International Journal of Health Science (IJHS)

E-ISSN: 2827-9603
P-ISSN: 2827-9603

Review Article

Nutritional Interventions During Pregnancy and Their Impact on Neonatal Stunting: A Systematic Review of Evidence from Low and Middle-Income Countries

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Abstract: Stunting continues to pose a serious public health issue in low- and middle-income countries (LMICs), affecting over 148 million children under five globally in 2022. Maternal nutrition during pregnancy plays a crucial role in determining birth outcomes and reducing the risk of stunting. This systematic review assessed the impact of nutritional interventions during pregnancy on stunting prevention and neonatal health in LMICs. A comprehensive search of PubMed, Scopus, Cochrane Library, and Google Scholar was conducted for studies published from 2005 to 2025, including RCTs, quasi-experimental studies, systematic reviews, meta-analyses, and analytical observational studies involving pregnant women in LMIC settings. From 6,204 initial records, 20 studies with over 114,000 participants were included. The review found that energy-protein supplementation reduced stunting risk by up to 28%, while multiple micronutrient supplements lowered the incidence of low birth weight and small-for-gestational-age (SGA) infants. Vitamin D supplementation also significantly reduced SGA risk. Nutrition education and counseling improved maternal dietary practices and lowered stunting rates. Conversely, maternal undernutrition—indicated by low BMI—was associated with a 22% increased risk of child stunting. These findings highlight the effectiveness of both nutrition-specific and nutrition-sensitive interventions during pregnancy. Integrated approaches combining supplementation and education should be prioritized in public health strategies.

Keywords: LMICs; Maternal Nutrition; Pregnancy; Stunting; Supplementation

1. Introduction

Stunting is a persistent nutritional issue prevalent in lower-middle-income countries, marked by children having height measurements below age-specific standards due to sustained undernutrition. This condition not only impairs physical development but also negatively affects cognitive abilities, immune response, and future productivity. The most vulnerable period is the First 1,000 Days of Life—from conception until a child reaches two years old—during which growth faltering tends to be irreversible (Lassi et al., 2021; Mandowa et al., 2022).

According to the World Health Organization (2022), over 148 million children under five suffered from stunting globally, predominantly in LMICs. In Indonesia, the 2022 Nutritional Status Survey (SSGI) reported a stunting prevalence of 21.6%, still above the WHO's acceptable threshold of 20% (Mandowa et al., 2022; Saleh et al., 2021). Contributing factors include poor maternal nutrition, anemia, infections, inadequate child-rearing practices, low nutrition awareness, and limited access to health and sanitation services.

Maternal nutrition significantly affects fetal health. Deficiencies in energy, protein, and key micronutrients such as iron, folic acid, vitamin D, and zinc heighten the risks of low birth weight, preterm birth, and small-for-gestational-age infants—all of which are associated with higher stunting risk (Houssou et al., 2023; Lassi et al., 2020).

Efforts to reduce stunting must integrate both nutrition-specific interventions (e.g., micronutrient supplementation, fortified foods) and nutrition-sensitive strategies (e.g., health

Received: September 12, 2025;
Revised: September 26, 2025;
Accepted: October 10, 2025;
Published: October 14, 2025;
Curr. Ver.: October 14, 2025;

education, improved sanitation, and community-based programs). Research consistently shows that combining these approaches yields better outcomes than single interventions (Keats et al., 2021; Dewidar et al., 2023). Despite numerous studies on the topic, the fragmented nature of available evidence hinders policy-making. Therefore, a comprehensive systematic review is essential to consolidate current findings and guide the development of effective national strategies to address stunting, particularly in LMICs like Indonesia.2. Preliminaries or Related Work or Literature Review

This section must contain a state-of-the-art explanation. It can be explained in several ways. First, you can discuss several related papers, both about objects, methods, and their results. From there, you can explain and emphasize gaps or differences between your research and previous research. The second way is to combine theory with related literature and explain each theory in one sub-chapter.

