there was a weak (r = 0.38) but statistically significant (p < 0.025) correlation between these two variables.

Discussion

The overall mean dietary Se intake of all the women in this study, 80 μg/d, is remarkably similar to that re-

---

**TABLE 1**

Mean analyzed dietary selenium intakes (μg/d) of lactating and nonlactating mothers during pregnancy (37 wk) and 1, 3, and 6 mo postpartum

<table>
<thead>
<tr>
<th>Time</th>
<th>Lactating mothers</th>
<th>Nonlactating mothers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestation (37 wk)</td>
<td>97 ± 4 (23)*</td>
<td>73 ± 6 (12)*</td>
</tr>
<tr>
<td>Postpartum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mo</td>
<td>84 ± 4 (23)*</td>
<td>63 ± 6 (13)*</td>
</tr>
<tr>
<td>3 mo</td>
<td>84 ± 4 (23)*</td>
<td>56 ± 6 (13)*</td>
</tr>
<tr>
<td>6 mo</td>
<td>87 ± 4 (23)*</td>
<td>69 ± 6 (13)*</td>
</tr>
</tbody>
</table>

* Mean ± SEM. Number of subjects in parentheses. Means within the same column or the same row with different a, b or x, y superscripts, respectively, are significantly different (p < 0.05).
TABLE 2
Plasma and erythrocyte selenium concentration of lactating and nonlactating mothers at 37 wk gestation and 1, 3, and 6 mo postpartum*

<table>
<thead>
<tr>
<th>Time</th>
<th>Lactating mothers</th>
<th>Nonlactating mothers</th>
<th>Lactating mothers</th>
<th>Nonlactating mothers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/L</td>
<td></td>
<td>ng/g Hb</td>
<td></td>
</tr>
<tr>
<td>Gestation (37 wk)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>112 ± 5 (21)*</td>
<td>130 ± 7 (12)*</td>
<td>472 ± 40 (15)*</td>
<td>613 ± 71 (5)*</td>
<td></td>
</tr>
<tr>
<td>(1.42 ± 0.06)</td>
<td>(1.65 ± 0.09)</td>
<td>(5.98 ± 0.51)</td>
<td>(7.76 ± 0.90)</td>
<td></td>
</tr>
<tr>
<td>Postpartum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 mo</td>
<td>136 ± 5 (21)*</td>
<td>151 ± 6 (13)*</td>
<td>470 ± 33 (20)*</td>
<td>599 ± 46 (11)*</td>
</tr>
<tr>
<td>(1.72 ± 0.06)</td>
<td>(1.91 ± 0.08)</td>
<td>(5.95 ± 0.42)</td>
<td>(7.58 ± 0.58)</td>
<td></td>
</tr>
<tr>
<td>3 mo</td>
<td>137 ± 5 (22)*</td>
<td>152 ± 6 (13)*</td>
<td>450 ± 33 (21)*</td>
<td>598 ± 41 (13)*</td>
</tr>
<tr>
<td>(1.73 ± 0.06)</td>
<td>(1.93 ± 0.08)</td>
<td>(5.70 ± 0.42)</td>
<td>(7.57 ± 0.52)</td>
<td></td>
</tr>
<tr>
<td>6 mo</td>
<td>138 ± 5 (22)*</td>
<td>144 ± 7 (11)*</td>
<td>501 ± 31 (23)*</td>
<td>637 ± 41 (13)*</td>
</tr>
<tr>
<td>(1.75 ± 0.06)</td>
<td>(1.82 ± 0.09)</td>
<td>(6.34 ± 0.39)</td>
<td>(8.06 ± 0.52)</td>
<td></td>
</tr>
</tbody>
</table>

* Mean ± SEM. Number of subjects in parentheses. Means within the same column with different a, b superscripts are significantly different (p < 0.05). Means for a given variable within the same row with different x, y superscripts are significantly different (p < 0.05).
† SI values (µmol/L) are given in parentheses below µg/L values.
‡ SI values (nmol/g Hb) are given in parentheses below ng/g Hb values.

