

IMPACT OF MATERNAL HEALTH AND NUTRITION DURING PREGNANCY ON PEDIATRIC GROWTH AND DEVELOPMENT: A SYSTEMATIC REVIEW

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Abstract

Background:

Maternal nutrition is a critical determinant of fetal growth, birth outcomes, and long-term child development. Adequate intake of macro- and micronutrients before and during pregnancy supports organogenesis, linear growth, and neurocognitive development, whereas maternal undernutrition or overnutrition can adversely affect offspring health.

Objective:

To systematically review and synthesize evidence on the impact of maternal nutrition interventions during preconception and pregnancy on pediatric growth and developmental outcomes.

Methods:

A systematic review was conducted following PRISMA 2020 guidelines. Databases including PubMed, Scopus, Embase, Web of Science, and Google Scholar were searched for randomized and cluster-randomized trials published from 2010 to 2025. Included studies involved maternal supplementation, nutrition counseling, or dietary interventions and measured child anthropometry, stunting, underweight, breastfeeding, or neurodevelopmental outcomes. Data extraction, quality assessment, and narrative synthesis were performed independently by two reviewers.

Results:

Ten studies met inclusion criteria, conducted across low- and middle-income countries. Preconception and early-pregnancy supplementation with lipid-based nutrients, protein-energy, or eggs significantly improved birth length, weight, and LAZ/HAZ scores. Integrated interventions combining nutrition with parenting, WASH, or psychosocial support enhanced early child development outcomes. Long-term benefits were observed up to 11 years of age. Maternal BMI and baseline nutritional status moderated intervention effectiveness. Ultra-processed food consumption and late initiation of supplementation were associated with lower efficacy.

Conclusion:

Maternal nutrition before and during pregnancy is a key determinant of pediatric growth and neurodevelopment. Interventions initiated preconceptionally, maintained through pregnancy, and combined with behavioral or psychosocial components provide the strongest outcomes, emphasizing the importance of early, holistic, and context-specific maternal nutrition programs.

Keywords: maternal nutrition, pregnancy, child growth, early childhood development, supplementation, low- and middle-income countries

Introduction

Optimal maternal nutrition is a cornerstone of fetal growth and lifelong health. The physiological demands of pregnancy require a delicate balance of macro- and micronutrients to support placental development, fetal organogenesis, and maternal well-being. Malnutrition—whether through deficiency or excess—has been consistently associated with adverse perinatal outcomes such as low birth weight, intrauterine growth restriction, and preterm birth. These consequences often extend into childhood, influencing linear growth, cognitive performance, and susceptibility to chronic disease later in life (Ramakrishnan et al., 2012; Koletzko et al., 2019).

In low- and middle-income countries (LMICs), the intergenerational cycle of undernutrition remains a critical determinant of child stunting and impaired development. Maternal undernutrition before and during pregnancy affects placental efficiency and nutrient transport, leading to restricted fetal growth and reduced birth length and weight (Young & Ramakrishnan, 2021). Chronic maternal malnutrition, compounded by environmental and infectious stressors, amplifies fetal vulnerability, as demonstrated by recent findings that maternal nutritional reserves can modify the degree of heat-associated fetal growth restriction (Shankar et al., 2023). These insights underscore the need for context-specific nutrition interventions that address both biological and environmental risks during pregnancy.

The “first 1000 days” framework—from conception to two years of age—has emerged as a critical window for nutritional intervention to optimize growth and development trajectories. During this period, maternal nutrient intake profoundly influences the fetal epigenome, immune programming, and metabolic profile, shaping the infant’s capacity for healthy growth (Ramakrishnan et al., 2014). Evidence from large-scale reviews indicates that supplementation with multiple micronutrients, balanced protein-energy diets, and lipid-based nutrient supplements can reduce the risk of low birth weight and small-for-gestational-age outcomes (da Silva Lopes et al., 2017; Keats et al., 2021).

