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Impact of maternal nutritional supplementation in conjunction with a breastfeeding support program on breastfeeding performance, birth, and growth outcomes in a Vietnamese population

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Abstract

Purpose: This study aimed to evaluate the effects of maternal nutritional supplementation (MNS) in conjunction with a breastfeeding support program on birth outcomes and breastfeeding performance.

Methods: A total of 228 singleton Vietnamese mothers aged 20–35 years at 26–29 weeks of gestation with pre-pregnancy body mass index (BMI) < 25.0 kg/m² were randomized to the intervention (n = 114), receiving MNS (252 kcal/day) daily up to 12 weeks postpartum and four breastfeeding education and support sessions or to the control (n = 114), receiving standards of care.

Results: The intervention was 2.09 times more likely to exclusively breastfeed over the 12 weeks than the control (95%CI: 1.05–4.13, p = .0358), after controlling for potential confounders. Infant’s breast milk intake was significantly higher in the intervention than the control among mothers with baseline mid-upper arm circumference (MUAC) < 50th (p = .0251). Infants in the intervention had significantly higher birth weight (p = .0312), birth weight-for-age (p = .0141) and birth head circumference-for-age (p = .0487), and higher head circumference-for-age z-score (p = .0183) development over the postnatal period, compared with the control.

Conclusions: Use of MNS and breastfeeding support improve birth outcomes and exclusive breastfeeding (EBF) rate in Vietnamese mothers. Additionally, it promotes breast milk production among mothers with lower baseline MUAC.

Introduction

Recent evidence has demonstrated that maternal nutritional status plays an important role in birth outcomes and infant growth, especially during the “first 1000 days window” from conception until 2 years of age [1–3]. However, the prevalence of suboptimal maternal nutritional status remains high, particularly in low- and middle-income countries, due to low-nutrient density of the diets coupled with raised nutrient requirements during pregnancy and breastfeeding [4–6]. Strategies aimed to improve maternal nutritional status during both pre-natal (pregnancy) and post-natal (breastfeeding) periods have the potential to improve maternal and child health [5–7].

Numerous studies have consistently demonstrated that maternal nutritional supplementation (MNS) such as multiple micronutrient or protein-energy supplement during pre-natal period significantly increased birth weight and reduced the risk of low birthweight, compared to the control group, and this effect appeared to be more pronounced among women who were undernourished during pregnancy and those living in low- and medium-income countries [3,8–11]. The raised maternal nutritional requirements during pregnancy also play an important role in building nutrient stores to support the mother for subsequent breastfeeding which is a highly nutritionally demanding task [4,12–14]. Hence, MNS during pregnancy may help the mother better accommodate the demands of breastfeeding. Further to this, MNS provided during post-natal period may further enhance maternal milk production [15–17].

While MNS during pre-natal period has been studied extensively, only a relatively small number of studies have been specifically designed to examine...
the effects of MNS during postnatal period on maternal and child health in low-income countries. No study to date has investigated the effects of MNS during pre-natal period and continued through to post-natal period on exclusive breastfeeding (EBF) rate, birth outcomes, and infant growth. Previous research has highlighted the importance of appropriate nutrition during the “first 1000 days window” for both short-term and long-term health benefits of the offspring. Maternal nutrition during pre- and postnatal periods represents a continuum of nutrition provision for the breastfed offspring during this critical 1000 days window. Good maternal nutrition prepares the mother to meet the high-nutritional demands of breastfeeding but the mother will still need to learn the techniques of breastfeeding in order to breastfeed successfully. We hypothesized that an improved perinatal nutrition care regimen comprising daily MNS supplementation started during pregnancy and continued through to lactation, bundled together with breastfeeding education, will significantly improve breastfeeding success, offspring growth outcome at birth and postnatally compared to current standards of care.

The impact of such an improved perinatal nutrition care regimen is likely to be greater in developing countries where perinatal maternal nutrition care and maternal nutritional status remains suboptimal, such as in Vietnam [18–20]. Thus, we conducted this study to determine the effects of an improved perinatal nutrition care regimen consisting of a daily MNS starting from the last trimester until 12 weeks postpartum in combination with a breastfeeding support program on EBF rate, birth, and growth outcomes of the offspring, compared with the controls receiving standards of care in Vietnamese women.

