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Association of Antenatal Care Components with Low Birth Weight: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Low birth weight (LBW) remains a major global health problem contributing to neonatal morbidity and mortality. Although antenatal care (ANC) is recognized as an effective strategy to improve pregnancy outcomes, evidence regarding the association between specific ANC components and LBW remains inconsistent. This study aimed to systematically review and quantitatively synthesize the evidence on the association between ANC visit frequency, timing of initiation, iron-folic acid supplementation, nutritional counseling, and LBW risk.

Methods: A systematic review and meta-analysis was conducted on 22 studies involving 227,957 mother-infant pairs identified through PubMed. ANC components, including number of visits, timing of first visit, iron-folic acid (IFA) supplementation, and nutritional counseling, were assessed as exposure variables. The outcome was LBW (<2.5 kg). Pooled adjusted odds ratios (AOR) with 95% confidence intervals (CI) were estimated using fixed-effects or random-effects models. Heterogeneity was assessed using the I^2 statistic, and publication bias using funnel plots.

Results: Lack of nutritional counseling showed the strongest association (AOR 1.88; 95% CI 1.21–2.92), followed by fewer than four ANC visits (AOR 1.55; 95% CI 1.24–1.95), lack of iron-folic acid supplementation (AOR 1.27; 95% CI 1.04–1.54), and late ANC initiation (AOR 1.10; 95% CI 1.01–1.20). Moderate heterogeneity was observed across several outcomes.

Conclusion: Adequate uptake of specific ANC components, namely nutritional counseling, sufficient visit frequency, iron-folic acid supplementation, and early ANC initiation, is associated with a reduced risk of LBW. Strengthening the implementation and coverage of these individual components is essential to improve neonatal outcomes.

Keywords: ***Antenatal care; Iron-folic acid supplementation; Low birth weight; Nutritional counseling.***

INTRODUCTION

Low birth weight (LBW) remains a major global public health problem and an important determinant of neonatal mortality. LBW is defined as birth weight less than 2500 g, regardless of gestational age.[1] Globally, LBW affects more than 20 million infants, representing approximately 15–20% of all births worldwide.[2] Around 90% of LBW infants are born in low- and middle-income countries (LMICs).[3] Infants with LBW are at increased risk of short-term complications such as sepsis, respiratory distress, and necrotizing enterocolitis, as well as long-term adverse outcomes including impaired growth, reduced cognitive development, and chronic diseases in adulthood.[4][5]

The occurrence of LBW is influenced by multiple factors, including maternal nutritional status, socioeconomic conditions, environmental exposure, and maternal behaviors that affect fetal development.[6] Among these factors, antenatal care (ANC) plays an essential role in improving maternal and neonatal outcomes through early detection and management of pregnancy complications.[7] ANC also provides important interventions, including nutritional supplementation, fetal growth monitoring, and prevention of adverse birth outcomes.[8]

However, key components of ANC remain suboptimal in many settings, particularly in low- and middle-income countries where access to healthcare services is limited. Many pregnant women initiate ANC late or do not complete the recommended number of visits, reducing the effectiveness of interventions during pregnancy.[9][10]

Inadequate implementation of key ANC components has been associated with adverse pregnancy outcomes, including low birth weight. Previous studies have reported that women who received adequate ANC components, such as sufficient ANC visits, early ANC initiation, iron-folic acid supplementation, and nutritional counseling, were less likely to deliver LBW infants than those who did not receive these components.[11][12] Adequate implementation of key ANC components, including sufficient ANC visits, early ANC initiation, iron-folic acid supplementation, and nutritional counseling, may reduce the risk of LBW through early identification and management of maternal and fetal complications.[11][12][13][14] However, some studies reported weak or non-significant associations after adjustment for socioeconomic and maternal factors.[15][16] Moreover, most previous studies have evaluated individual ANC components separately, and there is limited quantitative evidence comparing their relative associations with the risk of LBW. This lack of comprehensive synthesis limits the ability to identify which ANC components are most strongly associated with LBW across different settings.

