J Food Sci Technol
https://doi.org/10.1007/s13197-024-06025-w

ORIGINAL ARTICLE

Nutrient composition of human milk of Indian mothers: relation with maternal and infant anthropometry

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Revised: 28 May 2024 / Accepted: 27 June 2024

Abstract The aim of the study was to determine the nutrient composition of human milk (HM) of Indian mothers and investigate its association with maternal and infant anthropometric measures. Human milk is an ideal source of nutrition for optimum growth and development of infant. Among Indian mothers, HM composition data is scanty, especially during prolonged lactation. Mother-infant dyads (n = 50) comprising of two lactation group (0–6 m, n = 26) and (7–12 m, n = 24) residing in Delhi, India were enrolled. Height, weight, BMI, MUAC and head circumference were measured and compared with reference standard. The macronutrients and micronutrients of HM were analysed using MIRIS analyzer, ICP-AES and HPLC. Correlation plots were generated between HM nutrients and maternal, infant anthropometry. Mean BMI of mothers were 19.6 ± 2.6 (0–6 m) and 21.2 ± 3.7 (7–12 m) kg/m^2. Around 26% of mothers were underweight, 28% overweight. Among infants, 26% were underweight, wasted (18%), stunted (34%) and overweight (10%). The macronutrient composition of human milk were similar to reference values (means ± standard deviation). Both lactation group showed similar HM nutrient composition. Significant positive associations (r = 0.3–0.5) were found between maternal height, infant HCZ with HM energy, fat; maternal prepregnancy-weight, MUAC with retinol; maternal MUAC with crude protein.

Keywords Human milk · Lactation · Milk composition · Infant growth · Maternal nutrition

Introduction

The Sustainable Development Goals (SDGs 2) focus on preventing undernutrition in all forms by 2030 and consider ‘nutrition’ as an essential component for achieving other SDGs. Globally, the prevalence of malnutrition is declining but still 149.2 million children are stunted and 45.4 million children are wasted in the world (FAO 2022). Developing countries like India contributes the largest to this malnutrition prevalence which has affected mother’s health, and child’s growth, development, and survival. Around 19% of the women in the reproductive age group are underweight, 24% are overweight and 57% are anaemic in India (NFHS-5 2019-21). The rise in overweight/obesity and micronutrient malnutrition adds to prevailing concerns of undernutrition and leads to a triple burden of malnutrition (TBM) (Patel et al. 2020).

The nutritional status of the mother plays an important role in the birth outcome of their offspring and health status. Maternal malnutrition during pregnancy leads to obstructed labor, low birth weight babies, and postpartum blood loss. Breastfeeding plays an important role in a child’s survival and provides health benefits to the mother in maintaining birth spacing, replenishing maternal stores, and preventing childhood infections (IOM 1991). The *Indian Academy of Paediatrics (IAP)* recommends exclusive breastfeeding for the first six months, with continued breastfeeding minimum

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Published online: 10 July 2024

for 2 years or beyond but simultaneous introduction of complementary food after completion of 6 months (Tiwari et al. 2016). Human milk is an ideal source of nutrition for both preterm and term infants (IOM 1991; Hascoët et al. 2019). This dynamic fluid varies between and within the population, stage of lactation, diurnally, gestational age, mother's body mass index, parity number, maternal diet, and technique of pumping milk (Bravi et al. 2016; Butts et al. 2018). It contains important components for infant nutrition like (a) core nutrients including protein, fats, carbohydrates, vitamins, and minerals; (b) bioactive compounds such as immunoglobulins, lactoferrin, lysozyme, etc. (Ballard and Morrow 2013); (c) Infant microbiome(improves gut microbiota) with the help of Human Milk Oligosaccharides (Ballard and Morrow 2013).

The compositional variation in human milk is due to adaptation to changing infant needs, geographical location, and food supply (Abdelhamid et al. 2020). The human milk composition has been extensively researched in the first six months following delivery, but information on milk composition beyond 6 months is scarce (Czosnykowska-łukacka et al. 2018). Few studies have reported the association of human milk composition and anthropometric parameters which was limited to macronutrient composition only (Butts et al. 2018; Khanna et al. 2022). It was observed in studies that the macronutrient composition of human milk was associated with one or more maternal factors like maternal age, weight, height, protein intake, and frequency of nursing (Bravi et al. 2016; Kothari et al. 2018). Some studies also investigated the association of human milk protein and lactose in infant growth. However, high-fat percent in human milk affects growth velocity and leads to adiposity (Eriksen et al. 2018; Kothari et al. 2018).

The lack of research on human milk composition makes it difficult to design interventions that alter the composition for optimal infant growth and development. With that consideration, the objective of the present study was to investigate human milk composition and its associations with maternal and infant anthropometric parameters in (0–6 months) and (7–12 months) lactation groups. The findings of the present study could support limited evidence on how human milk composition is influenced by maternal and infant anthropometric measures.

