Maternal Diet, Breast Feeding and Infants' Growth

A fieldstudy in the Ivory Coast (West Africa)

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Abstract

Four mothers and their infants living in a rural village of the Ivory Coast were studied for maternal diet, breast milk composition and volume and infants' growth over an 18 months' period. Two of the mothers were young, had a low calorie intake and gave little supplementary nourishment to their infants; these infants had an unsatisfactory growth pattern. Two mothers were middle-aged, had a satisfactory calorie intake and their infants thrived well on breast milk alone for the first 6 months. Supplements were introduced by those mothers after their infant was 6 months old which provided adequate energy and protein intake and had a beneficial effect on the growth of the infants.

Detailed biochemical analyses of diets and breast milk have been performed and dietary allowances are discussed in the light of the present results. Despite important differences in dietary intake the milks produced by the four mothers showed no significant differences in biochemical composition. The mothers with low calorie and low protein intake produced however smaller quantities of breast milk when the infants were 4 to 7 months old.

Since breast milk provides a substantial amount of protein and calories for the infants even in late lactation, the implication with regard to adequate growth of the infants is to provide adequate dietary intake for the mothers as well as nutritional education aiming at the introduction of supplements in the infants' diet at about 4 to 6 months.

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Introduction

In a longitudinal study over 23 months of lactation (1), we have shown that breast milk composition in a rural community of the Ivory Coast differs but slightly from that of breast milk from mothers living in developed countries. A decrease of protein concentration of about 30% during the first 7 months is however observed.

The present study was undertaken in order to obtain more information on the influence of maternal diet on composition and output of breast milk and, consequently, on growth of the infants. The influence of short-term changes in dietary protein intake on milk composition has not been well documented. Maternal protein supplementation induces minimal changes of protein concentration in milk but increases milk output (2–5). It has been reported that protein and fat concentrations in breast milk are dependent on dietary protein and fat intake (6). Changes in diet may affect the fatty acid composition of breast milk (7–9).

It has been shown that poor nutrition results in lactation failure (16–12). During famine, however, there is no change in milk protein concentration (13–14). In the present longitudinal study over a period of 18 months, food intake, nutritional status and milk composition of the mothers as well as milk intake, supplementary food intake and anthropometrical measurements of the infants have been assessed at 3 monthly intervals. Associations between the various parameters have been analysed.

Methods

Selection of sample

Four women and their infants living in Kpouébo were selected for this study. General information about the mothers and the infants is given in table 1. Measurements were performed at 3 monthly intervals from December 1974 to June 1976.

Table 1
Anthropometric and Nutritional Data of the Mothers during 18 months of Lactation and Age of the Infants at First Sampling

Code number		1	2	3	4
Mother	Parity	1	3	11	12
	Age (years)	19	25	40	45
	Mean weight (kg)	50.7±0.9	48.7±0.5	56.7±0.6	53.4±1.8
	Height (cm)	149.5	153.5	158.5	155.5
	Mean weight for height (%)*	101	93	103	100
	Weight change during lactation	+2.3	−0.9	+1.2	−3.5
	Mean serum albumin (g/100 ml)	2.8±0.4	3.7±0.3	2.9±0.5	3.6±1.0
	Mean hemoglobin (g/100 ml)	10.6±0.8	12.4±1.7	13.1±0.9	11.6±0.5
Infant	Age at first sampling (months)	1.4	1.1	0.2	0.5

* According to Jelliffe (20)

Weighing and sampling of maternal food

During the two days preceding milk and blood sampling all prepared food was weighed immediately before consumption and samples of the cooked meals were immediately frozen for subsequent analysis. These samplings included the 2 or 3 main meals taken by the mother during the day. The amount of food taken in addition to these meals is minimal (Reinhardt and Lauber unpublished observation).

Measurement of milk and supplementary food intake of the infants

From 7 am to 7 pm during the same two days the four infants were weighed before and after each feed. Care was taken that any possible loss through urine could be accounted for by using an absorbing towel. Any supplementary food was weighed and sampled. Weighing errors were below 0.2%. In order to minimise disturbance of breast feeding on demand in the normal family environment, trained field-workers recruited within the village remained with the mother and child throughout the day. This cannot be achieved at night.