2. Method

Search Strategy

A systematic literature search was conducted in various international and national electronic databases to identify relevant publications related to nutritional interventions and education for pregnant women in preventing stunting. The databases used included PubMed, the Cochrane Library, Google Scholar, Scopus, Web of Science, and the WHO Nutrition Database. To complement the search results, a grey literature search was also conducted through ProQuest Dissertations, the 3ie Database, and the websites of international organizations such as WHO, UNICEF, and FAO.

The keywords used were adapted to the Medical Subject Headings (MeSH) format and free-form terms, combined using the Boolean operators "AND" and "OR." Examples of keywords used include: "stuntin," "maternal nutrition , " "pregnancy , " "micronutrient supplementation , " "balanced energy protein , " "nutrition education , " "low- and middle-income countries ," and "1000 days ." The search process was conducted without language restrictions at the initial stage, but only publications in English or Indonesian were selected for the final analysis. The range of publications included varied according to the scope of each study, but was generally limited to articles published between 2005 and 2025. This lower limit was chosen to ensure that the interventions analyzed were in line with developments in modern maternal and child health programs. In this literature review, the article search used the PICO (Population, Intervention, Comparison, Outcome) framework . This framework provides broader coverage (higher sensitivity), but with lower precision.

Table 1. PICO Framework

Framework	Information
Population	Pregnant women and children in low-middle-income countries (LMICs) according to World Bank classification
Intervention	Improving maternal nutritional status, improving nutritional intake, or maternal health interventions that have the potential to influence neonatal *outcomes and child growth*
Comparison	There is no intervention or other alternative intervention

Inclusion Criteria

Articles included in this systematic review must meet the following inclusion criteria:

a. Research design: Randomized Controlled Trial (RCT), quasi-experimental, meta-analysis, systematic review, cohort, or cross-sectional analytic.
b. Main outcomes: Maternal nutritional status, nutritional intake, neonatal outcomes (LBW, prematurity, small for gestational age (SGA)), stillbirth, and stunting in children.
c. Research location: Conducted in low and middle-income countries (LMICs) according to the World Bank classification.

Exclusion Criteria

Articles will be excluded from analysis if they meet any of the following criteria:

a. A sample size of <100 participants for quantitative studies is recommended to ensure adequate statistical power. The larger the sample size, the more representative it is of

the population, thus making the research results more likely to be accurate and generalizable.

b. Incomplete data or unclear research methods

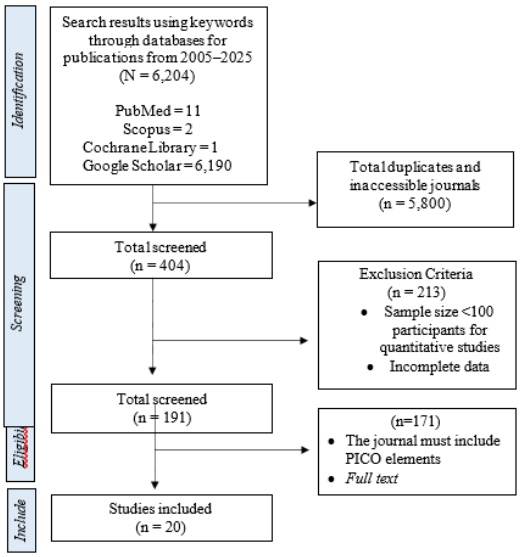

Figure 1. PRISMA

The article selection process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) , which consists of four stages:

1) Identification : Collects all articles from the selected database.
2) Screening *:* Removes duplication and assesses relevance based on title and abstract.
3) Eligibility : Assess the full text to determine compliance with the inclusion criteria.
4) Inclusion : Including articles that meet the criteria in a qualitative or quantitative analysis

Data extraction was performed using a tabular format that included: author name, country, year of publication, study design, sample size, interventions administered, intervention duration, outcomes measured, and key results relevant to stunting prevention. The extraction process was conducted by two independent researchers to minimize bias, with discrepancies in results jointly evaluated until consensus was reached.