Therefore, this systematic review and meta-analysis aimed to systematically synthesize and quantitatively evaluate the association between specific antenatal care components, including the number of ANC visits, timing of ANC initiation, iron-folic acid supplementation, and nutritional counseling, and the risk of low birth weight. Identifying the ANC components most strongly associated with LBW is important for optimizing ANC programs, prioritizing effective maternal health interventions, and informing evidence-based policies to reduce the burden of LBW, particularly in low- and middle-income countries.

METHODS

Search Strategy

This study was a systematic review and meta-analysis conducted according to the PRISMA 2020 guidelines. Literature searching was performed on March 3, 2026 using the PubMed database. The research question was developed using

the PECO framework: Population (pregnant women), Exposure (antenatal care components, including number of ANC visits, timing of the first ANC visit, iron-folic acid supplementation, and nutritional counseling), Comparator (adequate versus inadequate implementation of each ANC component), and Outcome (low birth weight <2,500 g).

The search strategy used the following keywords: "antenatal care" OR "prenatal care" OR "ANC" OR "maternal health services") AND ("utilization" OR "attendance" OR "visits" OR "coverage" OR "timing" OR "initiation" OR "iron-folic acid" OR "folic acid" OR "nutrition″ OR "nutritional counseling") AND ("low birth weight" OR "LBW" OR "birth weight"). Manual screening of reference lists was also performed to identify additional relevant studies.

Eligibility and Selection Process

Observational studies reporting effect estimates (OR or AOR) on the association between one or more ANC components and low birth weight were included. Eligible studies published in English between 2015 and 2025 were included. Studies with inaccessible full texts were excluded. All retrieved records were imported into reference management software, and duplicates were removed.

Quality Assessment

Data were extracted using a standardized data extraction form. Extracted data included the first author's name, publication year, country, study design, sample size, participant characteristics, ANC components, outcome measures, adjusted effect estimates (AORs) with 95% confidence intervals, and variables included in the adjusted analyses. The extracted data were cross-checked for accuracy, and discrepancies were resolved through discussion until consensus was reached. Subsequently, the methodological quality of each study was independently assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies, which evaluated sampling methods, exposure and outcome measurements, confounding factors, and statistical analyses.

Data Analysis

A narrative synthesis was conducted to summarize study characteristics, including author, year, study design, setting, sample size, and ANC-related variables. The primary effect measure was adjusted odds ratio (AOR) with 95% confidence intervals (CI). Meta-analysis was conducted using Review Manager (RevMan) version 5.4 with a random-effects model. Results were presented using forest plots, heterogeneity was assessed using the I^2 statistic, and publication bias was evaluated using funnel plots.

RESULT

Study selection and quality assessment

This review identified a total of 339 studies during the initial search process, including 248 studies from Scopus and 91 studies from PubMed. After removing 90 duplicate records, 249 studies remained for the screening stage. Subsequently, 213 studies were excluded based on the title and abstract. 36 full-text articles were sought for retrieval, while eight reports could not be retrieved. A total of 28 full-text articles were further assessed for eligibility. Following full-text evaluation, 13 studies were excluded because they did not specifically examine antenatal care components and low birth weight outcomes (n=8) or did not use a cross sectional study design (n=5). Finally, 15 studies were included in the qualitative and

quantitative synthesis which presented in Figure 1.