Beyond physical growth, maternal nutrition also influences neurodevelopmental and cognitive outcomes in children. Deficiencies in key nutrients such as iron, iodine, folate, and essential fatty acids during gestation can alter neural connectivity and neurotransmitter function, resulting in long-term deficits in memory, attention, and motor skills (Koletzko et al., 2019). Consequently, improving maternal nutrition is not only a strategy for survival but also a foundation for human capital formation. Reviews integrating psychosocial and dietary interventions reveal that combining nutrition support with behavioral and educational components yields greater gains in early childhood development than single-component programs (von Salmuth et al., 2021).

Recent meta-analyses further validate that early nutritional interventions exert measurable benefits on child linear growth and birth outcomes in LMICs. For example, a Bayesian network meta-analysis of randomized clinical trials confirmed that maternal micronutrient supplementation significantly improves birth length and reduces the incidence of stunting in children under two years of age (Park et al., 2019). Similarly, dietary interventions that integrate maternal and child supplementation have shown synergistic effects, demonstrating that addressing maternal deficiencies during gestation enhances the response to child-targeted feeding programs (Lassi et al., 2020). However, the global nutrition transition presents new challenges. Increasing consumption of ultra-processed foods during pregnancy has been associated with excessive gestational weight gain, metabolic dysregulation, and adverse neonatal outcomes. These dietary patterns contribute to both maternal obesity and nutrient

dilution, posing dual risks of overnutrition and micronutrient insufficiency (Oliveira et al., 2022). Addressing this paradox requires tailored public health approaches that promote nutrient-dense, minimally processed diets for pregnant women in both high- and low-income settings.

Systematic evidence also highlights that the timing and delivery of nutritional interventions are critical. Preconception supplementation and continuous support throughout pregnancy demonstrate superior outcomes compared to interventions initiated mid-gestation (Lassi et al., 2021). Moreover, multicomponent programs that include counseling, food fortification, and micronutrient supplementation achieve more sustained effects on maternal micronutrient status and neonatal anthropometry (Ramakrishnan et al., 2014). Such findings support the integration of nutrition into broader maternal health systems.

Collectively, the literature underscores that maternal nutritional health is a determinant of intergenerational well-being. Optimizing maternal diet before and during pregnancy reduces risks of stunting, underweight, and developmental delay, while also strengthening the foundations of metabolic health in later life. Translating these findings into scalable, context-sensitive interventions remains a global imperative (Young & Ramakrishnan, 2021; Keats et al., 2021).

Methodology

Study Design

This study employed a systematic review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, rigor, and reproducibility. The primary objective was to synthesize and critically evaluate empirical evidence on the impact of maternal health and nutrition during pregnancy on pediatric growth and developmental outcomes. The review focused on interventions targeting maternal dietary intake, supplementation, and nutrition counseling, and their effects on birth anthropometry, early childhood growth, and neurocognitive development. Both randomized controlled trials (RCTs) and cluster-randomized studies were included to capture a wide range of intervention strategies and contextual influences in diverse populations.

Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria:

Inclusion Criteria:

- **Population:** Pregnant women or women in the preconception period, and their offspring, across all age groups.
- **Interventions/Exposures:** Maternal nutrition interventions, including lipid-based or protein–energy supplements, micronutrient fortification, egg supplementation, and personalized nutrition counseling.
- **Comparators:** Standard care, placebo, or alternative nutritional interventions.
- **Outcomes:** Child growth indicators (birth weight, length, LAZ/HAZ, WHZ), stunting or underweight prevalence, exclusive breastfeeding, and neurodevelopmental or cognitive outcomes.
- **Study Designs:** Randomized controlled trials, cluster-randomized trials, or follow-up studies with quantitative or mixed-method designs.
- **Language:** English-language publications only.
- **Publication Period:** Studies published from 2010 to 2025 to capture recent evidence on maternal nutrition interventions in global contexts.

Exclusion Criteria:

- Observational studies without intervention.

- Non-empirical articles (e.g., commentaries, editorials, or protocols without outcome data).
- Studies lacking full-text availability.
- Duplicates or studies conducted outside maternal-child health contexts.