Methods
Study design and participants

This was a prospective, randomized, open-label, parallel-group, multicenter study. It was conducted in 20 commune medical stations and district hospitals across four Northern provinces in Vietnam including Hai Phong, Ha Nam, Ninh Binh, and Thai Nguyen between October 2013 and April 2015.

Healthy pregnant women aged between 20 and 35 years, first-time mother with a singleton pregnancy from 26 to 29 weeks of gestation and pre-pregnancy BMI <25.0 kg/m² were eligible for the study. Exclusion criteria were smokers, known to be allergic or intolerant to any ingredient in the supplement, had known gestational diabetes and/or a diagnosis of pre-eclampsia, or adverse maternal or fetal conditions that could have potential effects on child’s growth and/or development. Women and their infants were also discontinued from the study if the infant was pre-term defined as gestational age <37 weeks, had a birth weight <2500 g, or had conditions for the mothers or infants after delivery, which required intensive care admission ≥24 h. For more details, please refer to the Study Inclusion and Exclusion Criteria section (Supplemental Table 1).

The present study was approved by the Independent Ethics Committees of the National Institution of Nutrition and the Ministry of Health in Vietnam. Informed written consent was obtained from each mother and her infant. The study was performed in accordance with the ethical principles that had their origin in the Declaration of Helsinki. The trial was registered at clinicaltrials.gov, registration code NCT02016586.

Intervention and control

Eligible women (n = 228) were randomized to receive either standard of care (control, n = 114) or MNS and breastfeeding support (intervention, n = 114). For each study site, sealed envelopes containing the study group assignment were prepared for both mother and her infant. Randomization schedules were computer-generated using a pseudo-random permuted blocks algorithm. According to the local standards of care, women in the control group continued to take folic acid (400 mcg) and iron (60 mg) supplement until delivery and received breastfeeding advice during prenatal visits only if this was part of standard of care at the sites. Breastfeeding advice consisting of messages on the benefits of breastfeeding and the encouragement of EBF during the first 6 months was conducted by health care staff or health workers. Breastfeeding promotion as a part of standard of care was also provided through social media such as radio and television. Although the 10 steps of Baby-Friendly Hospital Initiative by WHO were not fully implemented across participating sites, practicing rooming in, encouraging mothers to breastfeed within a half an hour of birth and breastfeed on demand are common in these settings. The intervention group received two servings of MNS daily starting from the last trimester until 12 weeks postpartum, and breastfeeding support consists of one prenatal breastfeeding class, one breastfeeding consultant visit within 48 h of delivery, one telephone call at one week postpartum, and one face-to-face follow-up session at week 4 postpartum. Details of the content for each breastfeeding
education and consultation session are included in Supplemental Table 2. The MNS was a commercially available powder product (Similac Mum; Abbott Laboratories, Vietnam) which was packaged in a 900 g tin and labeled as clinical study product for use in the study. Two daily servings of MNS provide 252 kcal, 16.8 g of protein, 1.4 g of fat, 39.2 g of carbohydrate, and a variety of micronutrients (Supplemental Table 3).

**Study outcomes**

The primary outcome was EBF rate at week 12 post-partum. Other outcomes include infant’s breast milk intake, breast milk energy content, the infant’s weight, length and head circumference (HC), the mother’s energy, macronutrient and micronutrient intakes, the mother’s body weight, BMI, and mid-upper arm circumference (MUAC).

**Breastfeeding exclusivity**

Mothers recorded the infant’s intake of breast milk and non-breast milk including formula, juice, water, and complementary foods on a daily basis. The intake information was used to assess daily EBF from birth. WHO’s definition of EBF “receiving breast milk as the only source of nutrition (including milk expressed or from a wet nurse), with no other liquids or solids except for oral rehydration solution, vitamin drops, minerals, and medicines” is used to assess breastfeeding exclusivity [21].