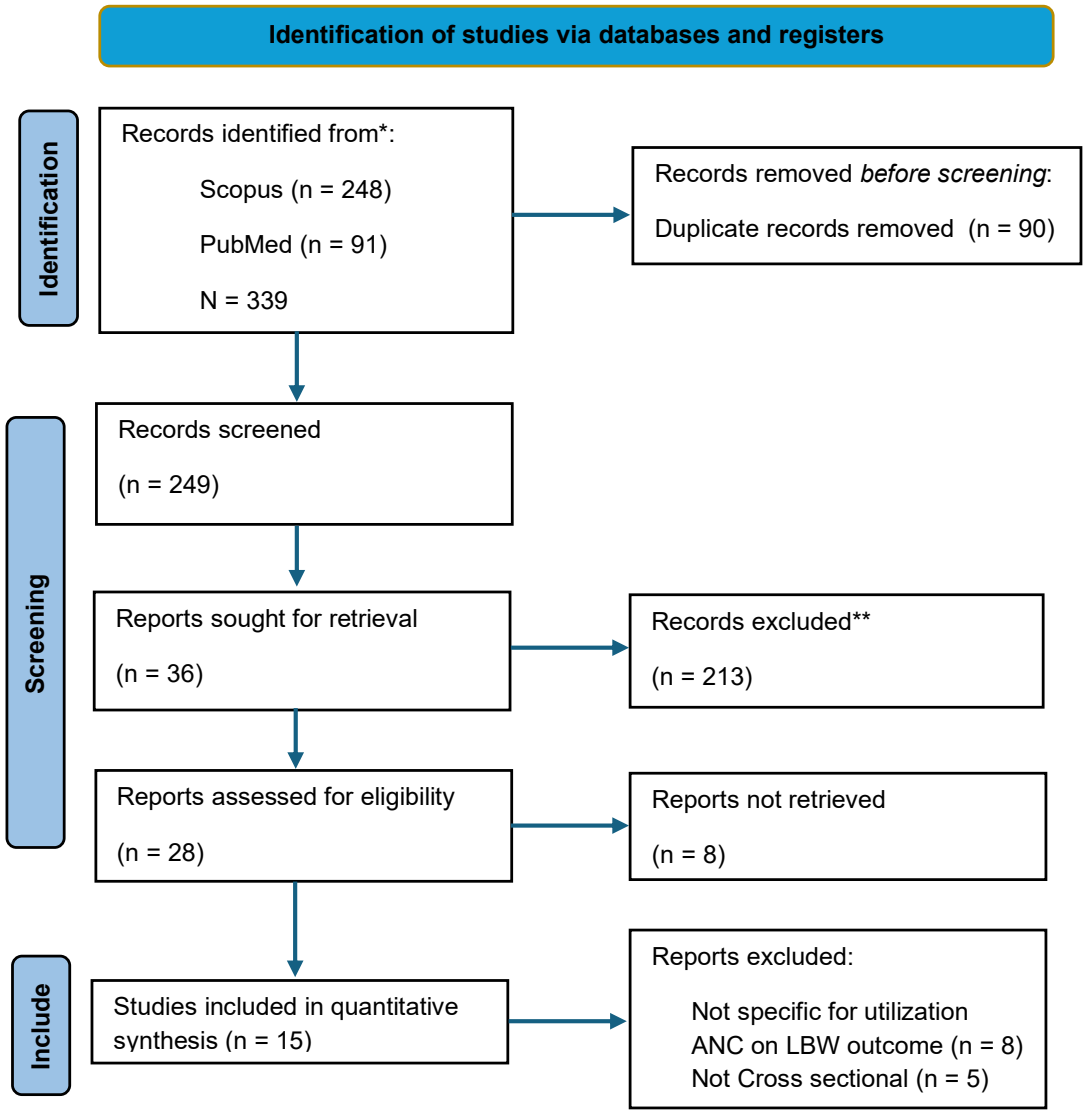

Figure 1. PRISMA diagram in the study selection process

Risk of bias

All included studies were considered to have a low risk of bias, as reflected by the high proportion of positive assessments based on the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies. Across most domains including sample selection (Q1, Q2), exposure and outcome measurement (Q3, Q4, Q7), and statistical analysis (Q8) the studies consistently met the quality criteria. However, methodological limitations were observed regarding confounding factors. Specifically, several studies failed to explicitly identify potential confounders (Q5) or lacked clear strategies to statistically mitigate or control for these confounding variables in their analysis (Q6). Despite these specific gaps, the overall methodological quality remained robust enough to warrant inclusion.

