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Local Food-Based Supplementation and Behavior Change Communication Improve Mid-Upper Arm Circumference (MUAC) in Pregnant Women: A Community-Based Intervention Study

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ABSTRACT

Chronic Energy Deficiency (CED) in pregnant women remains a major nutritional issue in Indonesia and contributes to adverse birth outcomes and the risk of childhood stunting. Community-based interventions that integrate nutrition education and food supplementation have shown promise but remain underutilized. This study aimed to evaluate the effectiveness of an integrated nutrition intervention, consisting of Behavior Change Communication (BCC)-based education and local food-based supplementary feeding (PMT), on improving the Mid-Upper Arm Circumference (MUAC) and nutritional status of pregnant women in high-stunting prevalence areas. A 16-week quasi-experimental pre–post study was conducted among 175 pregnant women in Purbalingga, Serang, and Bogor, Indonesia. Participants received weekly group-based BCC education and daily local snack supplementation (⩾350 kcal/day). MUAC, weight, BMI, hemoglobin levels, and dietary adequacy (energy, protein, fat, carbohydrate) were assessed pre- and post-intervention. Data were analyzed using the Wilcoxon Signed-Rank test and multiple linear regression. The mean MUAC increased significantly from 22.7 ± 1.1 cm to 23.6 ± 1.0 cm ($p < 0.001$), with a 27.4% reduction in CED prevalence. Regression analysis indicated that dietary compliance and baseline hemoglobin were strong predictors of MUAC improvement. The intervention also significantly increased maternal weight, BMI, and hemoglobin levels, while protein adequacy showed the most substantial improvement, aligning dietary intake more closely with national recommendations. The integration of BCC-based education with local PMT significantly improved maternal nutritional outcomes, particularly MUAC, protein adequacy, and hemoglobin status, thereby reducing the risk of CED and anemia. This dual-component approach is feasible for community-level stunting prevention and supports its inclusion in antenatal care services.

Key Messages:

- An integrated nutrition intervention, combining Behavior Change Communication (BCC) education with local food-based supplementary feeding (PMT), effectively improves maternal nutritional status by increasing MUAC and hemoglobin levels, thereby reducing the prevalence of Chronic Energy Deficiency (CED) among pregnant women.

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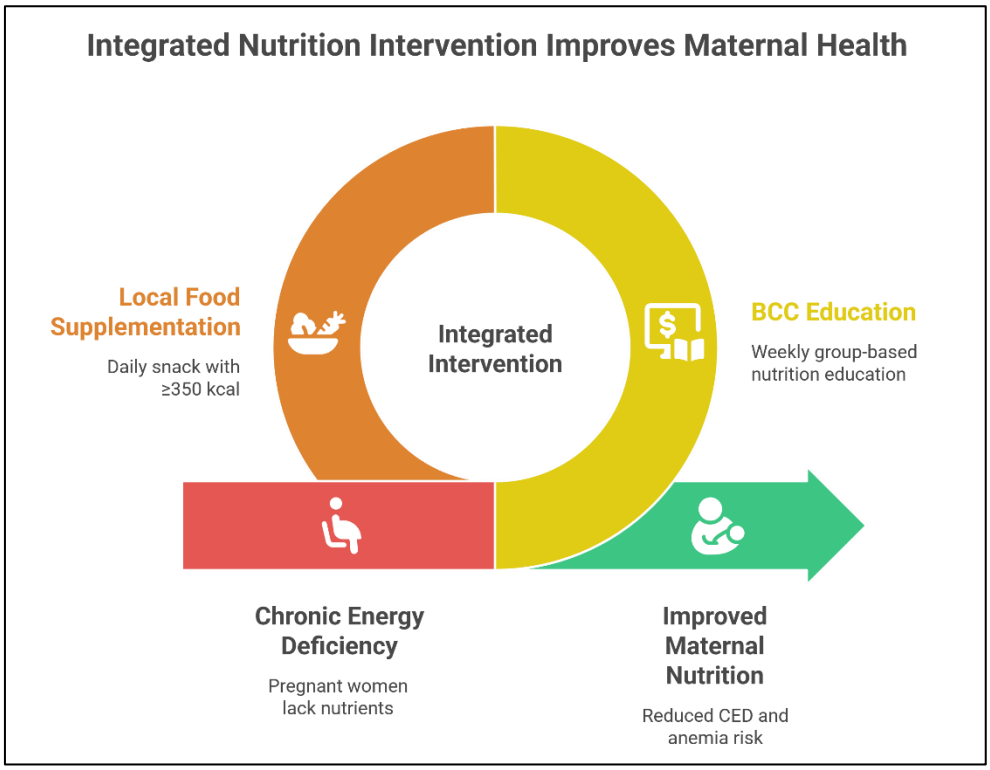
GRAPHICAL ABSTRACT