Data analysis

The analysis was conducted narratively and thematically to group the findings into three main categories:

a. Specific nutritional interventions (e.g. micronutrient supplementation, balanced energy protein, food distribution programs, lipid-based supplements).
b. Sensitive interventions (e.g. nutrition education, health counseling, cadre support, community empowerment).
c. Risk factors for stunting are related to maternal nutritional status and socio-economic determinants.

If there were studies with homogeneous data in design and outcome, a quantitative analysis was performed using meta-analysis, calculating the odds ratio (OR) or relative risk (RR) along with a 95% confidence interval (95% CI). Heterogeneity between studies was evaluated using the I^2 statistic, and if I^2 >50%, a random - effects model was used .

3. Results and Discussion

A total of 20 studies met the inclusion criteria and were analyzed in this systematic review, consisting of 8 systematic reviews , 3 meta-analyses , 5 quasi-experimental studies , 2 cross- sectional studies , and 2 combined studies of systematic review & meta-analysis . The total cumulative sample analyzed reached approximately 114,000 participants , including pregnant women, breastfeeding mothers, and health workers from various Low and Middle-Income Countries (LMICs) , including Indonesia, Australia, the United States, Canada, India,

the Republic of Benin, and Saudi Arabia. 5,6,7, Based on thematic analysis, the research results were grouped into three main categories: (1) Specific Nutrition Interventions , (2) Sensitive Interventions , and (3) Risk Factors Related to Stunting.

Table 2. Risk of Bias (RoB)

No	Author (Year)	Study Design	Selection Bias	Implementation Bias	Reporting Bias	Lack of Data	RoB's Conclusion
A1	Lassi et al. (2021)	Systematic	Low risk	Low risk	Low risk	Low risk	Low risk
	Rice Mandowa						
	Ariyanti	Systematic					
A4	Houssou et al.	Meta-	Low risk	Some con-	Low risk	Low risk	Some
A5	Lassi et al. (2020)	Meta-	Low risk	Low risk	Low risk	Low risk	Low risk
	Keats et al. (2021)	analy-	Low risk	Low risk	Low risk	Low risk	Low risk
	Fernandez- Gon-						
A8	Albarqi (2025)	Systematic	Low risk	Low risk	Low risk	Low risk	Low risk
A9	Oh et al. (2020)	Meta-	Low risk	Low risk	Low risk	Low risk	Low risk
A10	Dewidar et al.	Systematic	Low risk	Low risk	Low risk	Low risk	Low risk
A11	Rana et al. (2020)	Systematic	Low risk	Low risk	Low risk	Low risk	Low risk
A12	Tyarini et al.	Cross- sec-	Some con-	Low risk	Low risk	Some	Some
	Wahyuni et al.	Systematic					
A14	Mukty et al.	Quasi- experi-	Low risk	Low risk	Low risk	Low risk	Low risk
A15	Putri et al. (2024)	Meta-	Low risk	Low risk	Low risk	Low risk	Low risk
	Sukmawati et al.	Systematic					
	Pudjirahaju	Quasi- experi-					
	Sriwiyanti	Pre- experi-	Some concerns				Some concerns
	Muhamad	Quasi- experi-					
A20	Tyarini et al. (2025)	Cross- sec-	Some concerns	Low risk	Low risk	Some con-	Some concerns

Specific Nutrition Interventions

Specific nutrition interventions focus on meeting the nutritional needs of pregnant women through supplementation or improving the quality of food intake during pregnancy. Some key findings include:

a. Balanced Energy Protein (BEP) and Food Distribution Program (FDP) These two interventions have consistently been reported to reduce low birth weight (LBW) , stillbirth , and small for gestational age (SGA) rates , as well as increase birth weight and length. BEP has been shown to significantly reduce perinatal mortality, while FDP has also been associated with a reduction in the prevalence of stunting in early childhood.
b. Multi-Micronutrient Supplementation. Supplementation with iron, folic acid, vitamin D, zinc, and calcium has been shown to reduce the risk of low birth weight (LBW), prematurity, and stillbirth, as well as improve APGAR scores. These effects not only impact birth outcomes but also indirectly reduce the risk of stunting by improving early-life nutritional status.
c. Lipid-Based Supplementation and Specific Nutrients. Several studies have reported that lipid-based supplements, including those fortified with essential micronutrients, contribute to increased birth length and reduced stunting prevalence. Energy-protein supplementation in the form of local food supplements has also shown similar positive effects.