Table 1. Risk of Bias Assessed by JBI Critical Appraisal Tools

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Overall
Zhou et al., 2019 (China)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Acharya et al., 2018 (Nepal)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Thapa et al., 2022 (Nepal)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Zaveri et al., 2020 (India)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Tadesse et al., 2023 (Ethiopia)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Caira-Chuquineyra et al., 2023 (Peru)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Mohamoud et al., 2025 (Somalia)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Bellizzi & Padrini, 2020	Y	Y	Y	Y	Y	Y	Y	Y	Low
Gebremedhin et al., 2015 (Ethiopia)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Kastro et al., 2018 (Ethiopia)	Y	Y	Y	Y	N	Y	Y	Y	Moderate
Kpordoxah et al., 2024 (Ghana)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Elmoussaoui et al., 2024 (Morocco)	Y	Y	Y	Y	Y	Y	Y	Y	Low
Geberu et al., 2025	Y	Y	Y	Y	Y	Y	Y	Y	Low

Most included studies clearly defined inclusion criteria and used valid, reliable measurements for exposure and outcome variables. The majority identified potential confounding factors and applied multivariable analyses to control their effects. Based on the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, most studies showed low risk of bias**,** while one study had moderate risk of bias**.** Overall, the methodological quality was considered acceptable, supporting the reliability of this meta-analysis findings.

Characteristics of the included studies

A total of 13 cross-sectional studies were included, comprising hospital-based, community-based, and demographic health survey datasets conducted across low- and middle-income countries. Several studies consistently demonstrated that inadequate antenatal care components was associated with increased risk of low birth weight (LBW).

Thapa et al. (2022) in Nepal reported that mothers with ≤3 ANC visits had higher odds of LBW (AOR = 2.6; 95% CI: 1.0–6.6), while non-compliance with iron-folic acid supplementation also increased LBW risk (AOR = 2.1; 95% CI: 1.0–4.4). Zaveri et al. (2020) in India found that ≥4 ANC visits (AOR = 0.84; 95% CI: 0.80–0.88) and iron supplementation during pregnancy (AOR = 0.94; 95% CI: 0.90–0.98) were protective against LBW. Similarly, Caira-Chuquineyra et al. (2023) reported that inadequate prenatal care increased LBW risk (AOR = 1.39; 95% CI: 1.09–1.77), with fewer than six visits showing stronger association (AOR = 3.20; 95% CI: 2.48–4.13). Overall, studies consistently showed that inadequate ANC visits, delayed ANC initiation, poor nutritional support, and lack of iron-folic acid supplementation were associated with increased odds of low birth weight.

Table 2. Characteristics Study

No	Study	Country	Design	Sample Size	Outcome	Exposure Variables
1	Caira-Chuquineyra 2023	Peru	Cross-sectional (DHS)	10,186	LBW	ANC visits, timing first visit, ANC content
2	Elmoussaoui 2024	Morocco	Cross-sectional	350	LBW	Maternal & environmental factors
3	Mohamoud 2025	Somalia	Facility-based cross-sectional	384	LBW	ANC visits, IFA, nutrition
4	Bellizzi 2020	Multi-country	DHS secondary analysis	69,446	LBW	ANC visits, timing
5	Gebremedhin 2015	Ethiopia	Cross-sectional mixed	308	LBW	Nutrition, maternal factors
6	Kastro 2018	Ethiopia	Cross-sectional	432	LBW	Diet, maternal factors
7	Kpordoxah 2024	Ghana	Cross-sectional	402	LBW	ANC visits, IPV
8	Biracyaza 2022	Rwanda	DHS analysis	402+	LBW	ANC visits, IFA, counseling
9	Zhou 2019	China	Cross-sectional	8,964	LBW	ANC visits, timing, folic acid
10	Acharya 2018	Nepal	Cross-sectional	402	LBW	ANC visits, IFA, nutrition
11	Thapa 2022	Nepal	Cross-sectional	308	LBW	ANC visits, IFA compliance
12	Zaveri 2020	India	DHS analysis	147,762	LBW	ANC visits, IFA
13	Tadesse 2023	Ethiopia	Cross-sectional	Not stated	LBW	IFA, maternal factors