INTRODUCTION

Maternal undernutrition, particularly Chronic Energy Deficiency (CED), remains a pressing public health issue globally, with significant consequences for maternal and neonatal health outcomes (1). According to Keats et al. (2019)(1), more than 40% of pregnant women in developing countries are affected by CED, increasing the risk of low birth weight (LBW), preterm delivery, intrauterine growth restriction, and neonatal mortality. In Indonesia, the situation is similarly concerning; national data from the 2018 Basic Health Research (Riskesdas) indicated a CED prevalence of 17.3% (2), which escalated to 24.4% by 2022 according to the Indonesian Nutrition Status Survey (SSGI) (3).

The underlying drivers of this trend include limited nutritional literacy, poor access to diverse and healthy foods, and a lack of community-level nutrition education (4). These findings highlight the urgency of implementing comprehensive, community-based interventions tailored to the needs of pregnant women, especially those in resource-limited settings.

One promising approach is the implementation of local food-based supplementary feeding programs (locally known as *Pemberian Makanan Tambahan* or PMT). These interventions, utilizing affordable, culturally acceptable, and locally sourced foods, have shown significant potential in improving maternal energy intake and anthropometric indicators, such as hemoglobin levels and MUAC. Susanto et al. (5) demonstrated that structured PMT significantly enhanced hemoglobin concentration and dietary energy adequacy within a three-month period.

However, the effectiveness of PMT is notably amplified when combined with Behavior Change Communication (BCC) strategies. Damayanti et al. (6) emphasized that participatory nutrition education increased pregnant women's attendance at *posyandu* (community health posts), and improved their dietary behaviors and adherence to nutritional guidelines.

According to the Indonesian Ministry of Health (7), pregnant women require increased energy and protein across trimesters +180 kcal/day and +1.2 g/day protein in the first trimester; +300 kcal and +6.1 g protein in the second; and +450 kcal and +10.5 g protein in the third trimester. These recommendations align with global guidelines, including those from the World Health Organization WHO (8), which advocate

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for additional energy intake of 350–450 kcal/day and higher consumption of high-quality protein, particularly among women with CED or at risk of nutritional deficiencies.

Recent evidence underscores the importance of tracking anthropometric changes such as Mid-Upper Arm Circumference (MUAC) to assess the impact of interventions on maternal nutrition status. A 2025 study conducted by Hussain et al. (9) titled *"Impact of the Mamta UNICEF: A Fortified Food Nutrition Program on Childhood Malnutrition During Pregnancy in Pakistan,"* found significant improvements in MUAC following a 12-week fortified feeding intervention that combined food assistance with BCC. Therefore, this study aimed to evaluate the effectiveness of an integrated intervention, consisting of Behavior Change Communication (BCC)-based nutrition education and local food-based supplementary feeding, in improving the mid-upper arm circumference (MUAC) and nutritional status of pregnant women in high-stunting prevalence areas.

This study is strengthened by its contextualization within both national and global dietary standards. The design of the intervention closely followed the Indonesian Recommended Dietary Allowance (AKG 2019) (7) and the WHO (2019) guideline on maternal nutrition, ensuring that the provision of local supplementary foods and the nutrition education delivered through BCC were evidence-based and aligned with international best practices. This contextual alignment enhances the relevance of the study findings for both national policy and broader maternal health strategies.

METHODS

Design and Subjects

This study used a quasi-experimental pretest-posttest single-group design. A total of 175 pregnant women in their first or second trimester (≤26 weeks gestation) were recruited from three high-stunting districts in Indonesia: Purbalingga, Serang, and Bogor, using purposive sampling. All participants were clinically healthy and agreed to complete the 16-week intervention (17).

The sample size was estimated to detect a moderate effect size (Cohen's d = 0.4) with 80% power and a 5% significance level, with additional allowance for potential dropout. Subject selection followed inclusion and exclusion criteria adapted from Hardinsyah et al. (17):

- Inclusion criteria: Gestational age ≤26 weeks, no chronic illness, residence in target areas, willingness to participate.
- Exclusion criteria: Severe pregnancy complications, comorbid conditions (e.g., hypertension, TB, malaria), or intent to relocate during the study.