**Anthropometry**

Maternal and infant anthropometric measurements were performed by research staff of the National Institution of Nutrition (NIN), Vietnam who was trained on standardized methods for collecting the measurements. Maternal weight and MUAC were measured at baseline, within 48 h of delivery and weeks 4, 8, and 12 postpartum. Maternal height was measured only at enrollment. MUAC measured at baseline was used to assess the mother’s nutritional status during pregnancy. Infant’s weight, length, and HC at birth were collected from medical records. Subsequent measurements at weeks 4, 8, and 12 were conducted by the research staff. Weight-for-age, HC-for-age, and length-for-age were expressed as sex-age-specific z-scores using the WHO Child Growth Standards [22]. Small for gestational age (SGA) was defined as birth weight (BW) or birth length (BL), which was at least 2 standard deviations (SD) below the mean for the infant’s gestational age [23]. The detailed maternal and infant anthropometric data collection is presented in Supplemental Table 4.

**Breast milk intake and breast milk energy**

Breast milk intake was measured in the mother’s home at weeks 4, 8, and 12 postpartum using a standard 24-h test weighing procedure as previously described [24]. The total number of breastfeeding sessions and the duration of each breastfeeding session during each 24-h test weighing were recorded. Total milk intake was calculated by the sum of the differences in the infant’s weight before and after each nursing episode during the 24-h period. Breast milk samples for macronutrient analyses were collected between 8 am and 12 pm at weeks 4, 8, and 12 according to a standardized sampling protocol. Details of the test weighing procedures and breast milk sampling, transportation, storage, and analytical methods are presented in Supplemental Table 5.

**Dietary intake and nutritional adequacy**

Dietary intake was assessed at baseline and at weeks 4, 8, and 12 postpartum by trained research staff from NIN using a standardized 24-h food recall methodology. Mothers were asked to recall food and beverages including the supplements she consumed in the previous 24 h. Nutrient composition of the food recalls were analyzed using Vietnam Food Composition Tables. As the estimated average requirement (EAR) is only available for a number of nutrients for Vietnamese, the alternative method for assessing nutrient adequacy in this study is to use 77% of the 2016 recommended daily allowance as a cutoff value [25].

**Socio-demographic factors**

Socio-demographic factors collected included maternal age and education level, economic status by ownership of assets from an inventory of household items such as vehicles, entertainment appliances, and household appliances. An index was constructed using an established principal component analysis method [26] to weigh the contribution of each asset to the index. Information on delivery mode (natural, C-section), gestational age (weeks), and infant’s gender was collected from the medical records.

**Statistical methods**

**Sample size**

The sample size was calculated based on EBF rates at 6 months. A systematic review showed a 14.5% higher
6-month EBF rate in the intervention group receiving pre- and post-natal breastfeeding support compared to the control group receiving standard of care respectively [8]. In addition, a randomized controlled trial reported a 10% higher EBF rate at week 20 postpartum in the high-energy supplement group compared to the low-energy supplement group [16]. Therefore, it was estimated that a sample size of 228 mothers (114 per group) would be required to detect a difference of 24.5% (14.5% plus 10%) in EBF rates between groups using a two-tail test \( \alpha \) of 5% with 80% power assuming a 50% attrition rate (SAS® Version 9.2, SAS Institute, Cary, NC).

**Statistical analysis**

All the statistical analyses were performed on the intent to treat (ITT) data set using SAS, version 9.3. Descriptive data including anthropometric measurements, infant’s breast milk intake, and breast milk energy content were summarized by means and SDs. All continuous variables were checked for normality using combination methods including stem-and-leaf plot of residuals, normality plot, and Shapiro–Wilk test and declared non-normal if found significant \( p < .001 \). The nonparametric Wilcoxon test was used to examine the differences between the two groups for continuous variable with non-normal distribution. Chi-square test was used to compare all categorical variables between groups. \( p \) values \(<.0500\) is considered statistically significant and \( .0500 \leq p \) values \( .1000\) is considered a trend.

The impact of the intervention on the probability of EBF, the 24-h breast milk intake at weeks 4, 8, and 12, infant’s weight, height, and HC from birth to week 12 postpartum, maternal weight, and BMI from baseline to week 12 postpartum was examined using generalized estimating equations (GEE) with an independent correlation structure, controlling for potential confounders. In addition, analysis of covariance (ANCOVA) was used to assess the impact of the intervention on birth outcomes, controlling for confounders. With respect to maternal macronutrient intakes over time, the repeated measures analysis of variance (ANOVA) was used, after conducting the log-transformation to improve their normality. Details of factors, covariates, and modeling process GEE and ANCOVA analyses are provided in Supplemental Table 6.