Anthropometrical measurements

On the third day mothers' weight and babies' weight, height, mid-upper arm circumference and head circumference were measured. The mothers' height was measured at the beginning of the study only. Measurement methods have been previously described (1).

Milk and blood sampling

Breast milk and fasting blood samples were taken 7 times, when the infants were about 1, 4, 7, 10, 13, 16 and 19 months old. The breast to be sampled was covered during the night before sampling with a sticking plaster and milk extracted with an electrical pump. Maternal blood samples were collected in EDTA and kept at 4°C.

Transport and storage of samples

Food, blood and milk samples were transported at 4°C to the laboratory within half a day and were kept at −20°C until analysed.

Milk and plasma composition

All methods have been previously described (1).

Food composition

Humidity: All samples were thawed and weighed before and after lyophilization, the weight difference being the water content. For all the other determinations the lyophilised samples were homogenized.

Total protein: Total nitrogen was determined in 20 mg samples by the method of Lauber (15). *Total lipids:* An aliquot of the homogenized lyophilizate was extracted for 2 hours with chloroform/methanol 2:1 in a Soxhlet apparatus. After evaporation of the solvent the residue was collected in 60–70° petroleum ether. After filtration of the solution the solvent was evaporated and lipids determined gravimetrically. A chloroform solution of the extracted lipids was used for further analyses: *Cholesterol* was determined by the Liebermann-Burchard method (16). *Lipid phosphorus* was determined by the method of Morrison (17). *Fatty acid composition of total lipids:* Transmethylation and gas chromatography were performed as previously described (1). *Ashes, calcium, magnesium, copper, zinc and manganese:* Aliquots of lyophilised food samples were incinerated in quartz crucibles at 55°C overnight after carbonisation on a mushroom-shaped burner. Ashes were weighed and analysed by atomic absorption in a hydrochloric acid solution.

Calories were calculated using the equivalents of Rubner (18) for proteins, lipids and carbohydrates.

The mean daily intake of the various constituents was calculated from the total amount consumed during the two days at each sampling.

Analysis of data

In the present study the data constitute a 7×4 table in which the 7 rows and the 4 columns represent the 7 visits and the 4 mother-child pairs respectively. Each of the 28 cells of this table contains all the measurements performed on a mother-child pair on one visit. The main interest of this study was the correlation between measurements. The analysis of variance has disclosed for several measurements a variation among the mother–child pairs which was significant at the 5% level. Consequently correlation coefficients calculated from the 28 cells contained both the within and among mother–child pairs information. In order to eliminate the correlations among mother–child pairs, which are not relevant to this study, the four within mother–child pairs correlation coefficients have been calculated for each pair of measurements. The significance of these coefficients was assessed by the test $t_i = r_i 5/1 - r_i^2$, $i = 1,2,3,4$. Since the four coefficients r_i are independent, the *overall* probability of the four tests can be calculated according to Fisher (19). Obviously this overall probability is meaningful only when the four coefficients have the same sign.

Results

During the 18 month follow-up, two mothers (1 and 3) gained weight whereas the two others (2 and 4) lost weight (Table 1). Only mother 4 lost more than 1 kg which could be explained by a decrease of adipose tissue stores accumulated for lactation during preganancy. This mother had after 18 months of lactation a weight for height of 98.3% of normal value according to Jelliffe (20). Serum albumin values of the four mothers showed random variations and there was no significant decrease during lactation. Mean values were satisfactory in mothers 2 and 4 and low in mothers 1 and 3. None of the mothers was anaemic. The lowest haemoglobin and albumin values were observed in mother 1.

