Dietary supplements for the lactating mother: influence on the trace element content of milk

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Milk production is a complex process where nutritional factors interact with structural hormonal and behavioural influences. In recent years important advances have been made in understanding the role of the nutritional status of lactating women on the outcome of breastfeeding. Many questions remain unanswered about the exact requirement of trace elements for lactating mothers. The effect of dietary zinc, copper and iodine supplements on the milk concentration of these micronutrients was studied. The supplementation trial employed a specific balanced nutritional supplement prepared for the nursing mothers. The study was carried out on women living in Ferrara and its surrounding area. The population under study was healthy Italian mothers, of good socioeconomic status, and their normal infants. In total, 32 women were enrolled in the study and 22 completed it. The infants (9F, 13M) were full-term, healthy singletons and were put to breast within 12 h of birth. All women who finished the study completed a 3 d dietary record. Nutrient analysis revealed the following mean daily dietary trace element intake in the lactating mothers: zinc = 12 mg, copper = 1.4 mg and iodine = 145 μg. The zinc and copper dietary intake was in agreement with the daily intake proposed for nursing Italian mothers, while the daily intake of iodine was below the recommended intake of 200 μg. The breastfeeding mothers were placed in 2 groups, with 7 primiparas and 4 multiparas per group: lactating women eating a traditional Italian diet without vitamin and mineral supplements, and lactating women enrolled in the nutrification programme and given a nutritional supplement to their traditional diet. The supplement (PerMamma Abbott) provided 20 mg zinc sulfate, 2 mg copper sulfate and 116 μg potassium iodide. These quantities cover about 60–90% of the recommended intake for nursing Italian mothers. Samples of 10 ml of milk were collected at 3, 30, 90 d postpartum. Zinc milk concentrations declined significantly over the study period for all lactating subjects, without differences in the rate of decline between the women who started supplementation during lactation and those who did not. Copper did not change during the first month of lactation, then declined at day 90 in supplemented and unsupplemented women, without significant differences between the two groups. An early sharp decline in milk iodine occurred in all lactating subjects, independently of iodine supplementation. After the first month of lactation breast milk iodide levels remained stable in all subjects under study. No significant differences between the two study groups were observed. The lack of correlation between the iodide level in breast milk and maternal dietary intake of iodine is not in agreement with previously published reports. The present results indicate that in healthy, well-nourished lactating Italian women, whose diet is adequate, the levels of zinc, copper and iodine in milk are not influenced by short-term supplementary intakes and that the milk levels of the trace elements studied are maintained over different levels of intake. Further research and examination by longitudinal studies are needed to establish the exact relationship between the amount of iodine furnished to the nursing mother and the iodine content of human milk. The role of compensatory homeostatic mechanisms which act during lactation needs further consideration and closer scrutiny.

Breastfeeding, copper, dietary intake, dietary requirements, human milk, iodine, lactation, recommended dietary allowance, supplements, zinc


The importance of nutrition in relation to lactational performance is an old concept. It has been recognized historically that the maternal diet plays a major role in the various physiological responses to lactation. Increase in appetite and, consequently, in the amount of dietary nutrients absorbed by the nursing mother has always been associated with good lactation and with the quantity and quality of the milk produced.

However, the exact role of the nutritional status of lactating women on the various outcomes of breastfeed-
ing is still poorly understood. Milk production is a complex process, where nutritional factors interact with structural, hormonal and behavioural influences (1). The complicated metabolic adaptations to the lactational process influence the outcome of lactation so that the relationship between maternal nutrition exposure and milk production is non-linear. Indeed, women living under poor economic circumstances and in inadequate living conditions, with marginal nutritional intake, do not necessarily produce less milk (2).

In recent years, the complexity of the impact of nutrition on lactation has become more evident. Important advances have been made in understanding the process of lactation and several studies have shown which nutrients in milk are directly affected by maternal dietary intake (3, 4).

Concentrations of zinc and copper in human milk may be uninfluenced by maternal dietary intake (6, 7). This is the case with zinc and copper: their content in mature human milk and their physiological pattern of decline during lactation appear to be uninfluenced by maternal dietary intake (6, 7). Concentrations of zinc and copper in human milk may respond to dietary supplementation only when nutritional status is poor (8). This does not apply to iodine because maternal dietary intake is positively related to the concentration in human milk (9). The mammary gland avidly accumulates iodine and iodized salt intake is significantly related to the iodine content in human milk (9).