Number of Prenatal Care Visits

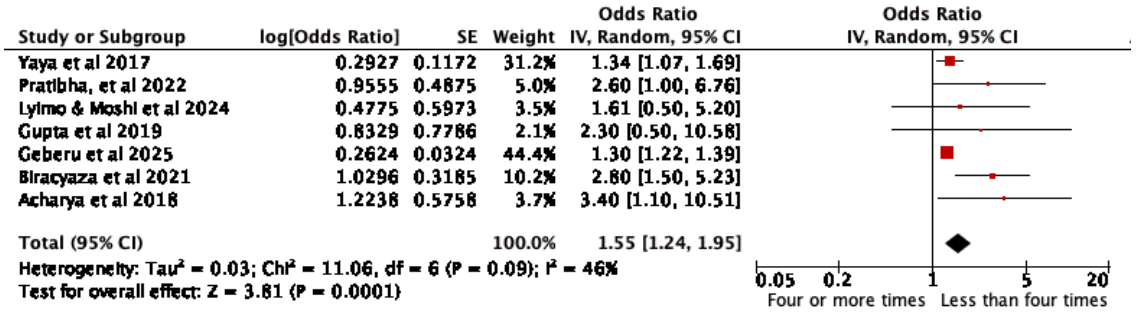

Figure 2. Pooled odds ratios of low birth weight associated with fewer than four antenatal care visits

Of the seven studies included in the present meta-analysis, most reported that mothers with fewer than four antenatal care visits were significantly more likely to deliver low birth weight infants. The pooled analysis demonstrated that pregnant women who attended fewer than four visits had 1.55 times higher odds of experiencing this outcome compared with those who attended four or more visits (OR=1.55; 95% CI: 1.24–1.95; p=0.0001). Moderate heterogeneity was observed in the pooled analysis (I^2=46%; p=0.09), indicating moderate variability in study findings that may reflect differences in population characteristics, healthcare access, study settings, and operational definitions of antenatal care components. Studies with larger sample sizes, particularly Gebru et al. and Yaya et al., contributed the greatest statistical weight to the pooled estimate and largely influenced the overall precision of the analysis.

Nutritional Counseling

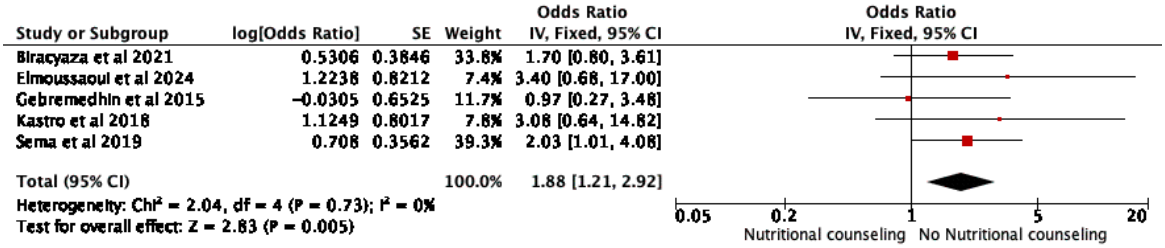

Figure 3. Pooled odds ratios of low birth weight associated with no nutritional counseling

Five studies investigated the relationship between the absence of nutritional counseling during pregnancy and low birth weight. The pooled effect estimate indicated that mothers who did not receive nutritional counseling were more likely to deliver low birth weight infants, with an overall odds ratio of 1.88 (95% CI: 1.21-2.92; p = 0.005) in Figure 3. No significant heterogeneity was observed among the included studies (I^2 = 0%; p = 0.73), indicating consistency in the pooled effect estimate across studies.

