Breast milk zinc and copper concentrations in Bangladesh

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Breast-fed infants in Bangladeshi villages were weighed at 1, 2, 6, 9 and 12 months. The concentrations of zinc and copper in the breast milk were measured and the daily intake of these elements calculated. Breast milk Zn concentration decreased over the year but was comparable with that found in developed countries. The calculated daily intake decreased from 17·7 to 8·0 μmol (10–30 % of recommended dietary allowances (RDA); National Academy of Sciences, 1980). Breast milk Cu concentration also fell over the year and was lower than that reported from developed countries. Calculated daily Cu intake was 1·95–2·63 μmol (RDA 7·81–15·63 μmol). Deficiencies of trace elements may therefore be a problem in poorly nourished communities where breast feeding is continued for several years with only small amounts of additional food. Breast milk may not be adequate as the only source of infant nutrition after the first few months of life in Bangladesh.

Breast milk: Copper: Zinc

Unsupplemented human milk is all that is required to maintain growth in the first 6 months of life in infants of well-nourished mothers. Breast milk of poorly nourished mothers, although surprisingly good, is often suboptimal in quantity and quality. The volume produced is smaller, and the concentrations of fat, water-soluble vitamins, vitamin A, calcium and protein are lower than in breast milk from well-nourished women (Jelliffe & Jelliffe, 1978).

Little is known of the breast milk concentrations of essential trace elements in developing countries. Deficiencies of zinc and copper may occur in communities where breast-feeding is continued for several years with only small amounts of additional food, and such deficiencies may limit the rate of weight gain (Golden & Golden, 1981; Simmer *et al.* 1988) and accentuate the anaemia, bone disease and susceptibility to infection (Al-Rashid & Spangler, 1971; Levy *et al.* 1985; Sutton *et al.* 1985) which occur in malnourished children. We therefore measured Zn and Cu concentrations of breast milk in Bangladesh and discuss whether the calculated daily intakes are adequate.

PATIENTS AND METHODS

The study was carried out during 1985–6 in seven villages in Chandpur, 64 km south-east of Dhaka. 85 % of the infants in these villages are breast-fed for 24–30 months (Brown *et al.* 1982). Thirty-four mothers were randomly selected. Their mean height was 1·49 (SD 0·06) m. Their mean weight was 40·7 (SD 4·6) kg at 1 month and 39·2 (SD 4·8) kg at 12 months postpartum (73–76 % average ideal body-weight; Metropolitan Life Insurance Company, 1983).

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Table 1. *Weights (kg) of infants in Bangladesh*

(Mean values and standard deviations; no. of infants in parentheses)

Age of infants (months)	Females		Males	
	Mean	SD	Mean	SD
1	3·37	0·55 (13)	3·59	0·49 (16)
2–3	4·28	0·72 (14)	4·60	1·57 (11)
6	5·64	1·13 (15)	6·29	0·89 (10)
9	6·18	1·35 (14)	7·00	1·05 (12)
12	6·38	1·07 (15)	7·45	1·18 (13)

Bangladeshi health assistants visited the villages when the babies were 1, 2–3, 6, 9 and 12 months of age. The babies were weighed and breast milk collected between 10.00 and 14.00 hours from each breast at the beginning and end of feeds. Sample size varied due to cessation of breast-feeding associated with further pregnancies and occasionally due to unavailability of the mothers.

Breast milk was stored at $-20°$. Samples of whole milk (0·5–1·0 ml) were ashed in Pyrex beakers and then digested in 1·0 M-hydrochloric acid. All glassware and plastic test tubes were soaked in 10% HCl for 24–48 h and then rinsed three times in deionized water. Concentrations of Zn and Cu were measured by atomic absorption spectrophotometry using an air acetylene flame (model 257; Instrumentation Laboratories, Cheshire). For analysis of Zn the spectrophotometer was operated at 213·9 nm and, for Cu, at 324·7 nm. Standards were diluted with 1·0 M-HCl (Aristar grade; British Drug Houses Chemicals Ltd, Poole, Dorset). Both internal and external standards (Nyegaard, Birmingham) were used with 98% agreement. The absorption of 1·0 M-HCl in the Zn and Cu wavelengths was negligible.

Trace element intakes were expressed as absolute intakes and as intakes per kg body-weight. The daily intakes of Zn and Cu were calculated from the breast milk concentration and the expected volume produced. The volumes of breast milk measured by Brown *et al.* (1986) studying women from the same Bangladeshi villages were used. They admitted the mothers and infants to hospital wards for 2–3 d on several occasions. During the first 24 h of each visit, the women nursed their infants *ad lib.*, and the amounts consumed were estimated by test weighings. During the second 24 h, all milk was extracted from both breasts every 3 h using a mechanical breast pump. The next day test weighing was repeated.

Our study was approved by the ethical committee of the Bangladesh Research Council and informed consent was obtained from the mothers.

The results are expressed as means and standard deviations and were analysed by the unpaired Student's t test.