Many questions remain unanswered concerning the role of maternal nutrition on the concentration of trace elements in breast milk and, consequently, on the recommended daily allowances (RDA) for the lactating mother (10). A number of conclusions drawn from recent controlled supplementation trials challenges some of the RDA for lactating women. In accordance with recent research, the recommended US–Canadian dietary guidelines for pregnant or lactating women have been partially revised (11).

More work in this area is needed to elucidate the various factors involved in the regulation of the micronutrient metabolism during lactation. Final conclusions can only be obtained by further well-programmed clinical studies.

To gain a better understanding of these problems a food supplementation trial was performed employing a specific, balanced nutritional supplement prepared for the nursing mother. This supplement provides about 60–90% of the recommended daily intake of trace minerals. The product administered during the study is commercially available in Italy.

Subjects and methods

Area studied

The study was carried out on women living in Ferrara and its surrounding area. Ferrara is a small town, close to the sea, in the north-east of Italy.

Study design and subjects

The population under study comprised healthy Italian mothers and their normal infants. The mothers were of good socioeconomic status, with no previous history of thyroid disease. They were recruited at the maternity unit of S. Anna’s Hospital in Ferrara and all of them were non-smokers, non-vegetarian, with normal weight gain during pregnancy and had uncomplicated pregnancies, labours and deliveries. None of the women experienced more than minor problems during pregnancy.

The characteristics and aim of the study were explained in detail and all subjects interested gave informed consent. A total of 32 women was enrolled in the study. The subjects had delivered at term and intended to breastfeed exclusively for at least 16 wk. Ten women dropped out of the study because of loss of milk supply. The infants (9F, 13M) were all full-term, healthy singletons and had appropriate weight for gestational age; they were put to breast within 12 h of birth.

Postpartum hospitalization lasted from 3 to 5 d. During this time the mothers followed the local standard
Dietary supplement for the lactating mother

Table 1. Mineral contents in human milk of unsupplemented lactating women (A) and supplemented lactating women (B).

<table>
<thead>
<tr>
<th>Mineral (mg l⁻¹)</th>
<th>Zinc (n = 11)</th>
<th>Copper (n = 11)</th>
<th>Iodine (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>8.16 ± 2.96</td>
<td>5.89 ± 2.65</td>
<td>0.53 ± 0.12</td>
</tr>
<tr>
<td>30</td>
<td>3.99 ± 1.01*</td>
<td>3.36 ± 1.40*</td>
<td>0.51 ± 0.12²</td>
</tr>
<tr>
<td>90</td>
<td>2.87 ± 1.23*</td>
<td>2.63 ± 1.35*</td>
<td>0.39 ± 0.10⁹</td>
</tr>
</tbody>
</table>

* p < 0.05 vs day 3.
* b > 0.05 vs day 3.
* c < 0.05 vs day 30.

hospital diet. The lactational performance and compliance of the mothers enrolled in the nutrification programme was recorded. The success of breastfeeding was verified by infant growth recorded during the study period.

The breastfeeding mothers were divided into two groups, with 7 primiparas and 4 multiparas in each group: (A) lactating women eating a traditional Italian diet without vitamin and mineral supplements (4F, 7M infants); and (B) lactating women enrolled in a nutrification programme and given a nutritional supplement to their traditional diet (5F, 6M infants). Women in group B were instructed to take a daily dietary supplement intended for use in pregnancy and lactation (PerMamma Abbott) according to the manufacturer’s information, without further nutritional modifications. The nutritional supplement provided 20 mg zinc sulfate, 2 mg copper sulfate and 116 µg potassium iodide. These quantities cover about 60–90% of the recommended intake of energy and nutrients for the Italian population (LARN) (12).

Compliance to the two regimens relied exclusively on information provided by the mothers.

Dietary survey

The women completed a 3 d dietary record. A qualified nutritionist inspected the records to ensure that they were complete and that sufficient details were provided. All lactating women who completed the study showed similar, normal, adequate eating patterns.