ported in two earlier studies from the Beltsville, MD area with adult males and females (nonlactating) consuming self-selected diets (11, 18). The wide range of daily Se intakes indicated by the 1-d dietary composites collected in this study (0.6–221 µg) is also remarkable and reflects the great diversity of food choices made by this population of women. The dietary record of the woman whose 1-d food composite contained only 0.6 µg of Se revealed that on that day she consumed two cups of coffee (with sugar and nondairy whitener), a glass of cola, and two apple- control candies. Some of these upper-middle-class women were strongly self-motivated to reduce their postpartum body weights to their prepregnant weight (9). This desire for weight reduction is also borne out by the low-energy intakes calculated from their diet records (6). Only two out of 423 1-d composites furnished > 200 µg of Se, the upper limit of the safe and adequate range for adults (2), and the dietary records showed that the subjects had consumed tuna fish on both of these days. Seafoods in general are a good dietary source of Se (14) but the bioavailability of the Se in tuna is relatively low (19).

The great dispersion in the dietary Se intakes suggested by the 1-d composites could be lessened considerably by consolidating the data into 3-d dietary pools. By doing this, the range of intakes contracted to 14–154 µg/d. Presumably, this range could be contracted further by analyzing composites collected over an even longer period of time. For example, the standard deviation of Beltsville Se intake data based on weekly composites (11) was only about one-half that of the daily composites reported here.

The various problems in ascertaining accurate estimates of Se intake, either by direct chemical analyses or by dietary records, has been discussed elsewhere (16, 20). For example, ~20 observation days of 24-h dietary recall data would be needed to estimate an individual’s Se intake within 20% of the true long-term intake (21).

The higher Se intakes seen in the lactating vs the nonlactating women could be explained largely on the basis of their increased energy intakes, presumably due to the increased energy demands of lactation. However, the mothers who had decided to breast-feed their infants consumed more calories and protein (6) as well as Se than the mothers who had decided not to lactate, even before lactation commenced (ie, during their gestation period). The reason for this increased consumption is not known, but perhaps the mothers who had made a commitment to breast-feed their babies were more concerned about their nutrition and therefore were consuming more food than the other women.

Plasma Se levels were reduced during pregnancy for both the lactating and nonlactating groups vs postpartum levels and these results are in agreement with others who also have observed declines in plasma Se values during pregnancy (22, 23). Red cell Se content, however, was unaffected by pregnancy, again in agreement with others.

TABLE 3
Selenium (Se) concentration in breast milk of lactating mothers and the calculated Se intake of exclusively breast-fed infants at different stages of lactation

<table>
<thead>
<tr>
<th>Age of infant</th>
<th>Breast-milk Se†</th>
<th>Volume of milk consumed†</th>
<th>Calculated Se intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>mo</td>
<td>µg/L</td>
<td>µmol/L</td>
<td>g/d</td>
</tr>
<tr>
<td>1</td>
<td>20 ± 1*</td>
<td>0.25 ± 0.01</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>15 ± 1†</td>
<td>0.19 ± 0.01</td>
<td>800</td>
</tr>
<tr>
<td>6</td>
<td>15 ± 1</td>
<td>0.19 ± 0.01</td>
<td>850</td>
</tr>
</tbody>
</table>

* Means within the same column with different letter superscripts are significantly different by Duncan’s multiple range test (p < 0.05) (13).
† Based on data from reference 15.
(22). The reason for the decline in plasma Se levels during pregnancy is not known but apparently is not due to alterations in the protein:water ratio in the plasma (22). Postpartum plasma and red cell Se levels were lower in the lactating group than in the nonlactating group despite the higher dietary Se intakes by the lactating women. On the basis of these results, one might conclude that the stress of lactation caused a decreased maternal Se status in the breast-feeding mothers. However, the plasma and red cell Se levels of the lactating group were lower than in the nonlactating group even during gestation (ie, before lactation began). The statistical probability of this happening by chance is quite remote but we have no reasonable physiological explanation for these results.