In addition, a post hoc analysis was performed to determine whether the effect of the intervention on infant’s breast milk intake differed between mothers with baseline MUAC below the median (<24.1 cm) versus those with baseline MUAC equal to or above the median (≥24.1 cm).

**Results**

A total of 228 women from 26–29 weeks gestation were randomized to either the intervention group \( n = 114 \) or the control group \( n = 114 \), of whom 113 women in each study group received their assigned treatment group and were included in the ITT population. Nine subjects (7.9%) in the intervention and 13 subjects (11.4%) in the control discontinued from the study (Figure 1). The characteristics of noncompleters were not significantly different from completers in each study group with regards to nutritional status and socio-demographic factors (data not shown).

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**Figure 1.** Study flow chart.
Socio-demographic characteristics, maternal nutritional status, and delivery mode were comparable between groups (Table 1). At birth, infants in the intervention group were significantly heavier than those in the control group ($p = .0346$). There were no differences between groups in BL and HC ($p = .5195$ and $p = .1204$, respectively).

### Table 1. Mother’s characteristics at baseline and infant’s characteristics at birth.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Intervention ($N = 113$)</th>
<th>Control ($N = 113$)</th>
<th>$p$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>23.9 (2.7)</td>
<td>24.1 (3.0)</td>
<td>.8142*</td>
</tr>
<tr>
<td>Self-reported pre-pregnant BMI (kg/m²), mean (SD)</td>
<td>19.2 (1.8)</td>
<td>19.2 (1.8)</td>
<td>.8203*</td>
</tr>
<tr>
<td>Mid-upper arm circumference, mean (SD)</td>
<td>24.1 (1.9)</td>
<td>24.2 (2.4)</td>
<td>.7471*</td>
</tr>
<tr>
<td>Wealth index score</td>
<td>0.06 (1.59)</td>
<td>-0.04 (1.62)</td>
<td>.6673*</td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td>Primary 1 (0.9)</td>
<td>2 (1.8)</td>
<td>.7081*</td>
</tr>
<tr>
<td></td>
<td>Secondary 27 (23.9)</td>
<td>32 (28.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High school 43 (38.1)</td>
<td>36 (31.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>College/University 42 (37.2)</td>
<td>43 (38.1)</td>
<td></td>
</tr>
<tr>
<td>Delivery mode, n (%)</td>
<td>Normal delivery 76 (68.5)</td>
<td>80 (72.7)</td>
<td>.4872*</td>
</tr>
<tr>
<td></td>
<td>C-section 35 (31.5)</td>
<td>30 (27.3)</td>
<td></td>
</tr>
<tr>
<td>Gestational age, mean (SD)</td>
<td>39.1 (1.3)</td>
<td>39.1 (1.6)</td>
<td>.8026*</td>
</tr>
<tr>
<td>Infant’s sex, n (%)</td>
<td>Male 60 (54.1)</td>
<td>59 (53.6)</td>
<td>.9503*</td>
</tr>
<tr>
<td></td>
<td>Female 51 (46.0)</td>
<td>51 (46.4)</td>
<td></td>
</tr>
<tr>
<td>Birth weight (g), mean (SD)</td>
<td>3153 (347)</td>
<td>3044 (385)</td>
<td>.0346*</td>
</tr>
<tr>
<td>Birth length (cm), mean (SD)</td>
<td>49.0 (1.7)</td>
<td>48.7 (2.2)</td>
<td>.5195*</td>
</tr>
<tr>
<td>Head circumference (cm), mean (SD)</td>
<td>33.1 (1.3)</td>
<td>32.7 (1.6)</td>
<td>.1204*</td>
</tr>
</tbody>
</table>

* $p$ Value is from Wilcoxon test.