Maternal food intake

The mothers' mean daily intake calculated over 14 sampling days (7 periods of 2 days) are given in Table 2. Carbohydrates, proteins and lipids provide approximately 75%, 13% and 12% respectively of total caloric intake (Fig. 1). Fatty acid composition of the diets were assessed in order to detect essential fatty acid deficiencies (Table 2). Linoleic acid (18:2) represents 1.6% of calorie intake. Mean total calorie intake was 2042 calories per day. It was lower in women 1 and 2 compared to women 3 and 4. A similar observation is met for protein: mean intake was 64 g/day (1.2 g/kg/day). Daily intake varied among the mothers (Table 2). The amount of animal protein was 1.9%, 6.3%, 7.9% and 3.1% for mothers 1, 2, 3 and 4.

Breast milk composition

As we were principally interested in growth of the infants, mean values for each component were calculated over the whole sampling period for each mother (Table 3).

Breast milk output in samples 2 and 3—i.e. when the children were respectively about 4 and 7 months old—was higher for mothers 3 and 4 than for

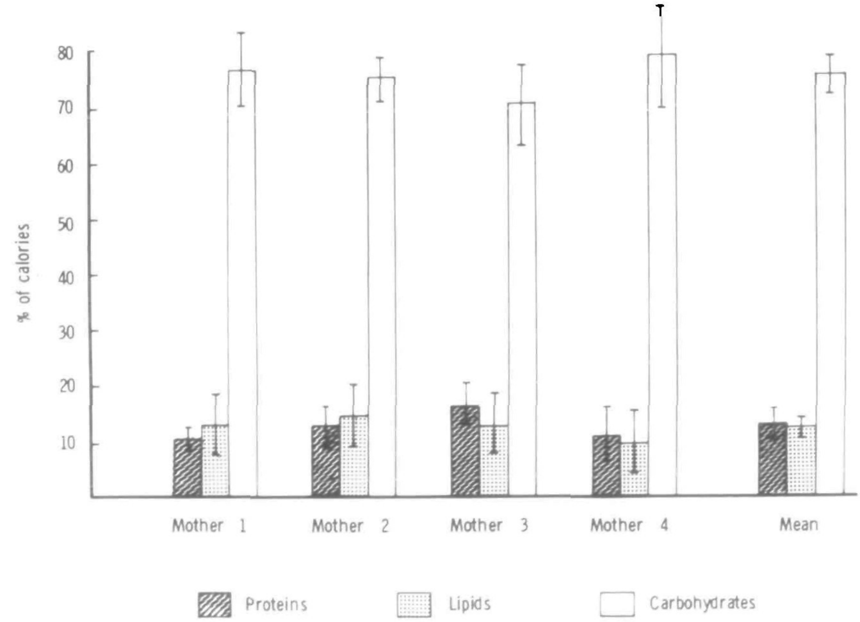


Fig. 1. Protein, lipid and carbohydrate content of the diets.

Table 2
Maternal Diet: Average Daily Intake

Woman	1	2	3	4	Mean
Mean weight (kg)	50.7	48.7	55.9	54.4	52.4
Protein (g/day)	46.8±14.2	61.0±20.9	82.2±12.0	65.1±31.9	63.8
(g/kg/day)	0.92±0.28	1.25±0.43	1.47±0.21	1.20±0.59	1.21
Carbohydrates (g/day)	356±78	343±67	362±107	434±156	374
Lipids (g/day)	26.4±11.2	29.0±9.1	28.0±9.1	22.9±12.9	26.6
Calories (per day)	1899±324	1926±301	2083±465	2261±716	2042
Phospholipids (mgP/day)	104±111	91.8±47.7	124±52.4	102±57.0	106
Cholesterol (mg/day)	728±583	406±248	490±198	649±378	568
Fatty acids (g/day)					
12:0	0.17±0.22	0.11±0.26	0.06±0.05	0.06±0.05	0.10
14:0	0.78±0.88	0.36±0.27	0.55±0.34	0.63±0.26	0.58
16:0	9.89±8.76	4.53±3.27	6.00±1.81	7.17±2.90	6.90
16:1	0.49±0.23	0.45±0.31	0.85±0.34	1.01±0.65	0.70
18:0	1.80±0.89	1.64±1.56	1.53±0.33	2.49±2.33	1.87
18:1	10.5±8.6	4.54±3.94	7.44±2.72	8.19±4.59	7.66
18:2	3.54±1.87	1.66±1.01	2.90±1.83	5.66±4.00	3.44
18:3	0.43±0.29	0.21±0.16	0.41±0.28	0.49±0.26	0.38
Metals, trace elements (mg/day)					
Calcium	503±169	571±352	736±157	519±192	613
Magnesium	425±135	372±67	558±156	403±161	439
Iron	24.6±9.2	28.4±14.6	32.5±6.8	26.8±8.2	28.1
Copper	3.5±1.6	2.7±0.7	5.9±2.8	5.1±2.5	4.3
Zinc	10.7±5.1	9.6±3.0	12.4±3.2	11.9±5.7	11.2
Manganese	3.2±2.4	2.2±1.0	2.9±1.1	2.9±1.2	2.8