The zinc, copper and iodine content of consumed foods was determined using the food composition tables of the Royal Society of Chemistry (13). In the women who completed the study the mean overall daily dietary intake of the trace elements studied was: zinc = 12 mg, copper = 1.4 mg and iodine = 145 µg. The dietary intake of zinc and copper was in agreement with the daily intake proposed for lactating women in tables of recommended intake of energy and nutrients for the Italian population (LARN) (12). The daily dietary intake of iodine was below the recommended intake of 200 µg for lactating women proposed by LARN (12).

Sample collection and analyses

The milk samples were collected at 3, 30, 90 d postpartum and were obtained in both groups using a breast pump (Lactina-Medela, Baar, Switzerland) after the subjects had cleaned the nipple and areola with deionized water.

The protocol for collection of milk samples was designed to minimize any interference with the nursing of the infant. Each individual 10 ml milk sample was pumped from both breasts into zinc-free plastic containers and was taken before the baby nursed. The mothers were asked not to exceed 10 min of pumping and to stop sooner if milk flow was markedly reduced.

Samples were frozen immediately after collection and stored at −30°C until analysis was carried out. All samples of human milk were analysed for mineral content of zinc, copper and iodine. Milk was mineralized in a high-pressure closed container with microwave heating. Assay of microelements was carried out in an inorganic mass spectrometer (VG Plasmaquad II STE; VG Elemental–Fisions Instruments, Winsford, UK) using standard assay procedures by AOAC Official Methods of Analysis (14). The method was evaluated for reproducibility and accuracy using standards set out by the Commission of the European Communities—Community Bureau of Reference (BRC), reference no. 063R, Trace and Major Elements in skim milk powder (sample identification no. 0286).

Anthropometric studies

Anthropometric data were collected in the morning. Weight was recorded on a stationary beam balance, accurate to within 10 g. Length was measured on a recumbent measuring board. Head circumference was recorded with a flexible, narrow steel measuring tape. All anthropometric measurements were taken three times and the median value was used.

Statistical analysis

Statistical analyses of data were carried out comparing means with a general analysis of variance (ANOVA). This studied the effect of times (day 3, 30 and 90), groups (A and B) and interactions, i.e. differences between groups in regard to the changes of means at the studied times. Within each group a one-tailed Dunnett’s t-test was used, taking day 3 as the control value after
verification by ANOVA that the means of day 3 for group A and B did not differ significantly. Differences were considered significant if \(p < 0.05\).

**Results**

The milk levels of zinc, copper and iodine in supplemented and unsupplemented women for the duration of the study period are presented in Table 1.

The milk zinc concentration declined significantly over the study period for all lactating subjects. There was no significant difference in the rate of decline between the women who started supplementation during lactation and those who were not supplemented.

The concentration of copper did not change during the first month of lactation, then declined at day 90 in supplemented and unsupplemented women, with no significant difference between the two groups.

The average iodine concentration showed a decrease in both groups under study. In the early declining phase (day 30 vs day 3) the iodine concentration in supplemented and unsupplemented lactating women was already significantly lower than on day 3. At day 90 both groups under study maintained iodine levels significantly lower than on day 3. No significant differences were observed between women taking the supplement and those who were not supplemented.

During the study period no statistically significant differences were observed in the infants of the two study groups with regard to gain in weight, length and head circumference (data not shown). No significant relationship was detected between maternal age and parity and milk mineral concentration (data not shown).

**Discussion**

Milk synthesis is a complex and remarkable process influenced and regulated by genetic heritage, age, parity, nutritional status and dietary intake (2). Milk production is the result of the interplay of the synthetic capacity of the mammary gland, the maternal diet and the amount of mobilizable tissue reserves (15). The mammary gland regulates, controls and limits the amounts of nutrients secreted into the milk by several complex mechanisms which remain to be determined. Thus, although breastfeeding increases substantially a woman’s requirement for nearly all nutrients, lactational performance is preserved over a wide range of maternal states and the composition of human milk is remarkably similar in quality and quantity among women of varying nutritional status (16). Even if the dietary intake of a nutrient is less than that recommended there will usually be little or no effect on the concentration of that substance in the milk (3). In addition, the normal mammary gland is not an excretory route for excessive maternal nutrient intake.

The concentration of major minerals in human milk does not reflect the maternal diet, and the concentration of trace elements is generally regarded as being resistant to the maternal dietary intake (3).

