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Original Research Article

Impact of nutrition education on maternal hemoglobin and calcium levels during pregnancy and their association with birthweight in an Indian cohort

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ABSTRACT

Background: Maternal nutrition during pregnancy is pivotal for fetal growth, neonatal health, iron stores across infancy and adolescence, and future adult disease risk. In India, this role is especially important because anemia, micronutrient deficiencies, and protein-energy malnutrition remain widespread despite national supplementation programmes. Many women still experience suboptimal outcomes due to poor dietary diversity and inconsistent adherence to iron, calcium, and protein recommendations. This study examined the effect of trimester-specific nutrition education on maternal hemoglobin and calcium levels during pregnancy. It examined whether these changes were associated with birth weight in an Indian cohort.
Methods: A prospective quasi-experimental cohort study was conducted at a tertiary care hospital in New Delhi among 200 pregnant women, systematically allocated to an intervention group receiving structured nutrition education or a control group receiving standard antenatal care. Maternal anthropometry, hemoglobin, calcium, and protein intake were assessed at baseline and in the third trimester, and maternal biomarkers at delivery and birth outcomes were analysed using regression methods.
Results: Of 200 women, 173 (88 in the intervention group, 85 in the control group) completed follow-up. At baseline, 45.7% were anemic; after the intervention, normal hemoglobin levels rose to 73.9% in the intervention group, compared with 35.3% in the control group. Hypocalcemia at delivery was 1.1% in the intervention group compared with 22.4% in controls. Protein intake and BMI improved significantly with education. Hemoglobin and calcium at birth were positively correlated in the intervention group ($r=0.372$, $p<0.05$), but not in the control group. Neonatal birthweight was marginally higher, and low birthweight was less frequent in the intervention group, though the differences were not statistically significant.
Conclusions: Trimester-specific nutrition education substantially improved maternal hemoglobin levels, calcium status, and dietary practices and is feasible for integration into routine antenatal care to support better perinatal outcomes in India.

Keywords: Birthweight, Calcium, Maternal hemoglobin, Nutrition education, Perinatal outcome

INTRODUCTION

Maternal nutrition during pregnancy is a critical factor influencing fetal growth, neonatal health, and adult disease. In India, the high prevalence of maternal anemia and deficiencies in essential micronutrients like calcium and vitamin D continues to hinder efforts to improve birth outcomes, despite well-established supplementation policies and programs. India has one of the highest global rates of low birth weight (LBW), with recent data estimating rates around 17-18%.[1] Nearly half of pregnant women are anemic, and many have insufficient calcium intake, both of which are associated with increased risks of preterm birth, LBW, and compromised developmental outcomes.[2-5] Improving maternal diet and biochemical status is therefore central to strengthening perinatal health in the country.

Adequate maternal calcium has been linked with lower risks of preeclampsia and better neonatal outcomes, highlighting the importance of nutrition education to ensure sufficient intake through both diet and supplements.[6,7] Protein intake during pregnancy is another key factor for fetal health, as proteins provide essential building blocks for tissue development. Inadequate protein intake can negatively affect placental and fetal growth, increasing the risk of LBW.[8] Addressing these multiple nutritional gaps simultaneously is likely to yield the most significant benefit for mothers and infants.

Globally, structured nutrition education and counseling have become essential strategies to address gaps in maternal health.[9] Studies show that structured nutrition education can improve maternal dietary practice, hemoglobin and calcium levels during pregnancy, and enhance adherence to iron-folic acid and calcium supplements.[9,10] In India, despite government initiatives, only a limited number of women receive structured counseling focused on diet quality and adherence to supplementation.[11,12] In low- and middle-income countries, such interventions have lowered the prevalence of anemia and micronutrient deficiencies, leading to healthier birth weights and a reduced incidence of neonatal morbidity.[9] This evidence suggests that pairing supplementation with behavior-focused counseling may be more effective than supplementation alone.

The impact of nutrition education integrated into routine antenatal care remains underexplored, particularly given the complex interactions among socio-economic factors, dietary practices, and variations in health services delivery. Although government guidelines promote supplementation, barriers to sustained improvement persist. These include gaps in nutrition literacy, cultural preferences, and variability in community health worker engagement. This study aimed to address these gaps by evaluating how trimester-specific nutrition education influences maternal hemoglobin and calcium levels, protein intake, and their association with neonatal birthweight in an Indian cohort. By focusing on a real-world tertiary-care setting, the study provides practical insights into how counseling can be embedded within existing antenatal services.