Table 3
Breast Milk Composition

Mother	1	2	3	4	Mean
Protein (g/100 ml)	0.96±0.13*	1.04±0.10	1.21±0.32	0.92±0.12	1.03
Total lipids (g/100 ml)	1.55±0.53	1.51±0.48	1.50±0.78	1.72±0.76	1.57
Triglycerides (g/100 ml)	1.23±0.41	1.07±0.24	1.30±0.83	1.25±0.63	1.21
Cholesterol (mg/100 ml)	13.1±7.3	16.0±5.4	21.1±15.8	16.3±10.9	16.6
Lipid phosphorus (mgP/100 ml)	0.62±0.27	0.80±0.43	0.75±0.56	0.64±0.22	0.70
Lactose (g/100 ml)	6.84±0.59	6.47±0.70	6.12±0.80	6.75±0.42	6.55
Calories (Cal/100 ml)	46.3±4.6	44.9±4.0	44.0±6.8	47.1±6.2	45.6

* Mean±1 S.D. of 7 milk samples.

mothers 1 and 2. In later samples these differences were less pronounced (Fig. 2).

Growth of the infants

Growth curves differed considerably for the 4 infants (Fig. 3). Infants 3 and 4 had satisfactory weight for age and weight for height values. Infants 1 and 2 fell below 80% of normal weight for age according to Harvard Standards and below 90% of expected weight for height at the age of 7 and 10 months respectively. The arm/head circumference ratio, another index of malnutrition (22), was constantly low in infant 1 whereas normal values were observed in infants 2, 3 and 4. According to the above anthropometrical criteria infants 1 and 2 suffered from malnutrition after the age of 6 months.

Influence of maternal diet upon breast milk and infants' growth

All correlations between maternal diet, breast milk and anthropometrical variables were calculated according to the statistical procedure described above. None of the dietary variables were correlated with breast milk volume or with breast milk constituents. Weight for height of the infants was however correlated with maternal carbohydrate intake and arm/head circumference ratio with maternal dietary lipid intake. No significant correlations were found between maternal plasma and milk constituents. Linoleic acid levels in diet, plasma and milk were unrelated.

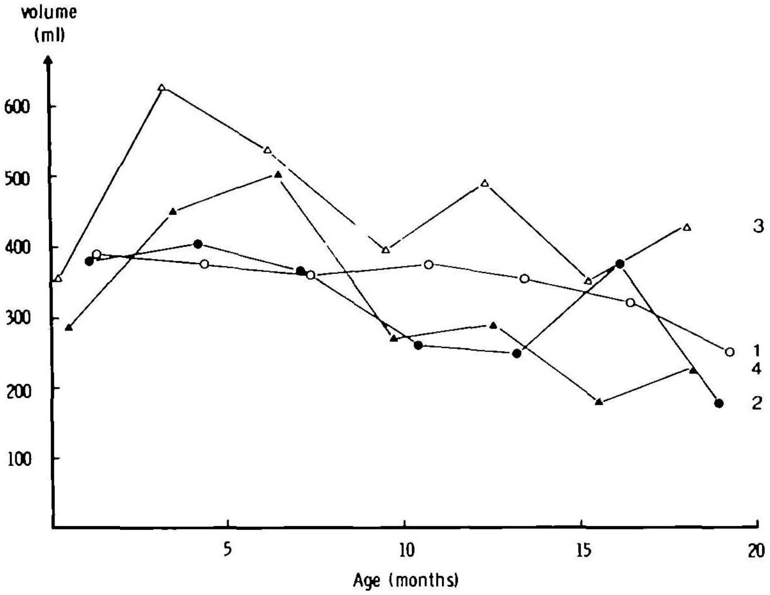
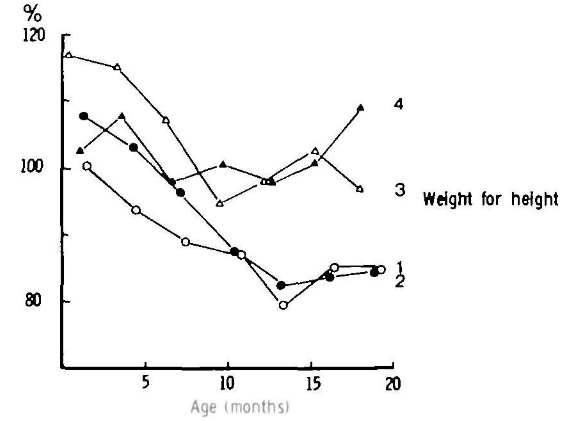