Intervention Procedures

The supplementary feeding intervention involved a 5-day/week meal plan for 16 weeks, composed of culturally adapted, nutrient-dense local snacks and lunches. Meals were prepared by trained local volunteers and consumed on-site at Posyandu. If participants were unable to attend, meals were sent home with written guidance.

Monitoring of consumption was conducted through daily logbooks, which were completed and verified by community health workers on a weekly basis. Participants with ≥80% adherence were categorized as "high compliance."

Each PMT package provided 350–500 kcal/day, with 10–20g protein, 10–15g fat, and 50–70g carbohydrates per portion. Recipes were modified to accommodate local preferences and underwent nutritional analysis.

Table 1. Examples of PMT Snack Packages

Package	Contents
1	Chicken Lemper (sticky rice with chicken) + Serabi Kinca (palm syrup pancake)
2	Dadar Gulung (coconut pancake roll) + Chicken Pastel (savory pastry)
3	Sosis Solo (chicken/beef roll) + Talam Jagung (steamed corn cake)
4	Cilok with chicken and peanut sauce
5	Chicken Risoles + Bolu Kukus (steamed sponge cake)
Reserve Menu	Cilok with quail egg filling

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Table 2. Examples of Lunch Packages

Package	Contents
1	Ketoprak Telur (rice cake with tofu, egg, peanut sauce) + Watermelon
2	Steamed rice + Fried chicken + Sweet soy tempeh + Sayur Asem + Melon
3	Lontong Kari Ayam (rice cake with chicken curry) + Orange

All meals were adjusted to meet Indonesian Recommended Dietary Allowance (locally known as Angka kecukupan Gizi or AKG) for pregnant women, without added fortification.

Behavior Change Communication (BCC) Intervention

Behavior Change Communication (BCC) was a central component of the intervention, designed to address the nutritional vulnerabilities of pregnant women at risk of Chronic Energy Deficiency (CED) in high-stunting areas of Indonesia. This approach combined structured nutrition education with the provision of locally sourced supplementary food (Pemberian Makanan Tambahan/PMT) to translate knowledge into practical, sustained behavioral change. The BCC strategy emphasized culturally appropriate content, community involvement, and household-level support to ensure relevance and acceptability. Sessions were embedded in existing community health platforms such as *Posyandu* (integrated health posts), which facilitated both accessibility and trust.

The BCC program was delivered once weekly over a period of 16 consecutive weeks, with each session lasting approximately 60–90 minutes. Educational content was developed from the national nutrition guidelines and adapted from the Gerakan Anak Sehat – Kolaborasi Inklusi Pengusaha Indonesia Atasi Stunting (GAS–KIPAS Stunting) program to ensure alignment with government stunting reduction strategies. Topics covered included: nutritional needs during pregnancy, anemia prevention, protein and micronutrient requirements, balanced meal composition, breastfeeding and complementary feeding practices, prevention of common maternal–child nutritional problems, clean and healthy living behaviors (Perilaku Hidup Bersih dan Sehat or PHBS), and food safety.

Sessions were led by trained facilitators, including nutrition lecturers and students, midwives, community nutritionists, and posyandu cadres. Educational delivery used interactive and visual tools such as flipcharts, illustrated leaflets (distributed for home reference), recipe demonstrations, and WhatsApp group discussions for ongoing reinforcement. Each meeting was accompanied by the distribution of PMT, consisting of nutrient-dense snacks and lunches providing 350–500 kcal/day with balanced macronutrients and adequate micronutrients. PMT was consumed on-site whenever possible; in cases where attendance was not feasible, participants were allowed to take it home. Compliance was monitored through daily consumption logbooks and verified weekly by facilitators.

To foster sustained adoption of healthy practices, participants were encouraged to attend with key family members such as spouses or mothers-in-law. This approach aimed to enhance the social support system around pregnant women, ensuring that nutrition messages were reinforced at the household level. Attendance and participation were tracked weekly, while informal knowledge checks and discussions were used to assess retention of key concepts. At the end of the 16-week cycle, all participants underwent a final evaluation, including anthropometric and hemoglobin measurements, to assess the intervention's impact.