METHODS

Study design and setting

A prospective quasi-experimental cohort study with a pre-post intervention design was conducted at the Department of Obstetrics and Gynecology, Hamdard Institute of Medical Sciences and Research (HIMSR), New Delhi. Data collection took over 19 months, from October 2023 to May 2025. The site was selected for its socioeconomic diversity, aiming to represent a varied cohort. The study enrolled pregnant women at their first antenatal visit, collected baseline data, and enrolled participants consecutively; the first 100 were assigned to the intervention group, which received structured nutritional counseling, while the next 100 were assigned to the control group, which received standard antenatal care. Allocation was systematic rather than randomized to mirror real-world clinical practice, ensuring feasibility and minimizing selection bias. Ethical approval was granted by the competent authority, and written informed consent was obtained from all participants before their participation.

Participants

A total of 1,892 pregnant women attending routine antenatal clinics were initially screened. Inclusion criteria included women aged 18-40 years with singleton pregnancies between 8+0 and 13+6 weeks of gestation. Women with gestational age beyond 14+0 weeks, multifetal pregnancies, conceptions through assisted reproductive techniques, pre-existing illnesses, or those diagnosed with gestational diabetes during follow-up were excluded. A structured nutrition counseling intervention was provided to the intervention group. The control group received routine antenatal care without targeted nutritional counseling.

Intervention

The intervention included personalized, trimester-specific, individualized nutrition counseling by a dietitian (15-20 minutes) at 8-14, 24-28, and 32-36 weeks, based on ICMR RDA, cultural dietary patterns (vegetarianism, fasting), weight gain as per the institute of medicine (IOM), strategies to improve hemoglobin and calcium levels, and adherence to prescribed supplements (iron-folic acid and calcium) during pregnancy, and other relevant nutritional guidance, all based on national nutritional standards using pictorial handouts. The control group received routine prenatal care.

Data collection

Baseline maternal assessments were conducted at enrolment to collect socio-demographic data, obstetric history, anthropometric measurements [including self-reported pre-pregnancy weight, measured height, and weights from subsequent trimesters to calculate body mass index (BMI, kg/m²)], biochemical markers, and nutritional factors. Venous blood samples were collected at baseline (8-14 weeks) and during the third trimester (32-36 weeks) to analyse hemoglobin (Hb) levels (other biomarkers were also assessed and are detailed in another manuscript under review). We also recorded maternal Hb at birth from the patients' discharge summaries along with calcium levels. Anemia severity was categorized as per WHO guidelines: normal (≥11 g/dL), mild (10-10.9 g/dL), moderate (7-9.9 g/dL), and severe (<7 g/dL). The hypocalcemia threshold was set at a serum calcium level below 8.5 mg/dL, based on established reference ranges for pregnancy. Dietary protein intake was evaluated using a validated 24-hour dietary recall questionnaire administered by a dietitian, with nutrient analysis performed using Indian food composition tables.

Fetal biometric data, such as estimated fetal weight (EFW), were obtained from second- and third-trimester ultrasound reports. Delivery outcomes, including mode of delivery and neonatal birth weight, were recorded from hospital registers and verified against antenatal records. Birth weight was measured within one hour of delivery using calibrated digital infant scales. LBW was defined as a birth weight of less than 2500 grams.

Statistical analysis

Descriptive statistics summarized maternal demographic and baseline clinical variables, as well as neonatal anthropometry. Continuous variables were expressed as mean±standard deviation. Categorical variables were presented as frequencies and percentages. Regression analyses examined associations between individual maternal predictors and LBW risk. All analyses were conducted using SPSS, RStudio, and MS-excel, with statistical significance set at p<0.05.

RESULTS

Of the 200 participants initially enrolled, 173 completed the study. The final sample included 88 women in the intervention group and 85 in the control group. This resulted in an overall attrition rate of 13.5%, with 27 participants dropping out of the study. Medical exclusions involved 12 women diagnosed with hypothyroidism and 4 with gestational diabetes mellitus (GDM). Additional withdrawals were related to pregnancy outcomes: three miscarriages, two preterm deliveries, and one case of multifetal pregnancy. Moreover, five participants were lost to follow-up before the study's completion.

Baseline characteristics, including socio-demographic, anthropometric parameters, and gestational age at enrolment, were comparable between groups, with nonsignificant differences (p>0.05), as summarized in Table 1. This balanced distribution of baseline characteristics supports comparability between the study groups and the reduces potential confounding in the analysis.