Material and methods

Subjects

Around 50 mother-infant dyads from two lactation groups (a) 0–6 months (0–6 m) and (b) 7–12 months (7–12 m) were recruited from Sept 2020 to Dec 2020 (Kumari et al. 2022). The subjects of the study were healthy Indian lactating mothers (21–32 years) with their infants 0–365 days after delivery. These mothers were from local communities from Ghazipur, a region in East Delhi. The sampling technique was purposive sampling and prior informed consent was taken from mothers for participating in the present study. Due to covid pandemic the sample size was restricted. The STROBE flow diagram of the present study has been presented in Fig. 1. The present study was approved by the *Institutional Ethics Committee namely Seva Mandal Education Society's, Matunga, Mumbai (Maharashtra)* vide dated 10th July 2020 with approval no. SMEs143a (Kumari et al. 2022).

Anthropometric measurement

The data on mother's age, pre-pregnancy weight (pp-weight), and height, number of children, infant age, gender, birth weight, length, and head circumference were collected from the mothers through a questionnaire cum interview schedule (Kumari et al. 2022). The current anthropometric measurements for infants (weight, length, and head circumference) and mothers (weight, height, and mid upper arm circumference-MUAC) were measured on the day of enrolment. The infant weight was measured using the Seca-354 electronic infant scale to the nearest 5 g (Seca, Birmingham, UK). The height was measured as supine length using Seca-417 infant meter to the nearest 10 cm (Seca, Birmingham, UK). The head circumference of the infant was measured using Seca-212 a non-stretch Teflon measuring tape to the nearest 1 mm. For mothers, the weight was measured using a digital weighing scale (Equinox) with a sensitivity of 0.1 kg. Height was measured with the help of an anthropometric rod (Galaxy Informatics, India), which had a sensitivity of 0.1 cm. The mid-upper arm circumference of the mother was measured using the same Seca-212 measuring tape. All the measurements were performed in duplicate on the day of enrolment.

Human milk collection

The milk samples of the mothers were collected using hand expression into a sterile propylene container available commercially (HMBANA Guidlines Committee 2020; Leghi et al. 2020). Around 25 ml of human milk sample was collected from each mother. The samples were collected preferably in the morning between 9 a.m. and 12 noon during home visits. The infant was placed on the sampled breast for 2 min before milk collection. As soon as the infant was nursed, the sample was collected from the opposite breast with hand expression. The total time for collecting milk samples varied between mothers on their varying letdown reflex initiated with the first visible spray of milk in the sample container. As soon as the milk sample was collected it was