### Exclusive breastfeeding rate

The EBF rate in the intervention group was sustained throughout the 12-week postpartum while the control group showed a decline over time (Figure 2). The intervention was 2.09 (95%CI: 1.06, 4.13, $p = .0358$) times more likely to exclusively breastfeed than the control over 12 weeks postpartum, after controlling for potential confounders.

### Infant’s breast milk intake

There was no significant difference in infant’s breast milk intake over 12 weeks postpartum between the intervention group ($n = 104$) and control group ($n = 100$) ($p = .3258$) (data not shown). However, in a posthoc analysis, among mothers with baseline MUAC <50th percentile (24.1 cm), infants in the intervention group ($n = 54$) consumed 64.2 g more breast milk than the control group ($n = 47$) over 12 weeks postpartum ($p = .0251$), after controlling for confounders (Table 2). There were no differences between groups in the number of breastfeeding episodes and the nursing duration over the 24-h test weighing period at three collection time points ($p > .05$), except for a significantly shorter nursing duration at 8 week postpartum in the intervention group compared to the control group ($p = .0115$) (Supplemental Table 7). No significant difference was found in breast milk energy content between groups at weeks 4, 8, and 12 postpartum (Supplemental Figure 1).

Figure 2. EBF rates at weeks 4, 8, and 12 postpartum $p$ values is from GEE analysis controlling for mother’s age and MUAC at baseline, infant gender, delivery mode, and study sites.
**Birth outcomes**

The infants in the intervention had significantly higher BW ($p = .0312$), BW-for-age ($p = .0141$), and HC-for-age $z$-score ($p = .0487$), compared with the control (Table 3). There was a trend toward higher birth HC in the intervention group ($p = .0886$) (Table 3). The percentage of infants with birth HC-for-age $< -2$ SD in the intervention group was significantly lower than the control ($p = .0182$) (Supplemental Figure 2).

**Longitudinal growth over the first 12 weeks of life**

The longitudinal growth of HC and HC-for-age $z$-score in the intervention group were significantly higher than the control group ($p = .0473$ and $p = .0183$, respectively), adjusting for potential confounders (Table 3). There were trends for higher weight-for-age $z$-score ($p = .0636$) and length-for-age $z$-score ($p = .0690$) development over time in the intervention group, compared to the control group.

**Table 2.** Effect of maternal milk supplementation and breastfeeding support on infant's breast milk intake over 12 weeks postpartum among mothers with baseline MUAC $< 50$th percentile.

<table>
<thead>
<tr>
<th>MUAC $&lt; 50$ percentile</th>
<th>Breast milk intake (g)</th>
<th>Postpartum</th>
<th>GEE analysis over 12 weeks postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention ($N = 54$)</td>
<td>Control ($N = 47$)</td>
<td>$p$ Value</td>
</tr>
<tr>
<td>Week 4</td>
<td>659.7 (218.7)</td>
<td>584.7 (189.2)</td>
<td>.1066$^c$</td>
</tr>
<tr>
<td>Week 8</td>
<td>664.6 (201.3)</td>
<td>610.7 (233.6)</td>
<td>.0183$^d$</td>
</tr>
<tr>
<td>Week 12</td>
<td>695.1 (209.1)</td>
<td>646.5 (234.6)</td>
<td>.0690$^d$</td>
</tr>
</tbody>
</table>

$^a$ Value is from the preliminary GEE model.

$^b$ Value from GEE analysis controlling for mother’s age, MUAC, wealth index score, infant gender, study site, and visit.

$^c$ Infant breast milk intake data is expressed as mean (SD).

$^d$ Value is from GEE analysis controlling for mother’s age, wealth index score, infant gender, visit, and study site.

**Maternal energy and macronutrient intakes**

At baseline, more than two thirds of women in both groups had inadequate intakes of calcium, iron, zinc, vitamin A, vitamin E, vitamin B2, and folate (Figure 3). At 12 weeks postpartum, nearly 100% of mothers in the intervention group had adequate intakes of calcium, zinc, vitamin E, vitamin C, and B-vitamins, except for folate. In contrast, more than three-quarters of the breastfeeding women in the control group continued to have inadequate intake of calcium, zinc, vitamin E, and vitamin B2.