Iron-folic acid Intake

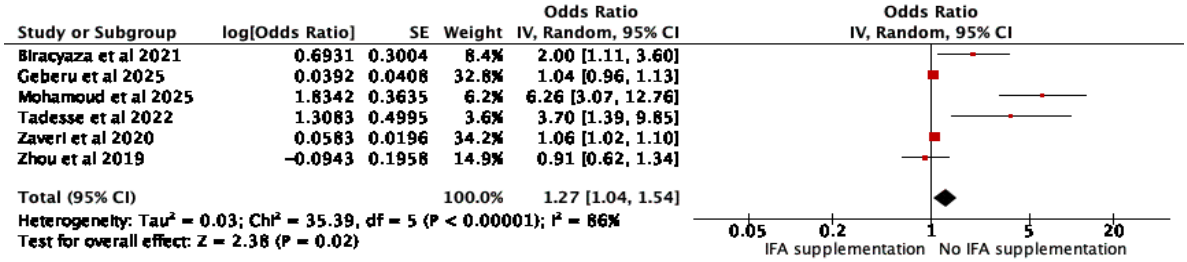

Figure 4. Pooled odds ratios of low birth weight associated with lack of iron-folic acid intake.

Six studies assessed the association between the absence of iron-folic acid supplementation during pregnancy and low birth weight. The pooled analysis demonstrated that mothers who did not receive iron-folic acid supplementation had significantly higher odds of delivering low birth weight infants, with a pooled OR of 1.27 (95% CI: 1.04-1.54; p = 0.02) in Figure 5. Most included studies reported a positive association between lack of iron-folic acid supplementation and low birth weight, although the magnitude of effect estimates differed considerably across studies. The highest odds ratios were reported by Mohamoud et al. and Tadesse et al., whereas several studies demonstrated more modest associations with narrower confidence intervals. Substantial heterogeneity was observed among the included studies (I^2 = 86%; p < 0.00001), indicating considerable variability in the reported effect estimates across studies.

Timing of First ANC Visit

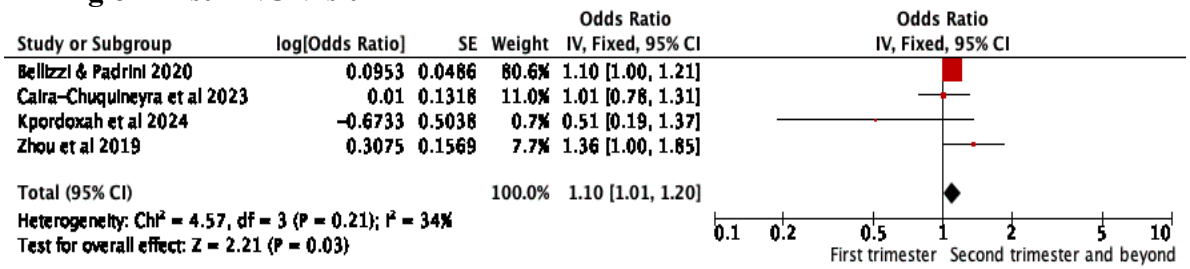

Figure 5. Pooled odds ratios of low birth weight associated with the first antenatal care visit.

Four studies evaluated the association between the timing of the first antenatal care visit and low birth weight. The pooled analysis demonstrated that delayed initiation of antenatal care, particularly beginning ANC during the second trimester or later, was significantly associated with an increased likelihood of low birth weight, with a pooled OR of 1.10 (95% CI: 1.01-1.20; p = 0.03) in Figure 8. The heterogeneity analysis showed low-to-moderate between-study variability (I^2 = 34%; p = 0.21), indicating relatively consistent findings across the included studies despite differences in study populations and healthcare settings.