The Se concentrations in breast milk reported here are in close agreement with those reported by others for North American women (24, 25). However, lower values were found in breast milk from women residing in countries with low-Se soils. For example, Se levels averaged only 7.6 and 10.7 μg/L (0.096 and 0.135 μmol/L) in breast milk collected 1 mo postpartum from mothers in New Zealand and Finland, respectively (4, 26). Still lower levels, 2.6 μg/L (0.033 μmol/L), were reported in Keshan disease areas of China (GQ Yang, personal communication).

The decline in breast-milk Se concentration seen here with advancing stages of lactation has not been observed consistently by others. For example, Kumpulainen et al (4) in Finland reported a decline in Se level from 10.7 μg/L (0.135 μmol/L) at 1 mo of lactation to 5.8 μg/L (0.073 μmol/L) at 3 mo of lactation in breast milk samples collected in 1976. However, these workers reported a much smaller decline from 11.8 to 10.0 μg/L (0.149 to 0.127 μmol/L) for similar samples collected in 1980 (5). These authors concluded that the maternal dietary Se intake in 1980, 50 μg/d, was sufficient to maintain breast milk Se levels throughout 6 mo of lactation whereas the 30 μg/d intake of the mothers in 1976 was not sufficient. Our lactating mothers were consuming considerably more dietary Se than 50 μg/d so the reason for the decline in their breast milk Se levels is not clear. Smith et al (25) reported a decline in breast milk Se levels from 18.0 to 15.1 μg/L (0.228 to 0.191 μmol/L) at 1 and 3 mo of lactation, respectively, for their mothers in Illinois, an area where Se levels in forage crops are similar to those in Maryland (27).

The Se content of the breast milk from our North American mothers was sufficient to satisfy their infants' recommended Se intake during the first 6 mo of life as defined by the estimated safe and adequate daily dietary intake of 10–40 μg established by the US National Research Council in 1980 (2). The only human health problem firmly linked to Se deficiency is Keshan disease, a cardiomyopathy of children and young women that occurs in those areas of China where the dietary Se intakes are extremely low (28). For breast-fed infants, for example, the Se intakes in those areas would be in the range of ~1–2 μg/d, considerably below the intakes of our North American infants. Furthermore, no adverse health consequences due to low-Se status have been identified in infants in Finland or New Zealand where the Se level of breast milk is lower than that in North America (26, 29).

The ability to demonstrate only a weak correlation between maternal plasma Se levels and breast milk Se content was somewhat disappointing given the large number of animal studies that would suggest such an association (1). Higashi et al (30) in Japan found that the level of Se in serum of lactating women was unrelated to the Se content of their milk but Williams (26) in New Zealand observed a strong relationship between the Se in whole blood and that in human milk. Kumpulainen et al (29) in Finland noted a strong correlation between maternal serum Se concentration and the total daily milk Se output. These workers also showed that the amount of Se secreted into the milk by mothers given Se supplements was highly dependent on the chemical form of the Se given. Therefore, the ability to demonstrate a correlation between blood and breast milk Se levels may be determined in part by the form of dietary Se ingested by the mothers.

Our results show that women residing in Maryland secrete enough Se in their breast milk to satisfy the dietary intake recommended for infants aged 0–6 mo. This would suggest that the dietary Se intake of these women, 80 μg/d, is sufficient to meet the demands of lactation. Thus, the North American diet presumably provides enough Se to maintain adequate breast milk concentrations for infant health and development during the first 6 mo of life. Additional research is needed to determine the influence of the chemical form of the Se in the maternal diet on the level and bioavailability to the infant of the Se in breast milk. Moreover, the effect of prolonged lactation (ie, > 6 mo) on the Se content of breast milk needs further investigation.

The authors thank Dr Robert D Reynolds for his support, Carol Issa for processing the dietary composites, and Michael Chansler and Laura Wood for performing the Se analyses.

**References**