Fig. 2. Daily breast milk volume (12 hours) at different stages of lactation.
Mother 1 = ○, 2 = ●, 3 = △, 4 = ▲

Total calorie and protein intake of the infants

Before the age of six months all infants were solely breast-fed. At 6 months supplements were introduced by the mothers which has been previously shown to be the time at which supplementation is started (21). It has been observed that these infants do not receive supplements before 7 am or after 7 pm (Reinhardt and Lauber unpublished observation). Therefore intake of supplements was also measured between 7 am and 7 pm.

Table 4 shows the proportions of the infants' total intake contributed by breast milk and supplements. These values have been calculated not taking into account the amount of breast milk ingested



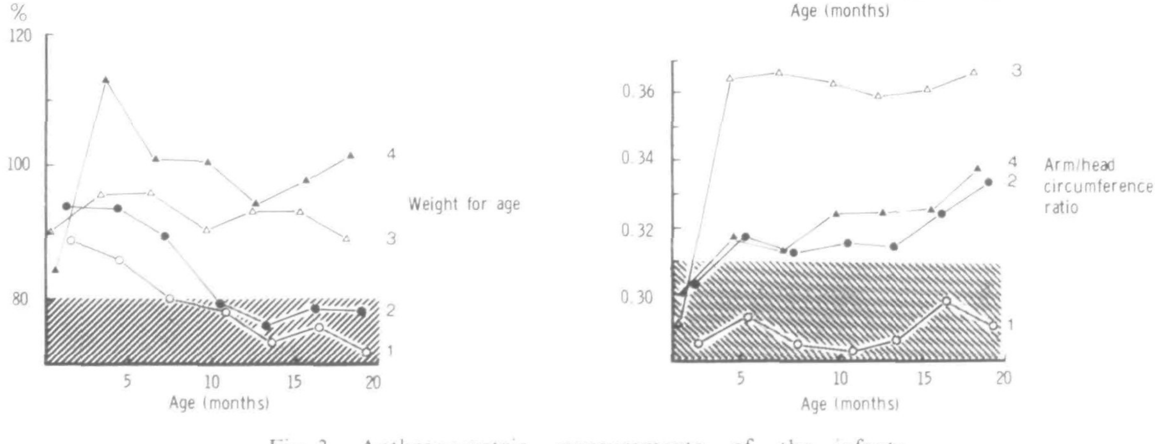


Fig. 3. Anthropometric measurements of the infants.
Infant 1 = ○, 2 = ●, 3 = △, 4 = ▲