RESULTS

Mean weights of the infants by sex are given in Table 1, and from 3 months of age (Fig. 1(*a*, *b*)) fell below the third percentile for children in developed countries (Tanner & Whitehouse, 1976).

Breast milk Zn concentration decreased with time, and significantly between 1 and 2 months ($P < 0·025$), 1 and 6 months ($P < 0·005$) and between 6 and 12 months ($P < 0·005$). Mean daily Zn intake from breast milk fell from 17·7 μmol at 1 month to 8 μmol at 9 months (10–30% recommended dietary allowance (RDA); National Research Council, 1980) (Table 2).

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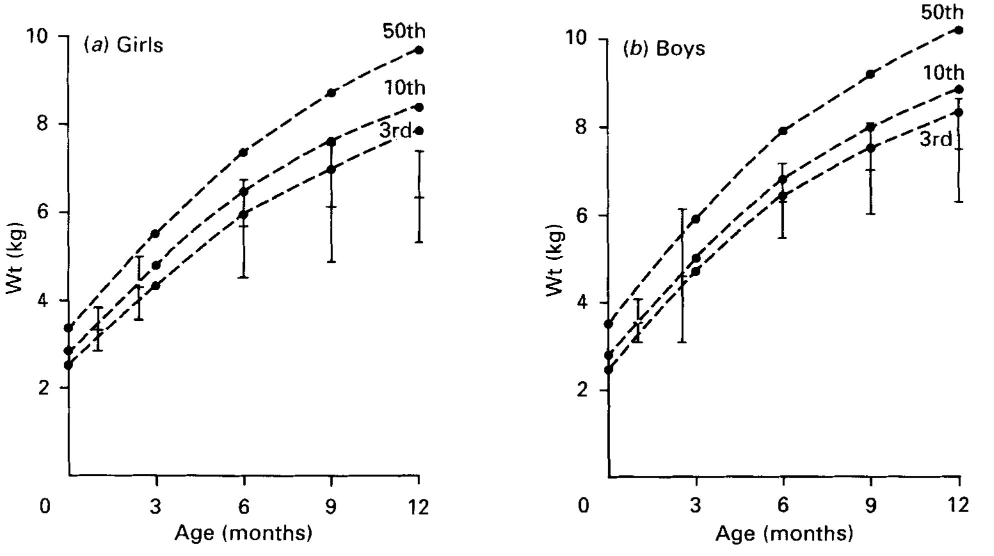

Fig. 1. Mean weights of Bangladeshi infants, (*a*) male and (*b*) female, compared with British standards (3rd, 10th and 50th percentiles, Tanner & Whitehouse, 1976). Values are means and standard deviations represented by the vertical bars.

Table 2. *Zinc in breast milk of Bangladeshi mothers*†

(Mean values and standard deviations)

Age of infant (months)	*n*	Breast milk Zn (μmol) Mean	SD	Calculated breast milk Zn intake‡ μmol/kg per d	μmol/d
1	31	30·0	15·1	5·1	17·7
2–3	11	19·1*	8·2	2·8	12·9
6	11	14·2**	6·2	1·8	10·9
9	21	11·1	9·4	1·2	8·0
12	30	8·3**	4·2	—	—
RDA					46–77

RDA, recommended dietary allowances (National Academy of Sciences, 1980).

Mean values were significantly different: * $P < 0·025$, 1 month *v.* 2–3 months; ** $P < 0·005$, 1 month *v.* 6 months and 6 months *v.* 12 months.

† For details of procedure, see pp. 91–92.

‡ Volumes (g/kg per d): 1 month 168 (SD 30), *n* 36; 2–3 months 149 (SD 29), *n* 75; 6 months 125 (SD 24), *n* 13; 9 months 118 (SD 24), *n* 5 (Brown *et al.* 1986).

Breast milk Cu concentration decreased over the first 12 months ($P < 0·005$) and mean daily Cu intake from breast milk was 1·95–2·63 μmol over the first 9 months (RDA 7·81–15·63 μmol) (Table 3).

DISCUSSION

The adequacy of breast milk as the only source of infant nutrition is related to the mother's diet in pregnancy, physical and emotional stress, maternal and fetal protein and energy

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Table 3. *Copper in breast milk of Bangladeshi mothers*†

(Mean values and standard deviations)

Age of infants (months)	n	Breast milk Cu (μmol/l) Mean	SD	Calculated breast milk Cu intake‡ μmol/kg per d	μmol/d
1	31	3·44	1·88	0·58	2·02
2–3	11	3·75	1·56	0·56	2·63
6	11	2·97	1·09	0·38	2·22
9	21	2·50	2·03	0·30	1·95
12	30	1·88*	1·25	—	—
RDA					7·81–15·63

RDA, recommended dietary allowances (National Academy of Sciences, 1980).
Mean value was significantly different: * $P < 0.005$, 1 month *v.* 12 months.
† For details of procedures, see pp. 91–92.
‡ Volumes (g/kg per d): 1 month 168 (SD 30), *n* 36; 2–3 months 149 (SD 29), *n* 75; 6 months 125 (SD 24), *n* 13; 9 months 118 (SD 24), *n* 5 (Brown *et al.* 1986).