DISCUSSION

This meta-analysis demonstrated that inadequate utilization of specific ANC components during pregnancy was significantly associated with increased risk of low birth weight (LBW). Specifically, fewer ANC visits, delayed initiation of ANC, absence of nutritional counseling, and lack of iron-folic acid supplementation were consistently associated with higher odds of LBW. These findings highlight the importance of comprehensive ANC in improving maternal nutrition, early detection of complications, and fetal growth outcomes.

Number of Prenatal Care Visits

This study showed a significant association between fewer ANC visits and increased risk of LBW. Adequate ANC attendance is essential for monitoring maternal and fetal wellbeing and identifying complications before they progress into adverse neonatal outcomes.[17] Previous studies have identified inadequate ANC attendance as a risk factor for LBW in both preterm and term deliveries, with socioeconomic and demographic factors also influencing the utilization of key ANC components.[18][19]

Regular ANC visits provide opportunities to assess maternal nutritional status, gestational weight gain, blood pressure, and fetal growth.[20] Inadequate attendance reduces opportunities for early detection and management of maternal

complications such as anemia, hypertensive disorders, and infections, which may contribute to placental insufficiency, intrauterine growth restriction, and low birth weight.[21]

Nutritional Counseling

This meta-analysis found that mothers who did not receive nutritional counseling had significantly higher odds of delivering LBW infants. Maternal nutrition during pregnancy is an important determinant of birth weight, and nutritional counseling during ANC plays a key role in improving maternal dietary practices.[22][23] However, nutritional counseling often remains suboptimal because of inadequate service coverage.[20]

Poor maternal nutritional intake may lead to deficiencies affecting placental development, fetal tissue formation, and intrauterine growth. Nutritional deficiencies during pregnancy have also been linked to long-term consequences, including stunting, insulin resistance, type 2 diabetes, and metabolic syndrome later in life.[24][25]

Iron-Folic Acid Intake

Mothers who did not receive iron-folic acid supplementation during pregnancy had higher odds of delivering LBW infants. Iron and folic acid are essential micronutrients that support maternal physiological adaptation, placental development, and fetal growth. Deficiencies in these micronutrients have been associated with impaired neurodevelopment and adverse pregnancy outcomes.[25] Folic acid also plays an important role in DNA synthesis, cellular proliferation, and placental vascular development.[26][27][28]

The association may also be explained through maternal anemia, which is strongly associated with placental insufficiency, impaired fetal nutrient transfer, intrauterine growth restriction, and increased risk of LBW.[29] Women who do not receive supplementation may additionally have poorer nutritional status and lower utilization of maternal healthcare services.[30]

Timing of First ANC Visit

Delayed initiation of ANC was significantly associated with increased odds of Low Birth Weight. Early ANC initiation, ideally within the first trimester, enables timely screening for hypertension, gestational diabetes, and infections, thereby reducing the risk of Low Birth Weight.[31][32][33] Delayed ANC limits access to essential interventions, including micronutrient supplementation, congenital anomaly screening, and preventive treatment, increasing the risk of adverse birth outcomes.[34]

Early ANC attendance also allows continuous monitoring, nutritional assessment, counseling, and timely referral for high-risk pregnancies.[35][36][37] Delayed initiation may additionally reflect socioeconomic barriers, including limited maternal education, poor healthcare access, financial constraints, and low awareness regarding the importance of pregnancy care.[38] These factors may increase vulnerability to adverse maternal and neonatal outcomes, including impaired fetal growth and LBW.

CONCLUSION

This study demonstrates that inadequate utilization of specific antenatal care components significantly increases the risk of low birth weight. Among the assessed interventions, the absence of nutritional counseling, insufficient visit frequency, lack of iron-folic acid supplementation, and delayed ANC initiation were identified as key contributing factors. Rather than just increasing general attendance, health policies should focus on ensuring the complete delivery of these individual ANC components to effectively reduce the burden of LBW.

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