BCC and PMT Intervention Flow

1. Baseline Screening – Identification of eligible pregnant women based on gestational age (≤26 weeks), health status, and residency. Informed consent obtained, baseline anthropometry and hemoglobin measurements taken.
2. Weekly Cycle (Weeks 1–16):
   - BCC Session (nutrition education, discussions, demonstrations)
   - PMT Distribution (snack + lunch package, 350–500 kcal)
   - Compliance Monitoring (logbooks, facilitator verification)
3. Monthly Review – Assessment of attendance, compliance, and barriers; refresher sessions provided if needed.

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4. Endline Evaluation (Week 16) – Final measurements (MUAC, weight, BMI, hemoglobin) and participant feedback; documentation of outcomes for program evaluation.

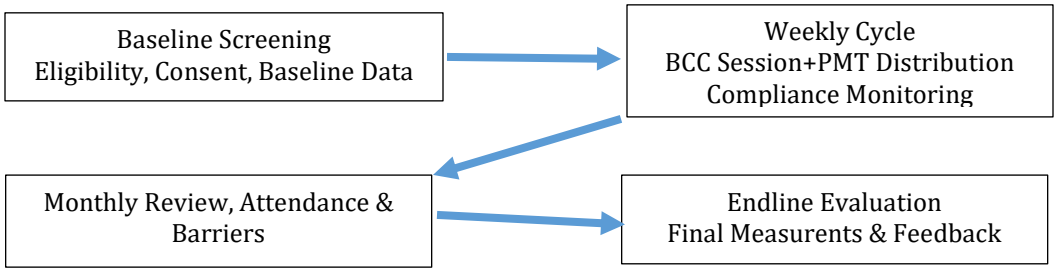

Figure 1. BCC and PMT Intervention Flow

Data Collection and Analysis

Data on MUAC, weight, BMI, and hemoglobin were collected at baseline and endline (week 16). Dietary intake was assessed using semi-quantitative Food Frequency Questionnaires (FFQ) and 24-hour recalls, analyzed with the Indonesian Food Composition Table (locally known as Daftar Komposisi Bahan Makanan—DKBM). Data were analyzed descriptively and inferentially. The Wilcoxon signed-rank test compared pre- and post-intervention outcomes. Multiple linear regression identified predictors of MUAC change (ΔMUAC), with baseline MUAC, baseline hemoglobin, and snack compliance as independent variables. Assumptions of normality, multicollinearity (VIF < 5), and homoscedasticity were checked. Analysis was performed in R with $\alpha < 0.05$.

CODE OF HEALTH ETHICS

This study was approved by the Health Research Ethics Committee of Universitas Muhammadiyah Semarang (No.: 202/KE/09/2023).

RESULTS

Subject Characteristics

Most participants were aged 20–35 years (84%), unemployed (74.29%), and from low-income households (77.71% earned below the regional minimum wage). At baseline, 30.29% had CED (MUAC <23.5 cm), and 51.4% were anemic (Hb <11 g/dL).

Table 3. Sociodemographic Characteristics

Variables	n	%
Maternal Age (years)		
- <20 or > 35	28	16,00
- 20–35	147	84,00
Education		
- Junior High School	110	62,86
- Senior High School	64	36,57
- Primary	1	0,57
Occupation		
- Unemployed	130	74,29
- Employed	45	25,71
Income		
- <Local Minimum Wage	136	22,29
- ≥Local Minimum Wage	39	77,71
Gestational Age		
- First Trimester	61	34,86
- Second Trimester	114	65,14
Parity		
- Primigravida	16	9,14
- Multigravida	159	90,86

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Variables	n	%
CED (MUAC <23.5 cm)		
- Yes	48	30,29
- No	127	69,71
BMI		
- Underweight	41	23.43
- Normal	92	52.57
- Overweight	34	19.43
- Obese	8	4.57
Anemic status (g/dL)		
- Moderate Anemia (7–9.9)	25	14.3
- Mild Anemia (10-10.9)	65	37.1
- Not Anemic	85	48.6
Tribe		
- Javanese	105	60,00
- Sundanese	62	35,43
- Betawi	5	2,86
- Batak	2	1,14
- Dayak	1	0,57

The Purbalingga Regency Minimum Wage (RMW) for 2025 is Rp. 2,338,283.12; The Regional Minimum Wage (RMW) for Serang City in 2025 is Rp. 4,418,261; The Regional Minimum Wage (RMW) for Bogor Regency in 2025 is Rp. 4,877,211; Low income is defined as less than the RMW, and high income is defined as more than the RMW.