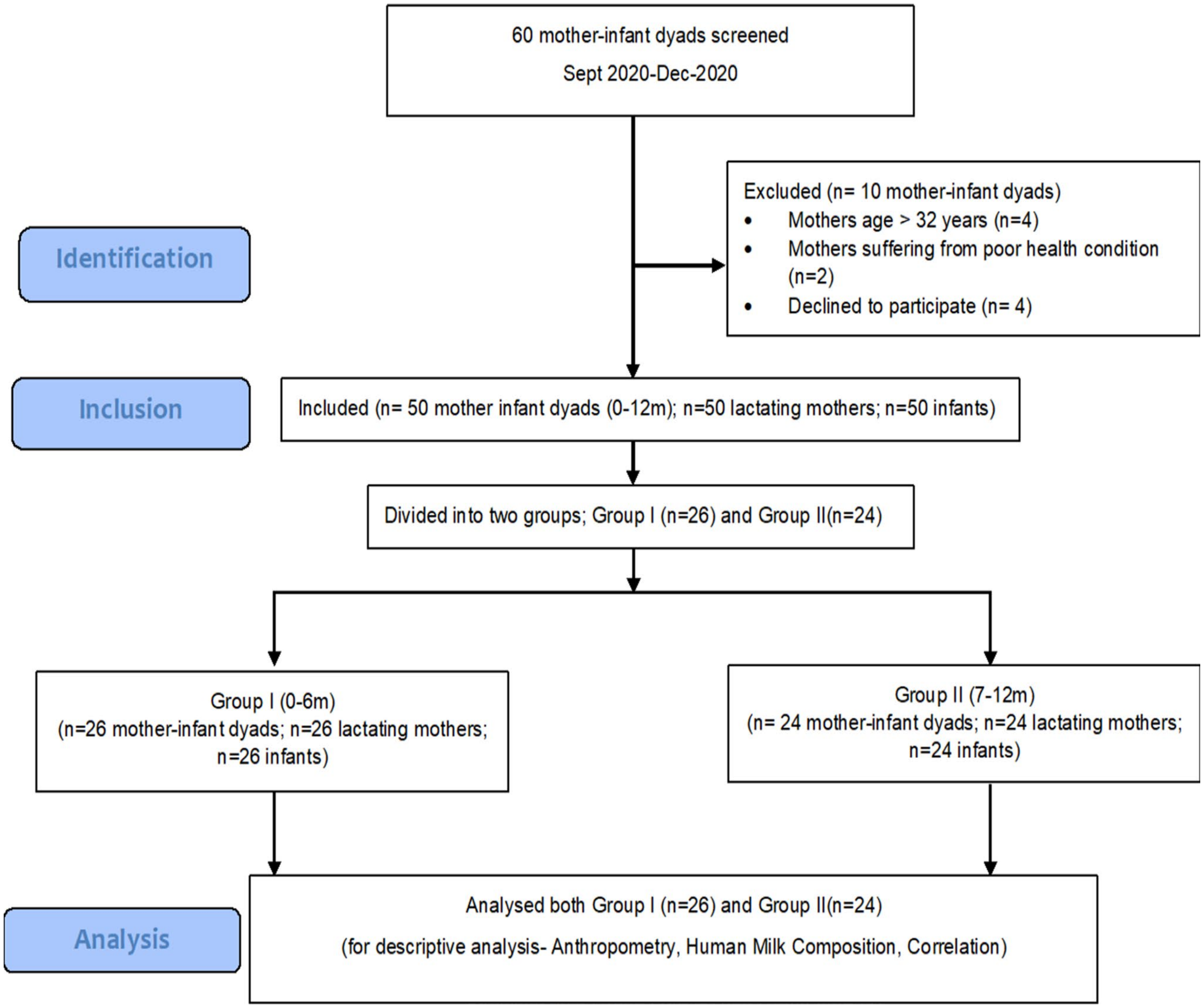


Fig. 1 Strobe flow diagram of the study

capped and kept in an insulated ice box and transferred to the freezer at – 20 °C until processed and analyzed. Before analysis samples were homogenized (1–5 s/1 mL probe) using Sonicator (Milk Homogeniser MIRIS, Uppsala, Sweden).

Around 10 mL of human milk sample was used for analysis of macronutrients like protein, fat, lactose, energy, and total solids, using MIRIS human milk analyzer (HMA MIRIS, Uppsala, Sweden) based on approved IR technology (Sinkiewicz-Darol et al. 2021). In MIRIS, the macronutrient concentration was reported as per 100 mL of milk sample for protein-total and true, fat and carbohydrate, and energy. The true protein was calculated as (total protein- 24% of non-protein nitrogen) (Groh-Wargo et al. 2016; Bzikowska et al. 2018). The remaining 15 mL human milk sample was aliquoted in 5 mL falcon tubes for analysis of retinol and minerals like calcium, phosphorous, iron, and zinc. The retinol content was measured with HPLC (Thermoscientific, Ultima, 3000) India (Kašparová et al. 2012). Minerals were measured using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Thermo Fisher Scientific, Germany) (Janve and Singhal 2018).

Statistical analysis

The statistical software of IBM SPSS version 23 (USA) was used for statistical analysis. The anthropometric data of the mothers, infant, and human milk composition were calculated using descriptive statistics (means and standard deviations or medians and interquartile ranges as applicable). The statistical test used was Levene's test for equality of variances/t-test for equality of mean ($p < 0.05$). The student's t-test was used for comparing the anthropometric data of children. The z scores for anthropometric indices like weight for age (WAZ), height for age (HAZ), weight for height (WAZ), BMI for age (BAZ), and head circumference for age (HCZ) were calculated using WHO anthro software, 2010 (3.2.2) for children under 5 years. The body mass index of the mothers was calculated and compared with the International Obesity Task Force classification for Asians, 2020 (WHO/IOTF 2000) and mothers MUAC with Food and Nutrition Technical Assistance cut-offs (FANTA 2018). Graphs were plotted in both Excel and Origin 2019b (USA). Originpro2023 (USA) software was used for calculating and plotting Pearson's r correlation coefficient between human milk nutrients and mother and infant nutritional status in the form of correlation plot.

Results and discussion

Anthropometric data of the participants

The mean maternal age of the mothers was 23 ± 1.9 (0–6 m) and 27 ± 4 (7–12 m) years respectively (Table 1). It was observed that a significant difference ($p < 0.001$) was found in the mother's age between the groups. However, there were no significant differences observed in the mean weight, height, BMI, MUAC, pp-weight, and BMI of the mothers of the two groups. For infants, the mean age (in days) was 124 ± 50 (0–6 m) and 318 ± 55.1 (7–12 m) respectively. As expected, the current weight, height, and head circumference of the older group (7–12 months) was significantly higher ($p < 0.05$) than the younger group (0–6 months). This aligns with the findings reported in previous studies (Abdelhamid et al. 2020; Young et al. 2023).

