Concentrations of Fe, K, Na, Ca, P, Zn and Mg in Maternal Colostrum and Mature Milk

by Silmara S. B. S. Mastroeni, Isaura A. Okada, Patricia H. C. Rondó, Maria Cristina Duran, Adriana A. Paiva, and Júlio M. Neto

Nutrition Department, School of Public Health, University of São Paulo and Institute Adolfo Lutz, São Paulo, Brazil

Summary

The objective of this study was to determine the concentrations of Fe, K, Na, Ca, P, Zn and Mg in colostrum and mature milk (2 months) from nursing mothers, and the correlation between the concentration of these micronutrients and newborn weight, maternal age, gestational age (GA), inter-pregnancy interval, and gestational weight gain. Thirty one women donated milk on the 2nd postpartum day and on the 2nd month of lactation. Micronutrients were analysed by atomic emission spectrophotometry. The concentrations (mean \[ \pm SD \]) of Fe (0.12 \[ \pm 0.08 \]; 0.09 \[ \pm 0.5 \] mg/100 ml), Zn (0.93 \[ \pm 0.36 \]; 0.15 \[ \pm 0.06 \] mg/100 ml), K (62.8 \[ \pm 11.5 \]; 46.2 \[ \pm 0.84 \] mg/100 ml) and Na (33.3 \[ \pm 12.3 \]; 20.5 \[ \pm 15.6 \] mg/100 ml) decreased from colostrum to mature milk, whereas Ca (21.4 \[ \pm 5.8 \]; 25.0 \[ \pm 3.1 \] mg/100 ml) and P (11.12 \[ \pm 2.8 \]; 13.7 \[ \pm 2.0 \] mg/100 ml) increased. Correlations were observed between Zn and Ca concentrations and GA (\( r^2 = 0.41 \), \( p = 0.042 \); \( r^2 = 0.48 \), \( p = 0.014 \), respectively), between Ca and K and inter-pregnancy interval (\( r = 0.56 \), \( p = 0.001 \); \( r = 0.38 \), \( p = 0.033 \), respectively), and between Mg and P and maternal age (\( r = 0.49 \), \( p = 0.005 \); \( r = 0.37 \), \( p = 0.042 \), respectively). The Zn concentration in colostrum showed a negative correlation with gestational weight gain (\( r = -0.49 \), \( p = 0.006 \)), and Na concentration showed a negative correlation with newborn weight (\( r = -0.38 \), \( p = 0.036 \)). The concentration of micronutrients in colostrum and mature milk (2 months) suffers alterations, including a decrease in Fe, Zn, K and Na and an increase in Ca and P, probably in order to satisfy the requirements of the nursing infant. Micronutrients are influenced by birth weight, maternal age, gestational weight gain, GA and inter-pregnancy interval.

Introduction

Human milk is the main source of nutrients for a child during the first months of life [1] and is particularly important in the case of those nutrients that are not stored by the foetus in utero [2].

The concentrations of many micronutrients vary with the progression of lactation, with the greatest changes occurring during the first postpartum week [3]. The micronutrients present in breast milk can vary between nursing mothers depending on diet or nutritional status. In general, the concentrations of water-soluble vitamins show a greater response to dietary ingestion than those of lipid-soluble vitamins and minerals.

Acknowledgements

The authors thank Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP, Brazil (grant nº 98/ 15796–3, for supporting this study).

Correspondence: Silmara S. B. S. Mastroeni, Rua Itajubá, 969 casa 22, Bom Retiro, Joinville, SC, Brazil, CEP: 89223–200. E-mail <silsalete@hotmail.com >.

Patients and Methods

This longitudinal study involved 43 healthy women admitted to a hospital in Jundiaí city, Brazil,
for delivery between August and October 1999. All participants had term babies [5], and gestational age was determined between 12–48 h of birth by the method of Capurro [6].

The women donated about 20 ml of breast milk on the 2nd postpartum day, and a 2nd milk sample was obtained during the 2nd month of lactation at the home of the donor. Only 31 women donated milk on the 2nd month of collection because 12 were excluded from the study due to change or lack of address. After washing the hands with water and soap, breast milk was removed by manual expression into polyethylene flasks previously washed with nitric acid. The samples were stored at −20°C for a maximum period of 30 days.

The concentrations of Fe, Zn, Ca, K, P, Na and Mg were determined simultaneously (in duplicate) by inductively coupled argon plasma-atomic emission spectrophotometry (Perkin Elmer, Optima 3000 DV). To guarantee the reliability of the results, a certified reference material (non-fat milk powder NIST 1549) was analysed together with the samples.

The difference in mean micronutrient concentration between colostrum and mature milk was analysed by the Student t-test. The correlation between micronutrient concentration and the variables studied was determined by Pearson’s correlation coefficient (p). A level of probability of p < 0.05 was considered to be significant.

Informed consent was obtained from the nursing mothers and the study protocol was approved by the Ethics Committee of the hospital.

Results

Table 1 shows the characteristics of the 31 nursing mother/infant pairs studied. Table 2 indicates the variation in micronutrient content between colostrum and mature milk. The concentrations (mean ± SD) of the following micronutrients decreased during the course of lactation: Fe (0.12 ± 0.08 and 0.09 ± 0.05 mg/100 ml), Zn (0.93 ± 0.36 and 0.15 ± 0.06 mg/100 ml), K (62.8 ± 11.5 and 46.2 ± 0.84 mg/100 ml) and Na (33.3 ± 12.3 and 20.5 ± 15.6 mg/100 ml) in colostrum and mature milk, respectively, whereas Ca (21.4 ± 5.8 and 25.0 ± 3.1 mg/100 ml) and P (11.12 ± 2.8 and 13.7 ± 2.0 mg/100 ml) showed an increase between colostrum and mature milk, respectively. Mean Mg concentration showed an increase from colostrum to mature milk, but the difference was not statistically significant (2.86 ± 0.7 and 2.99 ± 0.5 mg/100 ml; p > 0.05).