In the Indonesian national health system, Mid-Upper Arm Circumference (MUAC) has been formally recognized as a practical and effective anthropometric measure to assess the risk of Chronic Energy Deficiency (CED) in pregnant women. As stipulated in the Maternal and Child Health Book and Regulation No. 28 of 2019 on Nutritional Adequacy Standards (AKG) (locally known as Angka Kecukupan Gizi or AKG) by the Ministry of Health, a MUAC value of less than 23.5 cm is considered a threshold for identifying pregnant women at elevated nutritional risk. This standard provides a rapid, field-applicable tool for frontline health workers to identify women requiring immediate nutritional intervention, especially in resource-constrained settings.

In the current study, the mean MUAC increased from 22.7 cm to 23.6 cm after a structured nutrition intervention program, crossing the national clinical cutoff and indicating a shift from a risk zone to a safer nutritional status. Clinically, this change suggests not only an improvement in maternal muscle mass and energy stores but also a reduction in associated risks such as obstetric complications, intrauterine growth restriction (IUGR), and stunting in infants (22). A shift above this threshold is particularly critical given that MUAC correlates with maternal fat-free mass and fetal birth outcomes (16).

To achieve this impact, the intervention was meticulously aligned with both national and international dietary recommendations. The 2019 Indonesian AKG recommends incremental increases in energy and protein requirements throughout pregnancy: +180 kcal/day and +1.2 g protein/day in the first trimester, +300 kcal and +6.1 g protein in the second, and +450 kcal and +10.5 g protein in the third trimester (7). These guidelines were mirrored by the World Health Organization's 2020 guideline on "Nutrition Actions Effective in Improving Maternal and Child Nutrition," which calls for an additional 350–450 kcal/day and increased protein intake, especially for malnourished or at-risk women (14).

The intervention meals in this study comprising locally sourced healthy snacks (354–414 kcal; 8.8–28 g protein per serving) and nutrient-dense lunches (746–802 kcal; 26.9–68.4 g protein per serving), were specifically formulated to meet or exceed these recommended increases. As such, the dietary provision not only fulfilled the additional energy and macronutrient needs of the target population but did so in a culturally adapted and sustainable manner, leveraging affordable local ingredients.

The observed 0.9 cm increase in MUAC over the intervention period is both statistically and programmatically meaningful. Statistically, this change represents a clinically relevant improvement in maternal nutritional status, especially among those who initially fell below the national cutoff. Programmatically, this shift reinforces the value of integrating Behavior Change Communication (BCC) strategies with local food-based supplementary feeding (PMT) programs. The combination of nutrition

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education and culturally relevant food interventions enhances both knowledge and compliance, yielding better outcomes than food provision alone (10).

These findings support policy recommendations to scale up integrative community-based interventions as part of Indonesia's national strategy to combat CED and prevent stunting. Tailoring interventions to sociocultural preferences, food availability, and existing public health infrastructure, such as posyandu (community health posts), ensures greater sustainability and impact. The present evidence contributes to a growing body of research advocating for multisectoral, behavior-focused nutrition programs as a cornerstone of maternal and child health improvement efforts in low- and middle-income countries.

Dietary intake data were collected through structured interviews using a semi-quantitative Food Frequency Questionnaire (FFQ) and 24-hour dietary recalls. These tools assessed energy and macronutrient intake, which were then analyzed using the Indonesian Food Composition Table (DKBM). Compliance with supplementary feeding (PMT) was monitored through daily consumption logbooks, verified weekly by community health workers.

Table 4 shows the percentage adequacy of energy and macronutrients among pregnant women before and after the intervention. Significant increases were observed across all nutrients. The intervention improved the adequacy of energy, protein, fat, and carbohydrate intake compared to baseline values, with the highest increase observed in protein adequacy.

Table 4. Percentage adequacy of energy, protein, fat, and carbohydrates among pregnant women before and after intervention (n=175)

Nutrient	RDA for Pregnant Women (AKG 2019)	Before Intervention (% RDA, Mean ± SD)	After Intervention (% RDA, Mean ± SD)	p-value
Energy (kcal)	2,450–2,600 kcal	78.5 ± 12.3	95.7 ± 10.8	<0.001
Protein (g)	75–85 g	72.1 ± 13.5	96.4 ± 11.2	<0.001
Fat (g)	65–70 g	70.3 ± 14.1	88.2 ± 12.7	0.002
Carbohydrate (g)	360–400 g	74.5 ± 15.8	91.6 ± 13.9	<0.001

Percentages were calculated by dividing actual intake by the Indonesian Recommended Dietary Allowance (AKG 2019) for pregnant women.