Nutrient composition of human milk

The nutrient profile of milk of the two lactation groups (0–6 m) and (7–12 m) is presented in Table 2. The mean macronutrient level of human milk per 100 mL was slightly higher for 0–6 months as compared to 7–12 months but differences were not significant. Similarly the differences in various micronutrients like calcium (0–6 months: 49.22 ± 17.65 mg, 7–12 months: 48.89 ± 14.47 mg, $p = 0.945$), phosphorous (0–6 months:14.56 ± 4.95 mg, 7–12 months: 14.66 ± 6.30 mg, $p = 0.949$), iron (0–6 months: 0.90 ± 0.58 mg, 7–12 months: 0.92 ± 0.68 mg, $p = 0.956$), zinc (0–6 months: 0.98 ± 0.96 mg, 7–12 months: 0.66 ± 0.36 mg, $p = 0.132$) and retinol (0–6 months: 113.77 ± 106.06 mcg, 7–12 months: 38 ± 22 mcg, $p = 0.103$) were not significant between the two groups ($p > 0.05$). It was observed that most of the human milk reference values are outdated and relied on studies using inconsistent methods in both sample collection and analysis. Hence, in the present study, the human milk macronutrient composition was compared with the reference values given by the *Institute of Medicine* (IOM 1991; Leghi et al. 2020), and other

Table 1 Anthropometric characteristics of lactating mothers and infants(0–6 months) and (7–12 months) postpartum, Delhi, (n = 50)[a,*]. MUAC, mid-upper arm circumference

Maternal	0–6 months (n = 26)	7–12 months (n = 24)	p value	Infant and toddler	0–6 months (n = 26)	7–12 months (n = 24)	p value
Age (years)	23 ± 1.9	27 ± 4	0.000*	Baby age (days)	124 ± 50	318 ± 55	0.000*
	23(21–28)	27(21–32)			120(8–211)	330(215–386)	
Weight (kg)	48 ± 7	52 ± 9.3	0.131	Gender	(14 Female; 12 Male)	(11 Female; 13 Male)	
	47(40–61)	50(40–78)		Baby birth weight (g)[b]	2.8 ± 0.6	3 ± 0.5	0.397
Height (cm)	156 ± 4.6	157 ± 3.9	0.561		2.7(1.5–4.3)	3(2.4–4.5)	
	155(150–165)	157(147–163)		Current weight (kg)	5.3 ± 1.3	7 ± 2.1	0.001*
Body mass index (kg/m^2)	19.6 ± 2.6	21.2 ± 3.7	0.085		5.4(2.5–8.5)	7.3(2.5 ± 10.5)	
	19.7(16–26.7)	20.1(16.8–33.8)		Height (cm)	55.5 ± 7.4	63.1 ± 13.3	0.018*
Pre-pregnancy body weight (kg)	46.6 ± 6.0	50 ± 7.8	0.149		56.5(42.0–69.0)	65(37–110)	
	45(38–58)	48(40–70)		Head circumference (cm)	40.5 ± 6	44.9 ± 5.7	0.014*
Pre-pregnancy BMI (Kg/m^2)	19.1 ± 2.2	20.3 ± 3.1	0.087		41.5(22.0–55.0)	44.3(39–70)	
	19.3(16–25.8)	19.7(16.8–30.3)					
MUAC (cm)	26 ± 2.2	27 ± 3.5	0.235				
	26(22–30)	26.3(21–35)					

*$p < 0.05$ using Levene's test for equality of variances/t-test for equality of mean

[a]Values are expressed as Mean ± SD, median, and ranges

[b]Birth weight source was birth certificates, recall of respondents

Table 2 Human milk composition of lactating mothers (0–6 months) and (7–12 months) postpartum, Delhi, (n = 50)[a,*]

	0–6 months (n = 26)	7–12 months (n = 24)	Difference between (0–6 m) and (7–12 m) of lactation *p* value	Institute of Medicine (1991)	Leghi et al. 2020[b]	Different Indian studies (Khanna et al. 2022, Sharda et al. 1983)
Energy (kcal/100 mL)	60.7 ± 10	58 ± 11.4	0.326			
	59.5(43–83)	54(43–94)				
Fat (g/100 mL)	3.6 ± 1.6	3.0 ± 1.5	0.175	39.0 ± 4.0 g/L	42.4 ± 13.1 g/L	2.77–4.78 (g/100 mL)
	3.3 (1.5–8)	2.6 (1–7.5)				
Crude protein (g/100 mL)	1.1 ± 0.5	0.9 ± 0.3	0.066	10.5 ± 2.0 g/L	13.3 ± 4 g/L	0.87–2.33 (g/100 mL)
	1 (0.2–2.5)	0.9 (0.1–1.5)				
True protein (g/100 mL)	0.8 ± 0.4	0.7 ± 0.3	0.072			
	0.8 (0.1–2.1)	0.6 (0.1–1.2)				
Lactose (g/100 mL)	6.1 ± 0.6	6.3 ± 0.3	0.201	72.0 ± 2.5 g/L	64.3 ± 8.6 g/L	6.78–7.7 (g/100 mL)
	6.3 (3.8–6.8)	6.3 (5.2–6.9)				
Total Solids (g/100 mL)	10.9 ± 0.8	10.7 ± 1.2	0.567			
	10.9 (9.4–12.7)	10.5 (8.5–14.5)				
Calcium (mg/100 mL)	49.22 ± 17.65	48.89 ± 14.47	0.945	280 ± 26 mg/L	–	17.10–24.97 (mg/100 mL)
	45.6 (27.09–112.67)	44.5 (27.32–76.1)				
Phosphorous(mg/100 mL)	14.56 ± 4.95	14.66 ± 6.30	0.949	140 ± 22 mg/L		
	15.19 (5.04–23.77)	14.16 (5.02–34.7)				
Iron (mg/100 mL)	0.90 ± 0.58	0.92 ± 0.68	0.956	0.3 ± 0.1 mg/L		
	0.68 (0.45–3.05)	0.60 (0.45–3.14)				
Zinc (mg/100 mL)	0.98 ± 0.96	0.66 ± 0.36	0.132	1.2 ± 0.2 mg/L		0.61–3.72 (mcg/mL)
	0.65 (0.18–3.55)	0.55 (0.21–1.89)				
Retinol (mcg/100 mL)	113.77 ± 106.06	38 ± 22	0.103	670 ± 200 mcg/L		120–236 (IU/100 mL)
	89.8 (11.00–532.80)	38 (7–84)				