Table 4

Calorie and Protein Intake of the Infants. Breast Milk and Supplementary Food

Code	Sampling	Age (mo)	Weight (kg)	Calories milk	Calories suppl.	Total calories	Calories per kg	Protein milk (g)	Protein suppl. (g)	Total protein (g)	Protein (g/kg)
1	1	1.4	4.0	215	*	215	54	3.6	*	3.6	0.9
	2	4.4	5.6	178	*	178	32	3.7	*	3.7	0.7
	3	7.4	6.5	162	*	162	25	3.3	*	3.3	0.5
	4	10.7	7.4	156	33	189	26	3.0	1.0	4.0	0.5
	5	13.4	7.5	169	17	186	25	3.3	0.3	3.6	0.5
	6	16.4	8.2	132	76	208	25	3.0	1.2	4.2	0.5
	7	19.2	8.3	118	297	415	50	3.1	5.2	8.3	1.0
2	1	1.1	4.3	194	*	194	45	4.2	*	4.2	1.0
	2	4.2	6.2	171	*	171	28	4.8	*	4.8	0.8
	3	7.1	7.2	143	299	442	61	3.7	5.4	9.1	1.3
	4	10.4	7.4	117	203	320	43	2.3	3.8	6.1	0.8
	5	13.2	7.8	111	352	463	59	2.6	3.0	5.6	0.7
	6	16.1	8.5	179	125	304	36	4.1	2.5	6.6	0.8
	7	18.9	8.9	78	232	310	35	177	3.4	5.1	0.6
3	1	0.2	3.4	164	*	164	48	3.9	*	3.9	1.1
	2	3.2	5.9	333	*	333	57	9.7	*	9.7	1.7
	3	6.2	7.2	252	*	252	35	7.0	*	7.0	1.0
	4	9.5	8.2	149	47	196	24	3.6	1.4	5.0	0.6
	5	12.3	9.3	171	504	675	73	6.0	3.5	9.5	1.0
	6	15.2	9.9	175	266	441	45	5.7	2.4	8.1	0.8
	7	18.0	10.0	165	783	948	95	3.2	5.9	9.1	0.9
4	1	0.5	3.3	132	*	132	41	2.6	*	2.6	0.8
	2	3.5	6.8	234	*	234	35	3.8	*	3.8	0.6
	3	6.5	7.8	212	*	212	27	4.2	*	4.2	0.5
	4	9.7	9.2	129	669	798	87	1.9	5.1	7.0	0.8
	5	12.5	9.5	110	1194	1304	138	2.8	9.5	12.3	1.3
	6	15.5	1043	103	1224	1327	127	1.9	14.1	16.0	1.5
	7	18.2	1150	103	437	540	47	2.3	6.4	8.7	0.8

* Breast milk only feed. No supplements.

during the night. Supplements comprised principally yam, plantain banana and cassava. Infants 1 and 2 received smaller amounts of supplements than infants 3 and 4. Their growth curves after the age of 6 months are correspondingly less satisfactory. At about 18 months breast milk given during the day (7 am to 7 pm) still provides more than 30% of total protein and more than 20% of total calorie intake.

Discussion

It is difficult to draw conclusions from a sample of only four women, two older, experienced mothers of high parity and two younger, less experienced mothers of low parity. The work load due to the analyses of food, blood and milk samples would have been unrealistically high. Obvious limitations result therefore and the conclusions drawn from the present results have to be considered with caution.

The FAO/WHO Expert Committee (23) has devised a system for expressing the nutritional quality of protein as a score. With an average animal protein intake of 2–8% of the total calories, this protein score is about 70%. Protein requirements are therefore (23) 41 g per day plus 24 g/day for lactation. Women 2, 3 and 4 receive this minimum daily amount but woman 1 has an insufficient intake. Furthermore the proportion of animal protein in the diet is very much lower for this woman. The US Food and Nutrition Board (24) recommends a daily intake of 1800 calories for non-lactating women (22 years old, 50 kg moderate activity) and 1650 calories for women who are 45 years old. A lactation allowance of 500 to 600 calories is generally accepted (25–27). According to these recommendations calorie intake is insufficient for women 1 and 2 but satisfactory for women 3 and 4. Lactation performance in terms of volume in mothers 1 and 2 is much lower at the second and third sampling, i.e. when the infants are about 4 and 7 months old. This is reflected in unsatisfactory weight gain in the corresponding children during the first months of life. According to the growth curves of the children during the first 7 months (Fig. 3) it appears that a daily intake of 65 g protein and 2100 to 2200 calories is sufficient to allow satisfactory breast milk production. Physical activity should also be taken into account for protein and calorie allowances: mother 1 appeared to do more hard work than the others, though detailed assessment of physical activity was not attempted. The high proportion of carbohydrate in the diet (75% of total calories) is due to the predominance of yam, plantain, banana and cassava in the diet, a common finding in tropical regions.