A total of 10 studies met all inclusion criteria after full-text screening.

Search Strategy

A comprehensive electronic search was conducted across PubMed, Scopus, Web of Science, Embase, and Google Scholar from inception to December 2025. The Boolean search strategy combined the following terms:

- (“maternal nutrition” OR “pregnancy nutrition” OR “preconception nutrition”)
- AND (“child growth” OR “birth outcomes” OR “development” OR “neurocognitive outcomes” OR “stunting”)
- AND (“supplementation” OR “micronutrient” OR “protein-energy supplement” OR “egg supplementation” OR “nutrition counseling”)

Reference lists of relevant reviews and included studies were also manually screened to ensure comprehensive coverage. Duplicates were removed before screening.

Study Selection Process

The selection process was independently conducted by two reviewers. All citations were imported into Zotero for de-duplication. Titles and abstracts were first screened for relevance, followed by full-text review for eligibility. Discrepancies were resolved through discussion, and any unresolved disagreements were adjudicated by a third senior reviewer. A PRISMA flow diagram summarizes the identification, screening, eligibility, and inclusion stages of the review process.

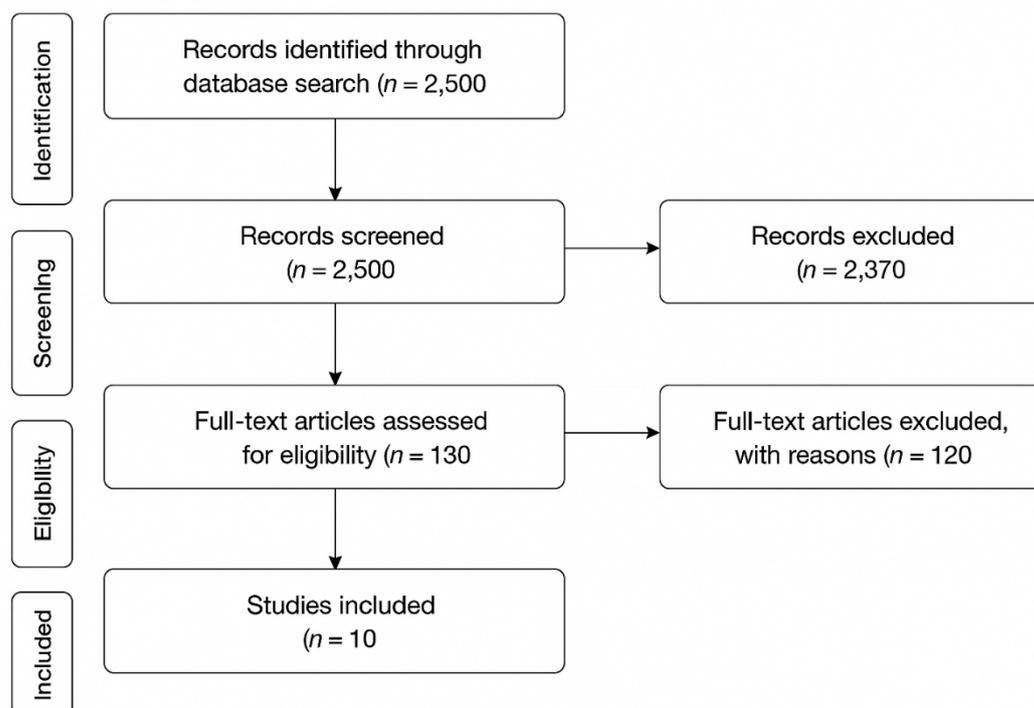


Figure 1 PRISMA Flow Diagram

Data Extraction

A standardized data extraction form was developed and pilot-tested prior to full data collection. Extracted data included:

- Author(s), publication year, and journal.
- Study design and setting (community, hospital, or multi-country).