Table 5. Comparison Before and After Intervention

Variable	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Δ Change	p-value
Body Weight (kg)	53,8 ± 5,1	59,6 ± 5,0	+5,8	0,001
BMI (kg/m^2)	22,8 ± 12,6	24,3 ± 12,7	+1,5	0,001
MUAC (cm)	22,7 ± 1,1	23,6 ± 1,0	+0,9	0,001
Hb (g/dL)	10,8 ± 1.,1	11,6 ± 1,0	+0,8	0,001

Multiple Linear Regression

Table 6. Multiple Regression with Δ MUAC as Y

Variabel Prediktor	β Coefficient	95% CI	Δ Change	p-value
Snack Compliance	0.41	0.23–0.59	+4.1 ± 1.8	0,001
Baseline Hb	0,28	0.11–0.45	+1.5 ± 0.7	0,002
Baseline MUAC	0,32	0.15–0.49	+0.9 ± 0.4	0,001

Adjusted R^2 = 0.17

DISCUSSION

Recent studies have increasingly emphasized the significance of integrating nutrition education with supplementary feeding to effectively improve maternal nutrition indicators such as Mid-Upper Arm Circumference (MUAC) and hemoglobin levels. The present study observed a mean increase of 0.9 cm in MUAC over a 16-week intervention period. Regression analysis identified adherence to the consumption

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of healthy local snacks as the strongest predictor of MUAC improvement, underscoring the role of dietary compliance in maternal nutrition programs.

The findings of this study demonstrate that the combined intervention of nutrition education based on Behavior Change Communication (BCC) and local food supplementation significantly improved the adequacy of energy and macronutrient intake among pregnant women. These improvements were statistically significant and were most pronounced in protein adequacy. The improvement helped align pregnant women's dietary intake with the Indonesian Recommended Dietary Allowance (AKG 2019). This is of particular importance given that protein plays a crucial role in fetal growth and in preventing chronic energy deficiency (CED). The rise in carbohydrate and fat adequacy also indicates that the local food-based supplementation was appropriately designed to meet maternal nutritional needs, aligning with national and international guidelines. Moreover, this improvement in nutrient adequacy may explain, at least in part, the significant increase in maternal weight gain observed in this study.

These findings align with those of Damayanti et al. (6), who demonstrated that combining nutrition education and local food supplementation in urban Jakarta led to significant improvements in pregnancy weight gain, MUAC, and hemoglobin status. Similarly, Hanley-Cook et al. (12) confirmed that balanced energy-protein (BEP) supplementation, when provided alongside nutrition education, had a notable effect on improving pregnant women's weight gain and hemoglobin levels in rural South Asia and sub-Saharan Africa.

The pivotal role of the BCC component itself is further underscored by a cluster randomized trial in Ethiopia. Gebremichael and Lema (23) demonstrated that a BCC intervention delivered solely by community health volunteers (Health Development Army), without supplementary feeding, successfully increased the proportion of pregnant women with optimal dietary practices from 34.9% to 65.1% (23). This finding confirms that a well-structured BCC strategy is a profoundly effective intervention on its own, and its effect is amplified when integrated with food-based strategies, as demonstrated in the present study.

Our findings are consistent with the study by Kundarti et al. (21), which demonstrated that supplementation with *Spirulina platensis* significantly improved MUAC and reduced the prevalence of CED among pregnant women in Malang, Indonesia. In their intervention group, MUAC increased by an average of 1.29 cm within 30 days, and 67% of participants were no longer classified as CED compared to only 7% in the control group. These results strengthen the evidence that locally appropriate supplementation strategies, whether through food-based PMT or nutrient-dense natural supplements such as Spirulina—are effective in addressing maternal undernutrition and its associated risks.

In addition, our findings align with previous research emphasizing the critical role of maternal diet quality in preventing anemia and chronic energy deficiency. For example, a study in Indonesian coastal areas reported that seafood consumption alone was insufficient to prevent anemia, as non-heme iron from fish has lower bioavailability compared to heme iron sources such as red meat and liver (18). This highlights the importance of dietary diversity and complementary supplementation strategies, which in our study were addressed through the provision of local food-based PMT. Furthermore, Yanti et al. (2024) demonstrated that CED and anemia in pregnant women significantly increased the risk of low birth weight, underscoring the urgency of improving maternal nutritional status during pregnancy.