Association analyses

At baseline, 45.7% of the cohort was anemic according to WHO criteria, with 31.8% mild, 13.3% moderate, and 1% severe. Mean hemoglobin concentration was 10.8±1.15 g/dl in the intervention group and 11.3±1.19 g/dl in the control group. Blood pressure remained stable across both groups.

The intervention group showed significant improvement in hemoglobin levels: moderate deficiency decreased to 5.7%, mild deficiency to 20.5%, and normal levels increased to 73.9%. In contrast, the control group had higher rates of moderate (27.1%) and mild (37.6%) deficiencies, with only 35.3% reaching normal hemoglobin levels (Table 2). These patterns continued at birth: the intervention group had significantly fewer cases of moderate anemia and a higher proportion of normal hemoglobin levels than the control group. The mean Hb concentration rose during the third trimester (11.4±0.71 g/dl) and increased further at birth (11.7±0.96 g/dl) in the intervention group. Conversely, a decline in Hb concentration was observed in the control group (at the 3rd trimester, 10.6±1.01 g/dl versus at birth, 10.6±1.33 g/dl) (Figure 1). Nutrition education resulted in increased adherence to iron-folic acid supplementation (56.25% to 100%, p<0.001) and vitamin D supplementation (0% to 84.37%, p<0.001).

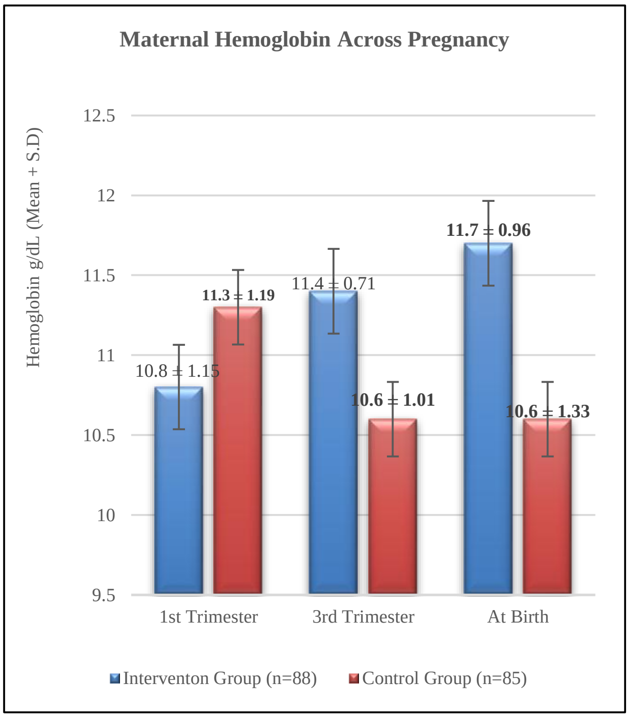

Figure 1: Change in maternal hemoglobin across pregnancy, e.g., from the first trimester to birth of the child.

Table 1: Baseline characteristics of participants in the intervention and control groups.

Characteristics	Intervention, (n=88)	Control, (n=85)
Age (in years), mean±SD (range)	27.23±4.25 (20-37)	27.59±4.23 (20-37)
Height (cm), mean±SD (range)	154.89±5.01 (142-162)	154.61±6.48 (143-170)
Pre-pregnancy weight (kg), mean±SD (range)	56.78±11.89 (37-80)	54.07±9.42 (36-70)
Pre-pregnancy BMI (kg/m²)	23.57±4.37	22.61±3.57
BMI status (kg/m²)	**(n=173)**	
Underweight (<18.5)	14.5% (25)	
Overweight/obese (≥25)	31.2% (54)	
Gestational age at baseline, median	12 weeks 4 days	
Religion		
Hinduism	57.2% (99)	
Islam	41.6% (72)	
Sikhism/Christianity	1.2% (2)	
Diet type		
Non-vegetarian	77.5% (134)	
Vegetarian	22.5% (39)	
Occupation		
Homemakers	89.7% (155)	
Working (senior/managerial etc.)	10.3% (18)	
Parity		
Primigravida	49.1% (85)	
Multigravida	50.9% (88)	
Education		
≥Bachelor's degree	50% (87)	
Illiterate (small %)	<2% (2)	
Socioeconomic status		
Lower-middle (SES III)	91%	
Upper-middle (SES II)	8.85% (15)	

Table 2: Summary of maternal Hb level at different gestational stages as per WHO guidelines and maternal calcium levels at birth.