*$p < 0.05$ using Levene's test for equality of variances/t-test for equality of mean

[a]Values are expressed as Mean ± SD, median, and ranges

[b]Values for "full breast milk expression" collected in the morning

studies on Indian mothers (Khanna et al. 2022) as shown in Table 2. It was found that the macronutrient composition of milk was similar to reference values (mean ± SD) of human milk and other studies on milk composition (Czosnykowska-łukacka et al. 2018; Yang et al. 2018; Young et al. 2023). Huang et al. reported the breast milk macronutrient concentrations of (0–12 months) mothers with protein (1.37 ± 0.73 g/100 mL), fat (3.20 ± 1.43 g/100 mL), and lactose (6.51 ± 0.40 g/100 mL) (Hascoët et al. 2019; Huang and Hu 2020). In comparison with IOM references, the calcium, iron, and zinc content of milk were higher, and phosphorous was in a similar range in the present study (IOM 1991). However, vitamin A (retinol) was observed to be less in the current study. The calcium, zinc, and retinol content of human milk in the present study was comparable with other studies on Asian (Sharda et al. 1983), Korean mothers (Kim and Yi 2020). Similar to our findings, other studies on human milk composition analysis showed no statistical significance ($p > 0.05$) between the lactation groups (Czosnykowska-łukacka et al. 2018; Kothari et al. 2018).

Nutritional status of the participants

The nutritional status of the mother and infant was assessed with the recommendations of WHO/IOTF BMI classification for adults (WHO/IOTF 2000) and WHO z-scores for children under 5 years (2009) and presented in Table 3. The proportion of BMI of all mothers being underweight, normal weight, and overweight were 26%, 46%, and 28% respectively. Around 14% of the mothers were malnourished with MUAC less than 23 cm. The present findings showed a similar trend with recent national-level data for the nutritional status of women aged 15–49 years from NFHS-5 wherein, 19% of women were thin, 24% were overweight or obese, and 57% had BMI in the normal range of International Institute for Population Sciences (NFHS-5 2019-21). Other studies from India reported 69% of women of reproductive age group with normal BMI, 14.7% underweight, and 16.4% overweight/obese category (Taneja et al. 2021; Young et al. 2023). Another study reported a much higher percentage of women residing in Maharashtra with low MUAC ≤ 23 (52%) (Borkar et al. 2022).

The nutritional status of the infant was assessed with anthropometric indices viz., weight for age (WAZ), weight for height (WHZ), height for age (HAZ), head circumference for age (HCAZ), and BMI for age (BAZ). As per z-scores of children, around 26% were underweight (< −2SD WAZ), 18% were wasted (< −2SD WHZ), 34% were

Table 3 Assessment of the nutritional status of mothers and their infants based on anthropometric indices (n = 50)[a]

Maternal BMI[b]	Current BMI			Pre-pregnancy BMI		
	0–6 m (26)	7–12 m (24)	Total (%)	0–6 m (26)	7–12 m (24)	Total (%)
< 18.5	10	3	26	12	7	38
18.5–22.99	12	11	46	13	13	52
23.00 to ≥ 30	5	10	28	1	4	10

Maternal MUAC[c] (cm)	0–6 m (26)	7–12 m (24)	Total (%)
< 23	3	4	14
> 23	23	20	86

Anthropometric indices (infant)	Nutritional diagnosis	Degree z-score[d]	z-score	Prevalence (%)
Weight/Age	Underweight	Severe	z W/A ≤ −3	12
		Moderate	z W/A −2 to −3	14
		Normal	z W/A −2 to +2	74
		Overweight	z W/A ≥ +2	0
Weight/height	Wasting	Severe	z W/H < −3	6
		Moderate	z W/H −2 to −3	12
		Normal	z W/H −2 to +2	70
		Overweight and obesity	z W/H > +2	12
Height/age	Stunting	Stunting	z H/A < −2	34
		Normal	z H/A −2 to +2	62
		Tall	z H/A > +2	4
Head circumference/age		Microcephaly	z HC/A < −2	14
		Normal	z HC/A −2 to +2	78
		Macrocephaly	z HC/A > +2	8
BMI/age		Severe	z W/H < −3	8
		Moderate	z W/H −2 to −3	14
		Normal	z W/H −2 to +2	68
		Overweight and Obesity	z W/H > +2	10