A correlation was observed between mean Zn and Ca concentrations and gestational age (r = −0.41, p = 0.042 and r = 0.48, p = 0.014, respectively). Mean Zn concentration in colostrum showed a negative correlation with gestational weight gain (r = −0.49, p = 0.006). A correlation was observed between mean Ca and K concentrations and the inter-pregnancy interval (r = 0.56, p = 0.001 and r = 0.38, p = 0.033, respectively), and between mean Mg and P concentrations and maternal age (r = 0.49, p = 0.005 and r = 0.37; p = 0.042, respectively). A negative correlation was observed between mean Na concentration and newborn weight (r = −0.38, p = 0.036).

Discussion

Micronutrients are essential for the normal growth and development of infants. Nutrient deficiency is rare in infants receiving breast milk compared to those receiving formula milk or cow’s milk. The micronutrients of mature human milk, although present at low concentrations, are well utilised by the nursing infant due to their high bioavailability [7]. Although the composition and volume of breast milk varies between women, the mean micronutrient concentrations observed in the present study were similar to and followed the same trend during the course of lactation as reported in other investigations [1, 3, 4, 8–15].

Zn was the micronutrient that showed the widest variability, corroborating the findings of other investigators [1, 4, 9–15]. A decline in Zn during the course of lactation is probably related to a decrease in protein content, since other studies

Table 2

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Colostrum (mg/100 ml)</th>
<th>Mature milk (mg/100 ml)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>0.12 ± 0.08*</td>
<td>0.09 ± 0.05</td>
<td>0.018</td>
</tr>
<tr>
<td>Zn</td>
<td>0.93 ± 0.36</td>
<td>0.15 ± 0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>K</td>
<td>62.8 ± 11.5</td>
<td>46.2 ± 0.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Na</td>
<td>33.3 ± 12.3</td>
<td>25.0 ± 3.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ca</td>
<td>21.4 ± 5.8</td>
<td>25.0 ± 3.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>P</td>
<td>11.12 ± 2.8</td>
<td>13.7 ± 2.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mg</td>
<td>2.86 ± 0.7</td>
<td>2.99 ± 0.5</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation

Table 1

Characteristics of the nursing mothers and newborn babies (n = 31)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.42 (5.46)</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>39.26 (1.32)</td>
</tr>
<tr>
<td>Weight gain (kg)</td>
<td>12.66 (4.18)</td>
</tr>
<tr>
<td>Number of pregnancies</td>
<td>2.68 (1.47)</td>
</tr>
<tr>
<td>Inter-pregnancy interval (years)</td>
<td>2.45 (3.04)</td>
</tr>
<tr>
<td>Type of delivery:</td>
<td></td>
</tr>
<tr>
<td>Vaginal</td>
<td>27</td>
</tr>
<tr>
<td>Caesarean</td>
<td>4</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>3102.58 (454.26)</td>
</tr>
</tbody>
</table>
have demonstrated that Zn in breast milk is mainly found associated with protein fractions [16–18], which give way to lipid content with advanced lactation [19, 20]. In the present study, a correlation was observed between Zn and gestational age. Trugo et al. [14] observed a tendency towards a lower Zn concentration in the colostrum from mothers of preterm infants. Although recent studies have confirmed these findings [21], other investigators have reported exactly the opposite [22]. On the other hand, some investigators have not found any difference [23], thus indicating the existence of a controversy in the literature regarding this subject. Still with respect to lipid fractions, it should be considered that large part of the Fe present in human milk is bound to lipids, a fact that might explain the subtle decrease in this micronutrient during the lactation period investigated.

The negative correlation observed in the present study between mean Na concentration, a constituent of colostrum, and newborn weight agrees with the findings of Krebs [21], and might reflect a compensation mechanism that contributes to faster weight gain in low weight infants. Gunther et al. [24] observed a decrease in Na and K levels in breast milk which was accompanied by an increase in lipid content. Picciano and Guthrie [25] found a decline in the Na level of foremilk with a lower fat content compared to hind milk with a higher fat content. Hyponatremia has been cited as a consequence of exclusive breast-feeding in the milk of mothers with preterm and very low birth weight infants [26].

In the present study, a tendency towards an increase in Mg, P and Ca concentrations between colostrum and 2-month mature milk was observed, in agreement with the findings of Prentice and Barclay [27]. In view of the increase in bone density during the first months of life, an increase in Ca, P and Mg concentration in the only food source of the newborn, i.e. breast milk, is expected. A correlation during the first months of life, an increase in Ca, P and Mg concentration in the only food source of the newborn, i.e. breast milk, is expected. A correlation and Mg concentration in the only food source of the newborn, i.e. breast milk, is expected. A correlation with gestational age, confirming the results of Butte et al. [33, 34] who studied milk from mothers of preterm infants. However, Atkinson et al. [35] and Schanler [36] found a higher Ca concentration in preterm milk compared to term milk. Careful interpretation of the results obtained by Sowers et al. [31], who investigated bone density and pregnancy after an extended period of lactation with bone loss, permits to infer that a prolonged gestational period contributes to the recovery of a large amount of Ca transferred to the infant during the first two trimesters of gestation.

In conclusion, the results of the present study suggest that the concentrations of the micronutrients investigated in colostrum and mature milk (2 months) from nursing mothers of term infants tend to vary during lactation, including a reduction in Fe, Zn, K and Na and an increase in Ca and P. These variations probably occur to satisfy the requirements of the nursing infant during the first phase of life and are influenced by birth weight, maternal age, gestational weight gain, gestational age, and inter-pregnancy interval.