Biomarkers	Control, (n=85)	Intervention, (n=88)
Maternal Hb levels in the 1st trimester		
Normal (≥11g/dl)	56 (65.9%)	38 (43.2%)
Mild deficiency (10-10.9 g/dl)	22 (25.9%)	33 (37.5%)
Moderate deficiency (7-9.9g/dl)	6 (7.1%)	17 (19.3%)
Severe deficiency (≤7g/dl)	1 (1.1%)	0
Maternal Hb levels in the 3rd trimester		
Normal	30 (35.3%)	65 (73.9%)
Mild deficiency	32 (37.6%)	18 (20.5%)
Moderate deficiency	23 (27.1%)	5 (5.7%)
Maternal Hb levels at birth		
Normal	33 (38.8%)	68 (77.3%)
Mild deficiency	22 (25.9%)	18 (20.5%)
Moderate deficiency	30 (35.3%)	2 (2.3%)
Maternal calcium levels at birth		
Normal (>8.5 mg/dl)	66 (77.6%)	87 (98.9)
Hypocalcemia (<8.5 mg/dl)	19 (22.4%)	1 (1.1)

Maternal calcium levels at delivery also favored the intervention group, with only 1.1% showing hypocalcemia (<8.5 mg/dl) compared to 22.4% in the control group, indicating a clear benefit of nutrition education on these important maternal biomarkers. Protein intake increased from 50.20±9.48 g/day to 57.54±9.51 g/day ($p<0.01$) in intervention group, while control group showed minimal change from 49.28±9.48 g/day to 49.85±7.34 g/day ($p>0.01$). Relationship between maternal hemoglobin levels at birth and serum calcium levels at birth was evaluated. A significant positive correlation ($r=0.372$, $p<0.05$) was observed in intervention group, suggesting that higher serum calcium levels are associated with higher hemoglobin levels at birth. In contrast, control group showed no significant association (r=0.023, p<0.05).

Continuous increases in gestational weight and BMI were observed across the groups. In the intervention group, the mean BMI increased from 24.28±4.24 kg/m² in the first trimester to 25.90±3.95 kg/m² in the second trimester and to 27.24±4.14 kg/m² in the third trimester. Similarly, the control group showed increases from 23.26±3.90 kg/m² in the first trimester to 24.97±3.82 kg/m² in the second trimester and 26.46±3.93 kg/m² in the third trimester. These data indicate a consistent increase in BMI throughout pregnancy in both groups.

The changes (delta/Δ) in weight (kg) during pregnancy showed a consistent upward trend for both intervention and control groups. Notably, the intervention group, which received trimester-specific nutritional counseling focused on weight management, experienced slightly lower overall weight gains. Specifically, from pre-pregnancy to the third trimester, the intervention group's average weight gain was 8.86±3.64 kg. In contrast, the control group gained 9.19±4.27 kilograms. Paired t-tests confirmed significant trimester-wise increases in BMI (p<0.001) and weight (p<0.001) within the intervention group.

Significant fetal growth was observed in both groups between the second and third trimesters. In the intervention group, estimated fetal weight (EFW) increased from 319.53 g to 2012.11 g (p<0.001). The control group exhibited a similar increase, with EFW rising from 347.05 g to 2069.67 g (p<0.001). Mean neonatal birthweight was slightly higher in the intervention group compared to the control group, and LBW rates were lower, although neither difference reached statistical significance (χ^2=0.551, p>0.05). Mean birthweight and rate of LBW between the groups are shown in Figure 2 A and B.

In group-specific logistic regression models, higher hemoglobin and calcium levels were linked to lower odds of low birthweight in both study groups. In the control group, hemoglobin had an OR of 0.73 (95% CI: 0.45-1.16), and calcium had an OR of 0.42 (95% CI: 0.09-1.92). In the intervention group, the OR for hemoglobin was 0.53 (95% CI: 0.24-1.15), and for calcium, it was 0.47 (95% CI: 0.03-9.05). Interaction analysis showed no statistically significant differences between groups for either hemoglobin (OR=0.73, 95% CI: 0.29-1.80) or calcium (OR=1.12, 95% CI: 0.04-30.90). Binary logistic regression analysis of LBW risk indicated that higher third-trimester BMI was associated with a very small, non-significant decrease in LBW risk (OR=0.99, 95% CI: 0.888-1.1, p>0.05).