WAZ weight for age z-score; *WHZ* weight for height z-score; *HAZ* height for age z-score; *HCZ* head circumference for age z-score; *BAZ* BMI for age z-score

[a]Values are specified in percentages [% (n)]. BMI, body mass index; MUAC, mid-upper arm circumference

[b]The formula of body mass index is weight (in kg)/ height(m^2). WHO (World Health Organization)/IOTF (International Obesity Task Force) classification of BMI for Asians (2000)- Underweight defined as BMI < 18.5 kg/m^2; normal weight as BMI between18.5 and 22.99 kg/m^2 and overweight as BMI ≥ 23 kg/m^2

[c]Food and Nutrition Technical Assistance III (FANTA), Global MUAC Cutoffs for Adults, 2018. Less than < 23 cm malnutrition.

[d]WHO Global Database on child growth and malnutrition, 2006

stunted (< − 2SD HAZ), 14% had microcephaly (< − 2SD HCAZ), 10% were overweight (> 2SD WHZ), 10% were overweight (> 2 SD BAZ). The malnutrition trend of children based on gender and age was assessed and presented in Fig. 2a and b using z-scores. In the present study, male children were lighter (mean WAZ, males: − 1.46 ± 1.55, females: − 0.93 ± 1.48, p = 0.219) and had smaller head circumference (mean HCZ, males: − 0.48 ± 1.46, females: 0.06 ± 1.9, p = 0.264) than the female children, though differences were not significant. However, females were observed to be significantly taller than males (mean HAZ, males: − 2.04 ± 1.9, females: − 0.86 ± 1.75, p = 0.027). The mean BAZ of females (− 0.58 ± 1.91) was lower than males (− 0.37 ± 2.01), but differences were not significant (p = 0.704). As expected, the children in the older group (7–12 months) were significantly taller (HAZ, 0–6 months: − 1.72 ± 2.07, 7–12 months: − 1.17 ± 1.7, p = 0.313), heavier (WAZ, 0–6 months: − 1.72 ± 1.52, 7–12 months: − 0.62 ± 1.34, p = 0.01), and had high BMI (BAZ, 0–6 months: − 0.98 ± 1.67, 7–12 months: 0.07 ± 2.11, p = 0.056) as compared to children in younger group (0–6 months). Though, the differences were not significant in WHZ (0–6 months: − 0.45 ± 1.99, 7–12 months: 0.06 ± 2.02, p = 0.379) and HCZ (0–6 months: 0.19 ± 1.59, 7–12 months: − 0.64 ± 1.75, p = 0.088) scores between the two groups. Malnutrition trends based on gender revealed lower WAZ, HAZ, and HCZ in males, while females exhibited lower WHZ and BAZ. These trends may be attributed to cultural practices, such as formula feeding, early introduction of solid foods, and frequent illnesses/infections among children (Taneja et al. 2021). The present study findings of malnutrition trend among children under 5 years is in confirmation with NFHS-5 data findings with 36% being stunted, 19% wasted, and 32% being underweight (NFHS-5 2019-21; Taneja et al. 2021). Other studies from India reported a lower malnutrition trend with 20% stunting, 19.5% underweight, and 8.2% wasting among children below 6 months (Young et al. 2023).

Correlation between nutrient composition of human milk and maternal, infant anthropometry

The relationship between maternal anthropometry and human milk composition is presented in Fig. 3a. It was found that maternal height was positively associated with human milk energy (r = 0.281, p = 0.04) and fat (r = 0.293, p = 0.04) (r = 0.281, p = 0.04) but negatively associated with milk true protein content (r = − 0.308, p = 0.03). Maternal pp-weight was positively associated with human milk retinol (r = 0.434, p = 0.002) whereas maternal pp-BMI is inversely related to retinol (r = − 0.396, p = 0.004) Maternal MUAC had a