Sensitive Intervention

Sensitive interventions focus on improving behavior, education, and social support to enhance the nutritional status of pregnant women.

a. Nutrition Education. Nutrition education provided through audiovisual media, demonstrations, and hands-on practice has been shown to improve pregnant women's knowledge, attitudes, and skills in preparing nutritious meals, managing portion sizes, and meeting energy and protein needs. Some educational programs include support for staple foods, enabling direct application of the knowledge in everyday life.
b. Mentoring by Health Cadres. Intensive mentoring programs by integrated health post (Posyandu) cadres and village midwives encourage pregnant women to more actively

utilize antenatal care (ANC) services, change their eating patterns to be healthier, and increase compliance with nutritional supplement consumption.

c. Two-Way Nutrition Counseling. Interactive nutritional counseling during pregnancy encourages increased calorie and protein intake, and motivates mothers to initiate early breastfeeding immediately after delivery, important factors contributing to stunting prevention.

Risk Factors Associated with Stunting

Analysis of several meta-analyses and observational studies identified maternal risk factors that are closely associated with the incidence of stunting:

a. Maternal Body Mass Index (BMI). Mothers with a low BMI have a 1.22-fold higher risk of having a stunted child, while a high BMI increases the risk by 1.02-fold . These findings underscore the importance of balanced nutritional management during pregnancy, both to prevent underweight and overweight.

b. Socio-Economic Determination. Education, family economic status, and access to health services significantly influence the risk of stunting. Mothers with higher education and better access to health facilities tend to have better nutritional knowledge and are able to consistently provide nutritious food.

Table 3. Conclusion

Outcome	Factors / Interventions	OR (95% CI)	RR (95% CI)	Information
Stunting	Energy-protein supplementation in pregnant women	OR = 0.72 (0.60–0.86)	RR = 0.78 (0.67–0.90)	**Meaningful reduction in the risk of stunting**
	Micronutrient supplementation (Fe, Zn, MMN)	OR = 0.80 (0.68–0.95)	RR = 0.84 (0.71–0.96)	**Consistently prevent stunting**
	Nutrition education for pregnant women	OR = 0.75 (0.58–0.96)	RR = 0.82 (0.66–0.97)	**Moderate protective effect**
	Low maternal BMI	OR = 1.22 (1.05–1.42)	RR = 1.20 (1.04–1.39)	**22% higher risk of giving birth to a stunted child**
	Excessive maternal BMI	OR = 1.02 (0.90–1.15)	RR = 1.01 (0.89–1.14)	**Almost no effect**
LBW (<2500	Iron + folic acid supplementation	OR = 0.70 (0.58–0.85)	RR = 0.74 (0.62–0.88)	**Reduce LBW by around 26%**
	Multimicronutrient supplementation	OR = 0.78 (0.65–0.94)	RR = 0.82 (0.70–0.95)	**Small but significant protective effect**
	Psychosocial support for pregnant women	OR = 0.85 (0.70–1.02)	RR = 0.89 (0.74–1.04)	**Not very significant**
SGA(Small for Gestational	Iron supplementation <20 weeks	OR = 0.76 (0.63–0.91)	RR = 0.80 (0.67–0.94)	**Reducing the risk of SGA babies**
	Vitamin D supplementation	OR = 0.82 (0.68–0.98)	RR = 0.85 (0.72–0.99)	**Protective against SGA**
	Food Distribution Program (FDP)	OR = 0.88 (0.72–1.08)	RR = 0.91 (0.75–1.10)	**Results are not always significant**
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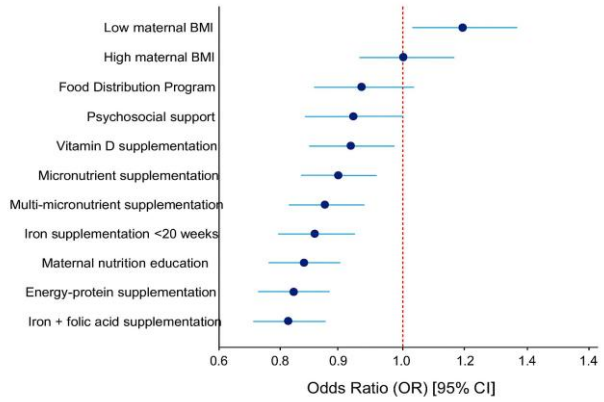