The mean gestational age at delivery was 38.80±1.40 weeks in the control group and 38.26±1.19 weeks in the intervention group. No significant difference in gestational age at delivery was observed between the two groups. We found that the caesarean delivery rate was higher in the control group (51.8%) compared to the intervention group (40.9%). In the intervention group, women who had a caesarean delivery had a higher mean third-trimester BMI (28.24±4.46 kg/m²) than those who delivered vaginally (26.56±3.81 kg/m²). However, this difference was close to but did not reach statistical significance (p>0.05). Conversely, in control group, the BMI difference between caesarean and vaginal births was statistically significant (27.68±3.77 kg/m² vs. 25.83±3.90 kg/m², p<0.05).

In group-wise analyses, mode of delivery showed no statistically significant links with hemoglobin or calcium levels in either group. In the intervention group, hemoglobin (OR=0.78; 95% CI: 0.48-1.26; p>0.05) and calcium (OR=0.20; 95% CI: 0.02-2.20; p>0.05) were not associated with normal delivery compared with cesarean section. In the control group, the odds ratios were 0.87 (95% CI: 0.62-1.23; p>0.05) for hemoglobin and 2.10 (95% CI: 0.69-6.41; p>0.05) for calcium.

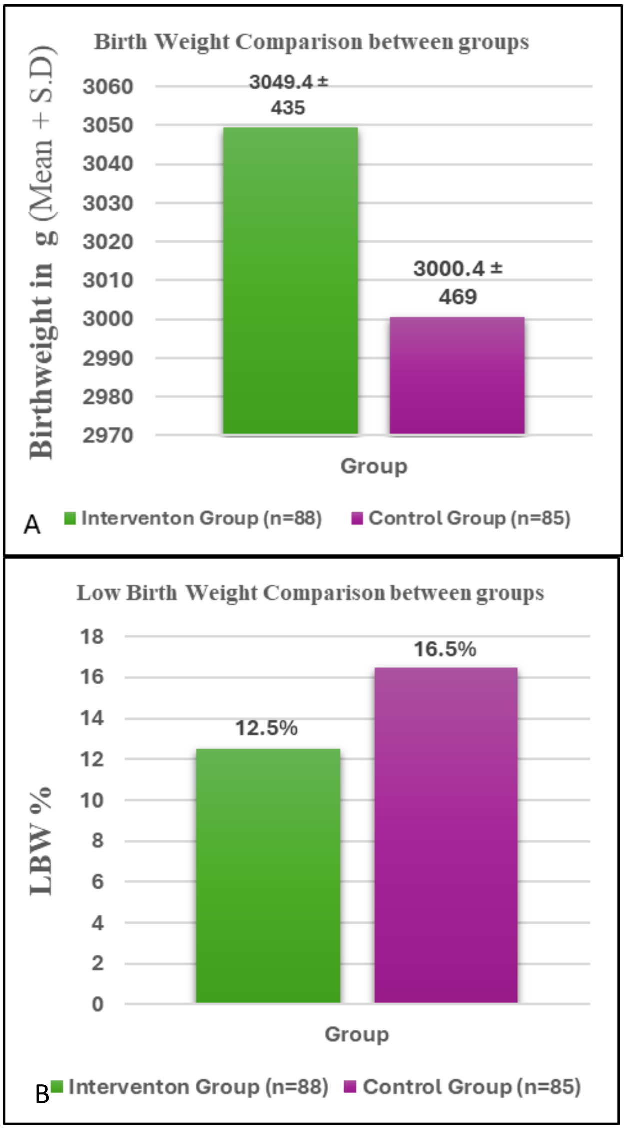

Figure 2 (A and B): Comparison of birth weight and LBW between the groups.

DISCUSSION

The findings of this study emphasize the significant impact of trimester-specific nutrition education on enhancing maternal hemoglobin and calcium levels during pregnancy in an urban Indian cohort. These improvements were linked to increased protein intake and reduced hypocalcemia rates at delivery among women who received structured nutritional counseling. Such results highlight the crucial role of targeted nutritional interventions in antenatal care, especially in a country like India, where there are persistently high rates of maternal anemia, and micronutrient deficiencies remain prevalent, despite national programs promoting iron and folic acid supplementation.[13] Our findings reinforce that simply providing supplements is insufficient unless complemented by behaviour-focused counseling that helps women translate advice into daily food choices.