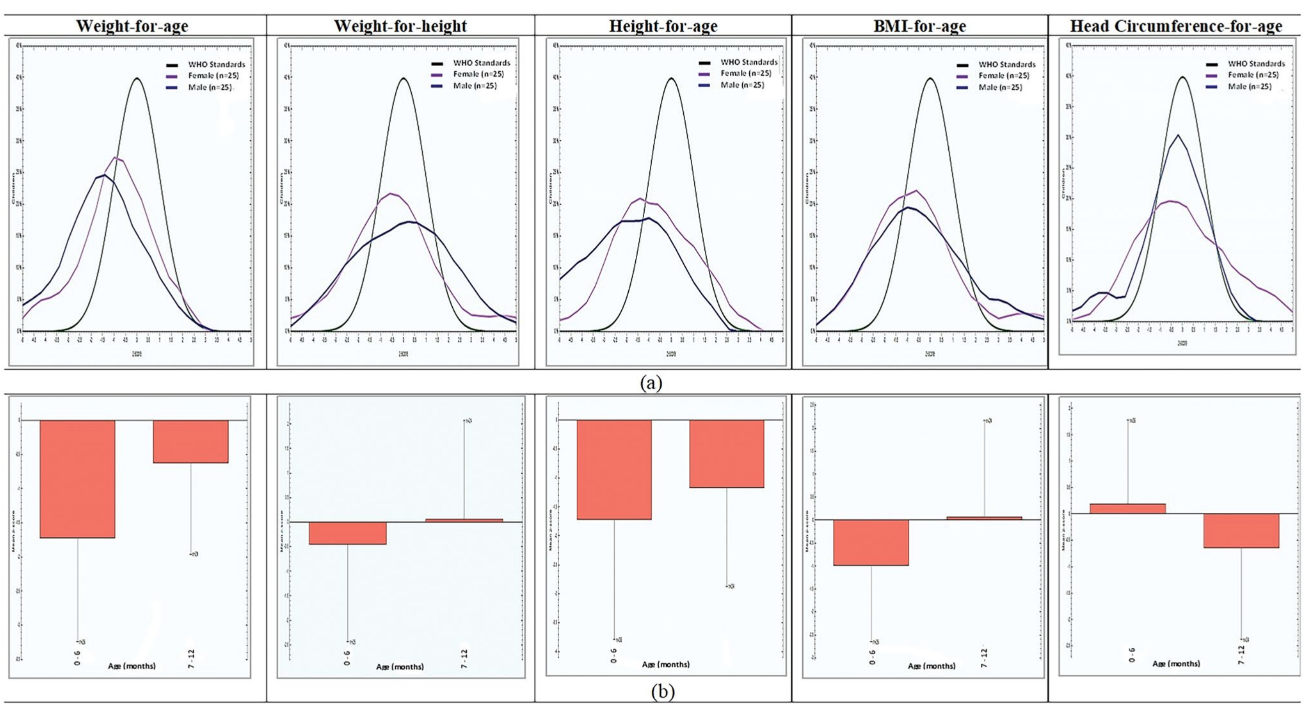
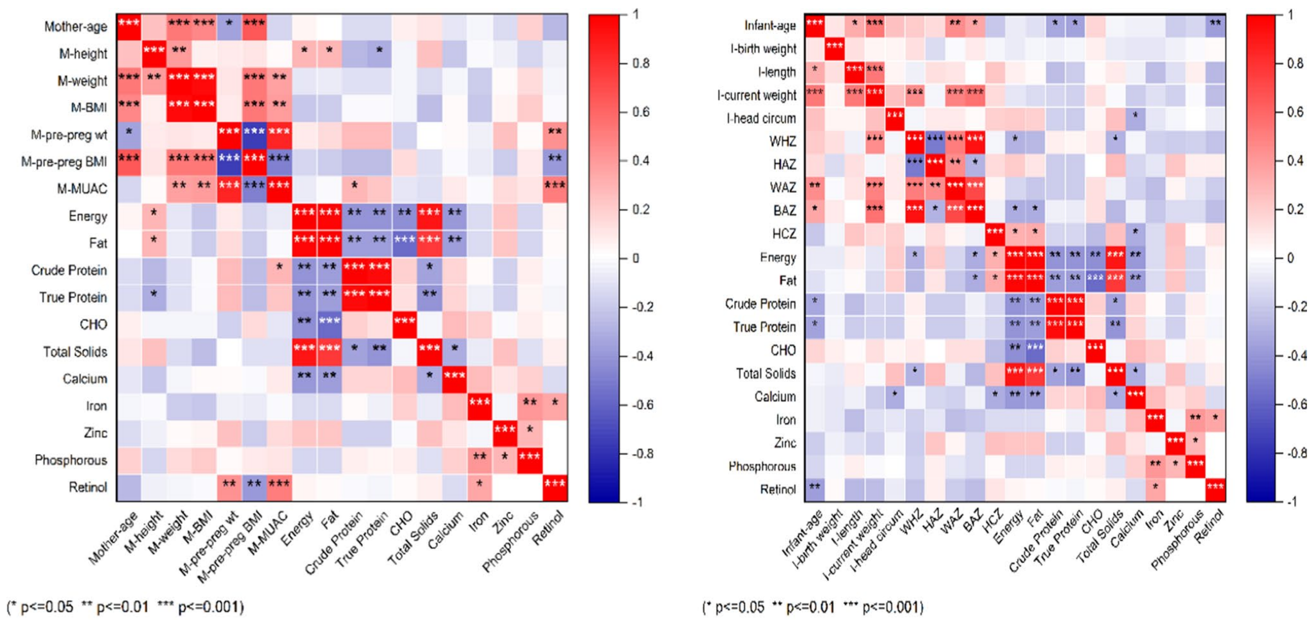


Fig. 2 Malnutrition trend based on gender (**a**) and age **b** in infants (n = 50). As per gender, low WAZ in males than females (p > 0.05); low WHZ in females than males (p > 0.05); low HAZ in males than females(p < 0.05); low BAZ in females than males females (p > 0.05) and low HCZ in males than females (p > 0.05). As per age, low WAZ in 0–6 m (p < 0.05); high WHZ in 7–12 m (p > 0.05); low HAZ in 0–6 m (p > 0.05); high BAZ in 7–12 m (p > 0.05) and low HCZ in 7–12 m (p > 0.05) *p < 0.05 using Levene's test for equality of variances/t-test for equality of mean