The level of zinc is highest in colostrum and declines progressively over the course of lactation (2, 17–23). Studies that have examined the effect of maternal zinc supplementation in milk zinc concentration have obtained mixed results. Two supplementation studies have found that milk zinc levels are influenced by maternal dietary intake (17, 18). However, the majority of the available reports noted a lack of correlation between maternal dietary intake of zinc and milk zinc concentrations (19–22).

In common with other studies, it was found that milk zinc concentration declined significantly over the course of the study period for all lactating subjects, from the highest values in colostrum to the relatively low values in mature human milk. No significant difference in the rate of decline between the supplemented and unsupplemented subjects was observed and no correlation was found between total maternal zinc intake and milk zinc concentrations. In agreement with other studies, zinc concentrations declined steeply during the first month and then more gradually (2, 23). However, at 3 mo zinc levels were slightly higher that those reported by the majority of other studies (23). The present results indicate that an intake of 12 mg Zn \(d^{-1}\) from a mixed Italian diet appears adequate for lactating women, even in the early postpartum months.

In healthy, breastfeeding women the concentration of copper in milk declines gradually over the first 4 mo of lactation and then remains stable up to 1 y of age (2, 23). In mature milk, copper concentrations range from 0.1 to 0.6 mg l\(^{-1}\), but most are at the lower end of the range (2). The variation in mean values differs significantly from study to study, probably also because of inter-laboratory analytical variation (23). Copper concentrations in milk are unrelated to intake from the diet or from supplements (23–25). The present findings are consistent with those of other investigations, because no correlation was found between maternal dietary intake and the copper content of breast milk.

Iodine is unique among the trace elements because it is accumulated by the mammary gland and its level in human milk is considered to be positively correlated with maternal intake (2, 9).

In early reports, usually based on a limited number of samples, the mean concentration of iodine in breast milk was reported to vary between 2.8 and 7.0 \(\mu g\) dl\(^{-1}\) (26). More recent and comprehensive studies have shown higher levels. In 3 large series from Europe the mean values were 7.0, 8.1 and 9.3 \(\mu g\) dl\(^{-1}\), respectively (26). The mean iodide level in mature milk from 37 breastfeeding women in North Carolina, USA, was much higher, 17.8 \(\mu g\) dl\(^{-1}\) (27). These results are comparable to findings obtained in California, where the mean iodine content in human milk was calculated at 14.2 \(\mu g\) dl\(^{-1}\) (28).
Few data are available on the iodine content of human milk at different stages of lactation. Gushurst et al. found no relationship between the stage of lactation (as measured by the age of the infant) and the iodide level in milk (27). In Belgium the mean iodine content at the fifth postnatal day was $9.4 \mu g \text{dl}^{-1}$ (26) and in Turkey the average iodine concentration in human milk samples collected from 25 mothers on their first or second day after delivery was $10.9 \mu g \text{dl}^{-1}$ (29). The mean total iodine measured in samples from 23 young mothers in Verona, Italy, was only $4.7 \mu g \text{dl}^{-1}$ and showed small variations with the length of gestation (30). These values are substantially lower than the mean iodine concentration in mature human milk in the USA (27, 28). In areas where iodine intake is marginal, the concentration of this trace element in human milk is very low. In north-western Zaire, an area affected by severe endemic goiter and where the iodine intake is only $15 \mu g \text{d}^{-1}$, the average iodine content of human milk was reported at only $1.3 \mu g \text{dl}^{-1}$ (26). It has been observed that a single cutaneous application to the mother at the time of delivery of a iodine-containing disinfectant or a single intramuscular injection of iodized oil resulted in a 10–13-fold increase in the iodine content of milk (26).

The levels of iodide in mature breast milk reported in the present study are in the same range as in earlier European studies (26). In contrast with previous reports, no influence was found of maternal iodine intake on the concentration of this trace element in milk. The results also indicate that in the well-nourished women examined the concentration of iodide declined steeply during the early stage of lactation. The early, sharp decline in milk iodide occurred in all lactating subjects, independently of iodine supplementation. After the first month of lactation, in all subjects under study, breast milk iodide levels remained stable.

The results clearly indicate that in healthy, well-nourished lactating Italian women, whose diet is adequate, the levels of zinc, copper and iodine in milk are not influenced by short-term supplementary intakes and that the milk levels of these trace elements are maintained over different levels of intake.