Table 4. *Breast milk zinc concentrations (μmol/l) of women from developed and developing countries*

Age of infants (months)... Source	0·5–1	2–3	5–6	9	12
Simmer *et al.* (present study)	30·0	19·1	14·2	11·1	8·3
Vuori & Kuitunen (1979)	—	20·0	7·5	7·4	—
Vuori *et al.* (1980)	—	29·1	11·1	—	—
Belavady (1978)	—	73·2	20·8	16·0	—
Shaw (1980*a*, *b*)	52·3	29·2	12·3	—	—
Matsuda *et al.* (1984)	44·6	16·9	16·9	—	—
Karra *et al.* (1986)	—	—	14·2	12·5	10·5
Kirsten *et al.* (1985)	35·1	—	—	10·0	—

stores and birth weight. Our findings demonstrate that the mean weight of breast-fed infants in Bangladesh begins to fall from the normal Western range at 2–3 months, which is consistent with previous reports of Bangladeshi infants (Brown *et al.* 1986) and indicates that breast milk may not be nutritionally adequate for these infants.

Breast milk Zn concentrations fell significantly from 1 to 12 months and levels were consistent with those reported from developed and developing countries (Table 4). Karra *et al.* (1986) have suggested that the decline in Zn concentration may be due to gradual involution of the mammary gland from decreased frequency of breast-feeding, and a progressive alteration in the mechanism of Zn transport to breast milk, namely from transcellular to paracellular pathways and with less binding to ligands.

Daily Zn intake was as low as 10% of the RDA at 9 months. Despite the high bioavailability of Zn from breast milk (Casey *et al.* 1981), the Zn intake of Bangladeshi infants would fail to reach the relatively low estimate calculated by Krebs & Hambidge (1986) to be essential for growth. We have previously shown that Zn depletion is an important factor limiting weight gain in children receiving nutritional rehabilitation in Bangladesh (Simmer *et al.* 1988). Similarly, Golden & Golden (1981), found that the

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Table 5. *Breast milk copper concentrations (μmol/l) of women from developed and developing countries*

Age of infants (months)... Source	0·5–1	2–3	5–6	9	12
Simmer *et al.* (present study)	3·44	3·75	2·97	2·50	1·88
Vuori & Kuitunen (1979)	—	5·16	2·66	3·91	—
Vuori *et al.* (1980)	—	5·63	3·28	—	—
Belavady (1978)	—	7·50	3·28	2·66	—
Shaw (1980*a*, *b*)	7·66	8·13	4·38	—	—
Matsuda *et al.* (1984)	6·94	4·22	3·13	—	—
Salmenpera *et al.* (1986)	—	3·59	2·34	1·56	2·19
Kirsten *et al.* (1985)	—	—	—	4·38	—

Jamaican diet did not provide adequate Zn for weight gain in children recovering from marasmus. In addition, Zn deficiency may contribute to the diarrhoea, rash, infection and vitamin A deficiency in malnourished children.

The concentration of Cu in Bangladeshi breast milk was lower than that reported from developed countries (Table 5), except for a recent Finnish study (Salmenpera *et al.* 1986). The Cu concentration of breast milk collected in India was similar to that from Bangladesh from 4 months but higher before this age (Belavady, 1978). Daily Cu intake was less than 25% of the RDA. Cu deficiency in infancy has been associated with anaemia, oedema and bone disease (Al-Rashid & Spangler, 1971; Levy *et al.* 1985; Sutton *et al.* 1985) and may well contribute to morbidity in Bangladeshi infants.

The daily Zn and Cu intakes from breast milk in Bangladesh were low mainly due to the low volume of milk produced. The volumes used in our calculations are consistent with, if not somewhat higher than, those measured in other developing countries (Jelliffe & Jelliffe, 1978). Therefore, increasing the volume of milk produced would be the best way of improving Zn and Cu intakes of breast-fed infants in Bangladesh and limited studies of giving supplementary protein to poorly nourished mothers have suggested such an improvement (Jelliffe & Jelliffe, 1978). Supplementing the mothers with Zn may decrease the abnormally steep decline in breast milk Zn concentrations (Krebs *et al.* 1985), whereas maternal Cu supplementation does not appear to influence breast milk Cu concentration (Salmenpera *et al.* 1986).

Alternatively, appropriate semi-solids could be introduced at 3–4 months. Zn is present in high concentrations in red meat, sea food and unprocessed cereals and nuts, and Cu in shellfish, liver and kidney. The weaning foods in these villages have been well documented and certainly, at present, would not supply enough Zn and Cu (e.g. 50% children by 30 months have never received meat, fish or eggs (Brown *et al.* 1982)).

In conclusion, dietary intakes of Zn and Cu are suboptimal in breast-fed Bangladeshi infants. Such deficiencies may contribute to their extremely poor growth. Trace element supplements are probably not feasible. Improving the mother's diet is the best solution, with education about the preparation and timing of weaning foods.

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