Similarly, the relationship between macronutrient intake and hemoglobin levels in pregnant women remains complex. Zalfa et al. (20) reported that energy, protein, iron, and calcium intake showed no significant correlation with hemoglobin levels among pregnant women in Bogor Regency. However, the authors emphasized that adequate intake combined with regular iron and calcium supplementation is still essential to prevent anemia during pregnancy. This finding reinforces our results, particularly the strong negative contribution of iron deficiency to maternal weight gain, suggesting that dietary interventions should be complemented by supplementation strategies to achieve optimal maternal nutritional outcomes.

Studies from Indonesia further reveal that nutrition education without complementary food support tends to have limited effectiveness in achieving meaningful anthropometric changes. Birner and Grosse (11) found that educational programs alone failed to significantly raise MUAC or hemoglobin levels

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among pregnant women, especially in food-insecure households. This emphasizes the importance of integrated interventions that simultaneously address both knowledge and access to nutritious food.

International studies mirror these outcomes. For instance, Tamiru et al. (15) in Ethiopia observed that the simultaneous provision of education and local food-based supplementation significantly improved MUAC, dietary diversity scores, and hemoglobin among pregnant women in agrarian communities. These findings highlight the critical role of culturally relevant and accessible nutrition support in achieving sustainable outcomes.

These conclusions are supported by a meta-analysis by Lassi et al. (24), which demonstrated that combining nutrition education with supplementary feeding programs reduces the incidence of anemia and low birth weight (LBW) through improvements in maternal nutrient intake and dietary **practices**. Furthermore, the comprehensive Cochrane Review by Keats et al. (1) affirmed that integrating behavior-centered education with food-based interventions is an effective and sustainable strategy for improving maternal nutrition in low- and middle-income countries.

Figure 2. Sample Snack and Lunch Menu for Pregnant Women and Mothers with Children Under Two (1 cycle per week – 5 menu varieties)

Figure 3. Saturday – Cycle Options

1. Cycle 1: Vegetable Salad with Egg and Peanut Sauce + Sliced Watermelon
2. Cycle 2: Steamed Rice + Fried Chicken + Sweet Soy Tempeh + *Sayur Asem* Tamarind Soup + Melon
3. Cycle 3: Rice Cake with Chicken Curry + Orange.

In a recent study conducted in the Bukavu region of the Democratic Republic of the Congo, Beitze (25) assessed the nutritional outcomes of mothers with low MUAC. The study found that those receiving both nutrition education and food supplementation showed markedly better progress in anemia reduction compared to those receiving education alone. This further confirms the value of dual-component interventions in addressing maternal malnutrition in complex, resource-poor settings (25).

Despite these promising outcomes, several limitations of this study warrant careful interpretation. The quasi-experimental design without a control group introduces the possibility of external confounding variables, making it difficult to attribute causality solely to the intervention. Furthermore, self-reported adherence to snack consumption may be influenced by social desirability bias, suggesting a need for objective compliance tracking in future studies. Additionally, unmeasured confounders such as household food insecurity, maternal infection status, and psychosocial stress were not included in the regression model.

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Future research should aim for randomized controlled trial (RCT) designs with larger, diverse populations, extended intervention periods, and multilevel analysis that includes socioeconomic and environmental determinants of maternal health. Objective dietary compliance measures (e.g., biomarkers or digital monitoring) would also enhance data reliability and program evaluation.

CONCLUSION

This study demonstrates that integrating Behavior Change Communication (BCC)-based nutrition education with local food supplementation significantly improved maternal nutritional outcomes, particularly MUAC, weight, hemoglobin, and dietary adequacy of protein and energy. Compliance with food supplementation emerged as the strongest predictor of MUAC improvement, highlighting the importance of adherence in achieving meaningful nutritional change. These findings support the effectiveness of dual-component interventions in addressing maternal chronic energy deficiency and preventing adverse outcomes such as anemia and low birth weight. Local food-based supplementation, when combined with culturally appropriate nutrition education, represents a feasible and sustainable strategy for inclusion in community-level stunting prevention and antenatal care programs in Indonesia and similar contexts.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

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