In this cohort, nearly half of the women were anemic at baseline, reflecting national prevalence data and highlighting ongoing gaps in implementing and adhering to nutritional guidelines. This mirrors the challenges faced by other low- and middle-income countries where nutritional interventions compete with social, economic, and health system barriers.[9] The significant improvement in hemoglobin levels in the intervention group aligns with other quasi-experimental and cohort meta-analyses showing that structured nutrition education can increase adherence to iron-folic acid supplementation and reduce the anemia burden.[9,10] In this study, moderate and mild deficiencies decreased, and normal hemoglobin levels increased substantially among counseled mothers, confirming the added value of intensive nutrition education in a real-world Indian setting. Our results suggest that front-line counseling by trained dietitians can meaningfully strengthen the impact of existing public programmes such as Anemia Mukt Bharat.

Calcium status, an often-overlooked aspect of antenatal nutrition, improved significantly through the intervention, as shown by the dramatic decrease in hypocalcemia. Calcium deficiency is a known risk factor for preeclampsia and fetal bone development issues, yet it remains insufficiently addressed in routine antenatal care in India.[6] The near-universal normalization of calcium levels among the intervention group emphasizes the potential of dietary counseling to address micronutrient gaps that supplementation alone cannot. High rate of hypocalcemia in the control group aligns with previous reports of inadequate dietary calcium intake among Indian women, underscoring the importance of structured nutrition education as a key strategy to close this gap.[14] Importantly, this focus on food-based sources such as milk, curd, and green leafy vegetables makes the approach scalable even in low-resource settings.

Protein intake increased significantly in the intervention group, supporting healthier patterns of weight gain during pregnancy. The steady increase in BMI and weight across both groups reflects the normal physiological changes of pregnancy. However, the slightly lower weight gain in the intervention group, despite improved protein intake, might indicate a higher-quality diet and better adherence to recommended gestational weight gain ranges, which help protect against adverse outcomes.[15] It is reasonable to presume that counseling may have helped women avoid excess energy from low-nutrient foods while improving intake of nutrient-dense options.

A key finding is the strong link between maternal hemoglobin and calcium levels at birth in the intervention group, a connection not seen among controls. This indicates that nutrition education may lead to combined improvements in maternal biomarkers, thus helping improve pregnancy outcomes. Global research supports these findings: studies from Africa, South Asia, and America show better maternal and neonatal health with nutrition counseling efforts, especially when these are adapted to local food habits and barriers.[9,16-18] However, challenges in implementation vary depending on the context. In India, educational progress is often limited by socioeconomic and cultural factors that affect dietary diversity and supplement use.[4,19] The present findings therefore support integrating structured counseling into existing antenatal care platforms while also investing in community-level strategies to address affordability and intra-household food allocation.

Despite significant improvements in maternal health, the average neonatal birthweight and the rate of LBW showed only modest, statistically insignificant increases. However, they were more favorable in the intervention group, likely due to sample size limitations and the complex, multifactorial nature of fetal growth. Nonetheless, higher third-trimester maternal hemoglobin and calcium levels remained associated with reduced odds of LBW, consistent with global evidence that such improvements reduce the risk of LBW, preterm birth, and neonatal morbidity.[7,20] These trends indicate that scaling such interventions to larger populations and initiating them earlier in pregnancy could yield more pronounced effects on birthweight at the population level.

Mode of delivery was not significantly linked to maternal hemoglobin or calcium levels in either group. Cesarean rates were higher among controls, and higher third-trimester BMI was associated with an increased chance of cesarean, especially in controls. This indicates that while nutritional interventions can improve maternal health, other clinical factors mainly influence delivery method. Nonetheless, slightly lower cesarean rates in intervention group may suggest indirect benefits from improved maternal health and gestational weight management. Future work could examine whether combining nutrition education with broader obstetric risk-reduction strategies can further reduce unnecessary cesarean births.

In conclusion, personalized nutrition education, delivered in a culturally relevant and trimester-specific way, effectively improves key maternal health indicators in an urban Indian cohort. These results support adding intensive dietary counseling into routine antenatal care, emphasizing its importance in closing ongoing gaps in maternal and child health. The broader implication is the need to include such counseling in routine care programs nationwide, with ongoing efforts to overcome barriers related to education, access, and adherence. Globally, similar intervention programs yield promising results, but more research is needed to confirm long-term benefits on neonatal outcomes and overall population health.

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