Although relatively few longitudinal data are available on the mineral composition of human milk and on the changes that take place with the duration of lactation, the zinc and copper content of human milk, as well as its pattern of decline, appear not to be influenced by maternal dietary intake. During lactation, complex homeostatic mechanisms are operating to maintain the zinc balance (31), including enhanced zinc absorption, reduced urinary and faecal excretion, and bone remodelling and resorption (31). These homeostatic mechanisms to conserve zinc appear to operate maximally in situations of low dietary intake (31). Jackson et al. observed that in a group of low-income, lactating women with chronically low zinc intakes, zinc absorption was extremely high and ranged from 60 to 85% (32). These findings suggest that even lactating women consuming less than 50% of the current dietary allowance are able to maintain zinc balance (31). A recent longitudinal study showed that during lactation, in response to the demand for zinc, there is a nearly twofold increase in zinc absorption (33). It appears, therefore, that an enhanced intestinal absorption of zinc is an important mechanism to meet the increased demands during lactation (33).

An important implication of these findings is the challenge to the current RDA for zinc for lactating women. Current dietary recommendations for zinc appear to be inappropriately set, because they do not take into account the aforementioned homeostatic mechanisms (31). The present study suggests that, in well-nourished women, the intake of zinc from a mixed diet is adequate to ensure normal levels in milk during the course of lactation and that further increases in dietary zinc do not influence its concentration in milk.

The results obtained by this study on the effect of iodine dietary supplementation on the secretion of iodine into milk are not in accordance with previously published data, which indicate that the iodine content of maternal milk is influenced by dietary and extradietary supply of this micronutrient to lactating women (2, 26). In this regard, it should be pointed out that studies on the influence of supplementary intake of iodine on the iodine content of human breast milk are scarce and have been conducted mostly in areas affected by severe endemic goiter (26). A recent study from Denmark, where the intake of iodine is relatively low, has shown that the correlation between iodine concentration in breast milk and iodine supplementation gives mixed results (34). Of particular interest is the finding that in women from the Danish region of Randers, the mean milk iodine content was lower in women taking iodine supplements ($16.5 \mu g \text{l}^{-1}$) than in unsupplemented women ($21.5 \mu g \text{l}^{-1}$) (34).

These considerations underline the need for longitudinal studies to establish the relationship between maternal iodine status, the amounts of iodine furnished to the nursing mother and the iodine content of human milk. Further research is also needed to establish the concentrations of iodine in human milk at different stages of lactation. With regard to this trace element, the impact of the antagonistic effects of organic and inorganic goitrogens on iodine utilization and requirements certainly also needs to be assessed in more detail (35).

Greater attention should also be paid to factors influencing the bioavailability and utilization of trace elements and to the metabolic interrelationships enhancing the release of stored trace elements.

In conclusion, the results of this study indicate that there is no relationship between zinc, copper and iodine short-term supplementary intake by healthy, well-nourished, lactating women and the content of these trace elements in human milk. The limited number of
subjects studied, as well as the possible influence of factors and variables influencing the bioavailability of the trace elements offered to the lactating mothers, make it difficult to draw definitive conclusions. However, most of the available evidence suggests that the success of lactation and long-term maternal and infant health are hardly influenced by intake of mineral supplements by healthy, well-nourished lactating mothers.

Mineral supplements may become necessary for individuals with specific lifestyle habits, when a distinct nutritional deficiency is evident, or when there is a marginal intake of one or more element. The narrow safety margin between the desired and the dangerous level of intake for some nutrients, and the risk of adverse interactions between nutrients suggest that great care is needed in accepting a general supplement policy during lactation.

It is becoming increasingly evident that current RDA for several nutrients during the lactation period may be higher than necessary and inappropriately set, because some compensatory mechanisms have not been duly considered. It is possible that some RDA for specific nutrients in the lactation period are higher than necessary for the general population and need consistent revisions.

An adequate intake of most nutrients can be obtained from a well-planned and diversified diet, possibly making specific food choices. Healthy, lactating women who under ordinary circumstances are capable of nourishing their infants by breast alone, should be provided with proper dietary guidance in order to obtain their nutrients from a varied and balanced diet rather than from dietary supplementation.

References

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