Although women in the intervention group had significantly higher intakes of energy, protein and carbohydrate (Supplemental Table 8), body weight, and BMI of this group were similar to the control group over the study period (both $p > .05$) (Supplemental Figure 3).

Adverse events (AEs) were reported in 17 (15.0%) and 11 (9.7%) mothers in the intervention and control groups, respectively. The majority of AEs were gastrointestinal disorders with seven AEs in the intervention group and six AEs in the control group. Overall, there were no statistically significant differences or clinically relevant trends between the groups for any system-related AEs. In terms of serious adverse events (SAEs), there were 68 mothers (35 [31.0%] in the intervention group and 33 [29.2%] in the control group) with at least 1 SAE. The majority of SAEs were for conditions occurring during labor and delivery. The most frequently reported cause for C-section delivery was for cephalo-pelvic disproportion, which was reported by 11 (9.7%) mothers in the intervention group and 8 (7.1%) subjects in the control group. There were no statistically significant differences between the groups or clinically relevant trends for any SAEs (data not shown).

**Table 3.** Effects of MNS and breastfeeding support on birth outcomes and growth outcomes from birth to 12 weeks of postnatal period.

<table>
<thead>
<tr>
<th>Growth parameters</th>
<th>Estimate (95% CI)</th>
<th>$p$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Birth outcomes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>92 (8,176)</td>
<td>Reference</td>
</tr>
<tr>
<td>Birth length (cm)</td>
<td>0.1 (–0.3, 0.6)</td>
<td>Reference</td>
</tr>
<tr>
<td>Birth head circumference (cm)</td>
<td>0.3 (0.0, 0.6)</td>
<td>Reference</td>
</tr>
<tr>
<td>Birth weight-for-age $z$-score</td>
<td>0.25 (0.05, 0.45)</td>
<td>Reference</td>
</tr>
<tr>
<td>Birth length-for-age $z$-score</td>
<td>0.18 (–0.10, 0.46)</td>
<td>Reference</td>
</tr>
<tr>
<td>Birth head circumference-for-age $z$-score</td>
<td>0.31 (0.00, 0.62)</td>
<td>Reference</td>
</tr>
<tr>
<td><strong>Longitudinal growth from birth to 12 weeks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (g)</td>
<td>68.7 (–34.2, 171.7)</td>
<td>Reference</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>0.27 (–0.1, 0.6)</td>
<td>Reference</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>0.26 (0.005, 0.52)</td>
<td>Reference</td>
</tr>
<tr>
<td>Weight-for-age $z$-score</td>
<td>0.16 (–0.03, 0.36)</td>
<td>Reference</td>
</tr>
<tr>
<td>Length-for-age $z$-score</td>
<td>0.19 (–0.01, 0.39)</td>
<td>Reference</td>
</tr>
<tr>
<td>Head circumference-for-age $z$-score</td>
<td>0.28 (0.05, 0.51)</td>
<td>Reference</td>
</tr>
</tbody>
</table>

$^a$ Value is from ANCOVA analysis controlling for gestational age and infant gender.

$^b$ Value from ANCOVA analysis controlling for mother’s age, mother’s MUAC at baseline, wealth index score, gestational age, infant’s sex, and visit.

$^c$ Value from GEE analysis controlling for mother’s age, mother’s MUAC at baseline, wealth index score, gestational age, infant’s sex, and visit.

$^d$ Value is from GEE analysis controlling for mother’s age, wealth index score, infant gender, visit, and study site.
Discussion

In this study, MNS during the last trimester of pregnancy significantly improved birth outcomes in Vietnamese mothers. Combining MNS with a breastfeeding support program during postpartum period increased and sustained EBF rate, and promoted postnatal growth in the offspring. In addition, the intervention increased breast milk production among mothers with baseline MUAC < 24.1 cm.

In the present study, MNS consumption during the last trimester of pregnancy was effective in promoting better birth outcomes including BW, BW-for-age, and birth HC-for-age z-scores, as well as reducing the risk of birth HC-for-age < -2 z-scores. Our findings are consistent with previous studies demonstrating the positive impact of MNS containing energy and protein during pregnancy on improving BW and reducing the risk of SGA [8]. To our knowledge, only one study reported a significant increase in the crude birth HC measurements by 3.1 mm in chronically undernourished women around 20 weeks gestation receiving a high-energy supplement of 1017 kcal, 22 g protein, and 56 g fat compared with an unsupplemented control group [27]. Our findings suggest that MNS consumption during the last trimester improves the intake of nutrients important to fetal growth and development, and thereby improves birth outcomes and reduces risk of SGA in this population.