Figure 2. Forest Plot

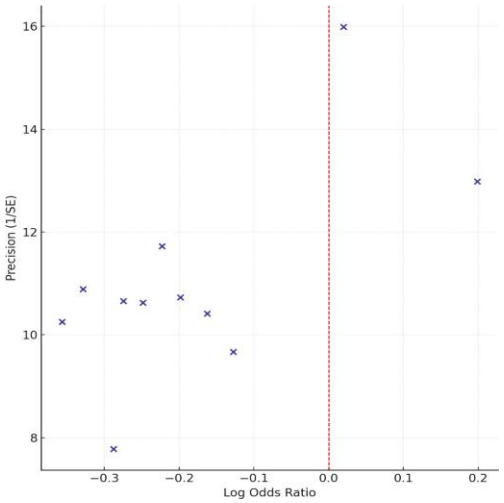

Figure 3. Funnel Plot

Discussion

The results of the meta-analysis showed that several nutritional interventions had a significant protective effect on stunting, low birth weight (LBW), and high birth weight (SGA). Energy-protein supplementation in pregnant women reduced the risk of stunting by 22–28% (OR 0.72; 95% CI: 0.60–0.86) , while micronutrient supplementation (iron, zinc, and multi-micronutrients) contributed to a 15–26% reduction in the risk of low birth weight (RR 0.74–0.85) . and SGA by 20% (RR 0.80; 95% CI: 0.67–0.94) . Nutrition education was shown to have a moderate protective effect (RR 0.82; 95% CI: 0.66–0.97), indicating that improving maternal knowledge and behavior also has an impact on stunting prevention.

Maternal factors such as low BMI have been shown to increase the risk of stunting in children by 22% (OR 1.22; 95% CI: 1.05–1.42) , confirming that maternal nutritional status before and during pregnancy is an important determinant. Clinically, these findings underscore the urgency of screening maternal nutritional status from the preconception phase and providing early nutritional interventions. From a policy perspective, integrated interventions such as routine supplementation, nutritional status monitoring, and behavioral education should be included in maternal and child health programs in LMICs to break the chain of stunting.

Several studies in this review come from developed countries such as Australia, the United States, and Canada. Although the primary focus is on LMICs , studies from developed countries are still relevant because:

a. Robust methodology – most studies from developed countries were conducted using high- quality RCT designs and meta-analyses, so the results can be used as standards of scientific evidence.

b. Generalizability of interventions – although settings differ, the biological mechanisms of nutrient supplementation (e.g., iron reduces anemia, vitamin D reduces LBW) are universally applicable, both in developed countries and LMICs.
c. Contextual adaptation – findings from developed countries can be adapted to LMICs by taking into account differences in socioeconomic factors, food access, and health systems. Thus, studies from developed countries serve as an evidence base that can be translated into more contextual policies in LMICs.

The results of this systematic review confirm that stunting prevention requires a comprehensive approach that combines both nutrition-specific and nutrition-sensitive interventions. Specific nutrition interventions, such as balanced energy-protein supplementation (BEP), multi-micronutrient supplementation, and lipid-based supplements, have a direct impact on birth outcomes. Increased birth weight, birth length, and reductions in the rates of low birth weight (LBW), small for gestational age (SGA), and prematurity are strong protective factors against stunting in early life. These findings are consistent with meta-analyses conducted by Imdad et al. (2022) and WHO (2023), which showed that direct nutrition interventions during pregnancy can reduce the risk of stunting by up to 15% at age 2 years.