(a) (b)

Fig. 3 Correlation between **a** maternal anthropometry and human milk composition; **b** infant anthropometry and human milk composition of 0–12 months postpartum, Delhi, (n = 50). Associations were analyzed using Originpro2023 (USA) and Pearson's correlation coefficient in the form of correlation plots. The red color indicates a positive association between variables and the blue color indicates a negative association between variables. Significant statistical associations were analyzed using *p* values (*$p<0.05$, **$p<0.01$, ***$p<0.001$). *M* maternal; *I* infant (Color figure online)

positive significant association with milk retinol (r = 0.509, *p* = 0.000) and crude protein content (r = 0.287, *p* = 0.043). Similar positive associations were found between HM retinol with maternal pp- weight and MUAC, and HM energy, fat, and the mother's height (Kothari et al. 2018). The true protein content of human milk showed inverse association with maternal height. It was observed that no correlations were found between milk composition and maternal pre-pregnancy parameters like weight, height, or BMI in the study of Hascoët et al. (Hascoët et al. 2019).

The correlation between human milk composition and infant anthropometry is presented in Fig. 3b. Human milk energy ($r = 0.311$, $p = 0.03$) and fat ($r = 0.327$, $p = 0.02$) were positively associated with infant HCZ. Infant age was observed to be inversely related to crude protein ($r = -0.339$, $p = 0.02$), true protein ($r = -0.341$, $p = 0.015$), and retinol ($r = -0.380$, $p = 0.007$) content of human milk. The milk energy was also negatively associated with infant WHZ ($r = -0.292$, $p = 0.04$) and BAZ ($r = -0.309$, $p = 0.028$). BM solids were negatively associated with WHZ ($r = -0.282$, $p = 0.04$) and fat with infant BAZ ($r = -0.313$, $p = 0.03$). The calcium content of human milk was inversely associated with infant HCZ ($r = -0.311$, $p = 0.028$). A significant inverse association was found between milk crude protein and true protein with infant age (Hascoët et al. 2019). HM energy and fat with infant BAZ. Similar inverse associations were observed between HM fat with infant lower adiposity and BMI (Eriksen et al. 2018; Abdelhamid et al. 2020). The calcium content of human milk was negatively correlated with infant head circumference and HCZ (Reyes et al. 2023). However, a study by Eriksen et al. reported a positive association between human milk calcium with HCZ (Eriksen et al. 2018).

The limitation of the present study was a smaller sample size, as a larger sample size could cover significant variations in demographic factors and statistical analysis. The constraints associated with standardization in multiple anthropometric measurements along with breast milk collection. As all the breast milk samples were collected in the morning, diurnal variations could not be ruled out. As human milk is the sole source of nutrition for growing infants and young children, the data on human milk composition and its correlation with anthropometry are scanty in India. Also, most of the studies focussed on the composition of human milk during the early lactation period (below 6 months postpartum) only. The present study studied both (0–6 m) and (7–12 m) lactation periods. It is important to study milk composition beyond the 6 months, as complementary feeding is started along with breastfeeding in this period. These results could help in guiding the type and quantity of complementary feeding based on a child's growth needs and breast milk content. The research effort also showed the dynamics of breast milk which support the anthropometric indices for the growth and development of children.

Conclusions

As expected, the present study showed significant differences in infant anthropometry between the lactation groups (0–6 m) and (7–12 m). The majority of the mothers and infants had optimum nutrition status but significant proportions of infants were stunted and obese as per recommendations. The breast milk composition of the mothers was within range as reported in other studies and no significant differences were observed between the two lactation groups. The present findings also confirm malnutrition even among exclusively breastfed infants due to positive or negative correlations between human milk composition and the infant's nutritional status. Hence, focussing on maternal optimum nutritional status could improve breast milk composition and further growth and development of infants and young children.

Acknowledgements The authors would like to acknowledge Institute of Chemical Technology, Mumbai; University Grants Commission, Government of India for providing funding for this research.

Author contribution Suman Kumari-Maurya: Investigation, Writing—review and editing. Uday S.Annapure: Conceptualization, Methodology, Formal analysis, Writing—review and editing. Shavika Gupta: Writing—review and editing.

Funding University Grants Commission, Government of India under NET-JRF scheme Grant No. 1246 (NET-JUNE 2014).

Data availability The data will be made available on request.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethics approval The study was approved by the *Institutional Ethics Committee namely Seva Mandal Education Society's, Matunga, Mumbai (Maharashtra)* vide dated 10th July 2020 with approval no. SMEs143a (Kumari et al. 2022).

Consent to participate The study participants read the consent form and voluntarily gave consent to participate in the study.

Consent for publication The identity of the study participants will be kept confidential if the data are published.

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