Numerous studies showed that breastfeeding support with formal or structured breastfeeding education during prenatal, postnatal, or combined, significantly increased EBF rates during the first 6 months postpartum [28]. However, an intensive breastfeeding support program including hospital counseling visit and seven home visits during 4 months postpartum showed to increase EBF but did not affect infant milk intake as measured by an isotopic method [29]. On the other hand, a randomized, double-blind study in undernourished mothers in Guatemala showed that high-energy food supplementation from 5 to 25 weeks postpartum sustained the EBF rate better than the control group [16]. The same study also found higher infant’s milk intake (by 64 g/day at weeks 25) among those who were more severely undernourished, defined as calf circumference ≤ 29.5 cm. In the present study, our intervention aimed to promote adequate nutritional intakes during pregnancy and breastfeeding through MNS, coupled with the provision of breastfeeding support. The intervention significantly improved and sustained EBF rate over 12 weeks postpartum. Similar to the Guatemala study, we also found significantly higher infant’s milk intake (64 g/day over the 12 weeks) in the intervention group among mothers with MUAC baseline < 24.1 cm when compared with the control group, despite that women in our study had higher mean BMI and MUAC at weeks 4 postpartum.
compared to Guatemala study. As there were no significant between-group differences in the number of nursing episodes during 24-h test weighing and the nursing duration at most postpartum time points, it is possible that the increased infant’s milk intake is due to the increased breast milk production in the supplemented mothers with baseline MUAC <24.1 cm. Collectively, the results from our study and previous research suggest that combining MNS (during pregnancy and breastfeeding) and breastfeeding support increase breast milk production to enable mothers to exclusively breastfeed, and this effect appears to be more pronounced among mother with lower baseline nutritional status.

The present study also showed that continuation of MNS during breastfeeding period improved head growth over time, in both actual measurement, and sex- and age-specific z-scores. The significantly higher infant weight at birth was weakened in trend over the 12-week postnatal period. This could be explained by the lower rate of EBF in the control group leading to supplementing breast milk with formula, which is known to have higher energy content compared with breast milk. Although birth length was not significantly different between groups, the trend of greater length for age z-score development over time was observed in the intervention group. The trend of higher breast milk intake was not statistically significantly different between groups. Therefore, we expected the milk energy and macronutrients to be of higher concentrations in the intervention compared with the control group. However, we did not observe this probably because of single milk sampling instead of multiple samplings over a 24-h period where the concentration of fat, lactose, and total protein were shown to be associated with feeding patterns, and therefore varied over the 24-h period [30,31].

The present study has some limitations. This was a nonblinded open-label study design; therefore there could be a risk of bias in the process of administering the study procedures to the two study groups, as well as the identification or reporting of interested outcomes due to knowledge of the subjects’ treatment status. However, we implemented blinded assessor to minimize the risk of bias. Although test weighing for assessing infant’s breast milk intake is commonly used, its limitations have been discussed [32]. The use of a single 24-h food recall imparts limitations on sufficient characterization of a subject’s usual intake as a result of day-to-day variation. Lastly, we do not have prospective data on EBF at 6 months for evaluating the impact of the intervention in increasing the EBF rate at 6 months as recommended by WHO.

In summary, continuation of maternal milk supplementation from the last trimester to the first 12 weeks postpartum, coupled with breastfeeding support showed to improve birth outcomes and EBF rates, when compared with the current pre- and postnatal care. This intervention model also increased breast milk production in Vietnamese mothers with pregnancy MUAC <24.1 cm. Given that the right nutrition during the first 1000 day window has a profound impact on a child’s ability to grow, learn, and thrive and that poor nutrition early in life has lasting effects on lifelong health [6]. The findings of this study suggest a low-fat and nutrient-dense MNS during pregnancy and breastfeeding has a positive impact on improving growth during this critical window.

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