Lipid intake varies considerably between different populations and regions and there is no established minimum requirement for fat in the diet (28). Lipids are however carriers of fat-soluble vitamins and provide essential fatty acids. Linoleic acid requirements are 0.6% of total calories (29, 30). In the present study maternal diet provides 1.6% of total calories as linoleic acid which is satisfactory.

The mothers' *calcium* intake (Table 2) is about half the recommended allowance. FAO/WHO suggested a "practical allowance" of 0.4 to 0.5 g/kg/day for adults, since signs of calcium deficiency are absent in countries where intake is in this range (31). Since a supplementary requirement of 0.5 g must be added for lactation (24), the calcium intake found in the present study is insufficient.

Iron requirements during lactation are 18 mg per day (28) and are met in these mothers. With a daily *zinc* intake of 11 mg the four mothers do not achieve the minimum zinc allowance of 25 mg per day (28) which may have important metabolic and immunologic (32, 33) consequences for both the mothers and their infants. Minimum requirements seem to be exceeded for *copper*, *magnesium* and *manganese* (34, 24).

When the present results are compared with those of a previous study (1), protein and lactose concentrations in milk are found to be similar. Total lipid, phospholipid, triglyceride, cholesterol and therefore calorie content was lower in the present study. This may be due to the use in the present study of a sticking plaster to avoid night-time breast feeding with the breast to be sampled the following morning. It is possible that, during the previous study, mothers—despite our recommendations—fed their infant during the night with the breast to be sampled on the following morning. It has been shown (35) that lipid concentrations change during a single feed and, thus, feeding during the night could well interfere with lipid concentrations. Furthermore the sticking plaster may interfere with normal physiology of the mammary gland which, under normal circumstances, is frequently suckled by the infant sleeping in close contact with the mother. These difficulties underline the problems related to breast milk studies where measuring and sampling procedures frequently interfere with normal physiological functions. Interestingly there were no appreciable differences in breast milk composition between the four mothers. In the second and third sampling periods (i.e. when the infants were about 4 and 7 months old) mothers 1 and 2 had much lower milk volumes than the two others which may account for the early levelling off of growth curves in infants 1 and 2 and is also related to lower calorie and protein intake in the respective mothers. Our statistical analysis provides evidence that the carbohydrate intake of the mothers, the main source of calories, was related to weight for height of the infants. It was however not possible to relate carbohydrate intake of the mothers to changes in breast milk composition or volume. In order to be able to show an effect of diet on breast milk volume and/or composition it might be necessary to analyse ingested food for more than two days before sampling milk for analyses.

The mothers may also be drawing on their fat stores for milk production, as shown in mothers 2 and 4 by decrease of body weight during 18 months of lactation. Mothers 1 and 3 however gained weight during this period. Albumin values were consistently low in mothers 1 and 3 a sign of possible maternal malnutrition.

Although anaemia (Hb < 10 g/100 ml) was not observed in any of the four mothers during the study, mother 1 had always lower values than the three others.

Considering that our calculations for total calorie and protein intake by the infants do not take into account the amount of breast milk ingested during the night, the present results clearly establish the important role of breast milk in providing a considerable proportion of total protein and calories in late lactation.

Finally, the fact that the infants of the two older high parity mothers were growing better may to a certain extent be due to non nutritional factors such as protection conferred by the environment (i.e. large family size, older children who can help with infant care, more experienced mothers). These factors might create differences in growth pattern and therefore limit our conclusions on growth of the infants. Two facts remain however: first, infants with unsatisfactory growth curves had mothers with low calorie and protein intake, second, these infants received significantly less supplements than the infants with satisfactory growth curves.

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