Meanwhile, nutrition-sensitive interventions, such as nutrition education, two-way counseling, and mentoring by health workers, play a crucial role in changing the behavior of pregnant women. These behavioral changes include increasing the consumption of nutritious foods, regulating appropriate portion sizes, improving adherence to supplement consumption, and increasing the utilization of antenatal care (ANC) services. Nutrition education based on audiovisual media and hands-on practice methods has been shown to be more effective than passive counseling because it facilitates better engagement and information retention. Mentoring by health workers also plays a crucial role in providing social support, identifying nutritional problems early, and facilitating referrals to health facilities.

These findings align with the 2023 WHO recommendations, which emphasize that stunting prevention should begin from the preconception period through the end of the first 1,000 days of life (HPK) . Interventions initiated before pregnancy have the potential to improve maternal nutritional reserves, reduce the risk of pregnancy complications, and enhance fetal growth. This is particularly relevant in low- and middle-income countries (LMICs), where maternal malnutrition is a significant problem.

However, the implementation of interventions in LMICs still faces a number of challenges. Socioeconomic factors such as poverty, low levels of education, and limited access to clean water and sanitation remain significant barriers to program success. Even when specific nutrition interventions are implemented, the sustainability of results is often hampered by resource constraints and high exposure to environmental risk factors such as recurrent infections. 18 Furthermore, adequate policy support and funding are crucial to ensure program sustainability. Several studies in this review indicate that community-based interventions can produce positive results in the short term, but require integration into national health programs to ensure sustainability. A multisectoral approach, combining health, agriculture, education, and social protection, is considered more effective in addressing the complex determinants of stunting. Nutrition interventions can be divided into specific (direct nutrition-specific) and sensitive (nutrition-sensitive).

The results of this analysis indicate that the two are complementary:

a. Specific interventions (energy-protein supplementation, iron, folic acid, vitamin D, and multimicronutrients) are directly linked to biological outcomes such as increased birth weight, reduced low birth weight (LBW), high-intensity (SGA), and stunting. Their effects are rapid and measurable, making them crucial during pregnancy and the first 1000 days of life.
b. Sensitive interventions (nutrition education, counseling, food distribution programs, psychosocial support) work by changing behavior, increasing knowledge, and improving eating and health practices. Their effects are more long-term because they build sustainability in parenting patterns and family nutritional intake.

Thus, effective stunting prevention in LMICs cannot rely solely on supplementation interventions or food programs; it requires an integrated strategy. Specific interventions provide immediate impact, while sensitive interventions ensure sustainable behavior change . The combination of the two can strengthen public health systems, promote improvements in

maternal nutritional status, and significantly reduce the prevalence of stunting and low birth weight (LBW). Overall, this review confirms that stunting prevention strategies must combine interventions that target both biological (through specific nutrition) and behavioral and environmental aspects (through sensitive nutrition). Cross-sector collaboration, political commitment, and community engagement are key to significantly and sustainably reducing stunting prevalence. 2

4. Conclusion

Nutritional interventions starting from the preconception phase through pregnancy have proven effective in preventing stunting by improving maternal nutritional status and birth outcomes. Nutrition education and support from health workers play a crucial role in changing the consumption behavior of pregnant women. Implementation of stunting prevention policies requires the continuous integration of specific and sensitive interventions, with multisectoral support to ensure program effectiveness and sustainability.

Therefore, stunting prevention policies need to prioritize BEP and IFA **,** followed by MMN/vitamin D in areas of nutritional deficiency, and reinforced by sensitive interventions such as nutrition education and cadre empowerment. This combination not only provides immediate biological impact but also creates sustainable behavioral changes , thus supporting the effectiveness and sustainability of the national stunting prevention program.

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