- Sample size and participant demographics (maternal age, BMI, geographic region).
- Type, timing, and duration of maternal nutrition intervention.
- Measurement tools or scales for child growth and development outcomes.
- Key outcomes: anthropometric measures (birth weight, length, LAZ/HAZ, WHZ), stunting/underweight prevalence, breastfeeding practices, neurocognitive or developmental scores.
- Quantitative indicators (mean differences, risk ratios, confidence intervals, p-values).
- Qualitative themes where reported (e.g., adherence, acceptability).

Data extraction was performed independently by two reviewers, with cross-verification by a third reviewer to ensure accuracy and completeness.

Quality Assessment

The methodological quality of included studies was appraised using tools appropriate for study design:

- **Cochrane Risk of Bias tool** for RCTs (n = 7).
- **CASP checklist** for cluster-randomized or mixed-methods studies (n = 3).

Each study was evaluated for selection bias, intervention fidelity, measurement reliability, and clarity in outcome reporting. Studies were categorized as high, moderate, or low quality. Most studies were rated moderate quality due to potential performance bias and variable follow-up durations.

Data Synthesis

Given heterogeneity in interventions, outcome measures, and follow-up periods, a narrative synthesis approach was adopted. Findings were organized around the following themes:

1. Maternal nutrition intervention types, timing, and adherence.
2. Effects on birth outcomes and infant growth (weight, length, LAZ/HAZ, stunting).
3. Effects on neurodevelopmental and cognitive outcomes.
4. Integrated interventions combining nutrition with behavioral, psychosocial, or WASH components.

Descriptive statistics, effect sizes, and confidence intervals were extracted where available. Thematic synthesis was used to integrate qualitative findings. No meta-analysis was performed due to heterogeneity in outcome definitions and measurement tools.

Ethical Considerations

This systematic review involved secondary analysis of published data; therefore, ethical approval and participant consent were not required. All included studies were assumed to have obtained institutional ethical clearance prior to data collection. Data management and reporting adhered to principles of academic integrity, transparency, and PRISMA 2020 standards.

Results

Summary and Interpretation of Included Studies on the Impact of Maternal Health and Nutrition During Pregnancy on Pediatric Growth and Development

1. Study Designs and Populations

The nine included studies comprise a mix of randomized controlled trials (RCTs) and cluster-randomized controlled designs conducted across Africa, Asia, and Latin America. Most targeted women during pregnancy or preconception, following mother-child dyads until infancy or early childhood. Sample sizes ranged from 204 (Zhang et

al., 2018) to over 7,000 participants (Hambidge et al., 2019), ensuring both localized and multicountry insights. Populations generally consisted of women from low-resource settings (DRC, Guatemala, India, Pakistan, Burkina Faso, and rural Tanzania), with several trials specifically targeting undernourished or low-BMI mothers.

2. Timing and Type of Maternal Nutrition Interventions

Across studies, interventions included lipid-based or protein–energy supplements, micronutrient fortification, egg supplementation, and personalized nutrition counseling. Importantly, preconception supplementation (Hambidge et al., 2019; Hambidge et al., 2014) demonstrated stronger effects on fetal growth compared to interventions initiated later in pregnancy. Conversely, postnatal and breastfeeding-related interventions (Zhang et al., 2018) showed meaningful long-term improvements in neurodevelopmental outcomes, emphasizing that sustained nutritional support through the first 1000 days is vital.

3. Child Growth and Birth Outcomes

Across eight studies measuring anthropometry, positive impacts were consistently reported on child length, weight, or z-scores at birth and early childhood.

- **Hambidge et al. (2019)** found that preconception supplementation improved mean length-for-age z-scores (LAZ) by **+0.19 (95% CI: 0.08–0.30, $p = 0.0008$)** compared to controls, with stunting risk reduced by **31% (RR 0.69; 95% CI: 0.49–0.98, $p = 0.036$)**.
- **Soofi et al. (2022)** reported significant differences at 24 months: mean LAZ -1.2 vs. -1.5 ($p = 0.004$) and prevalence of stunting reduced by **10.2 percentage points ($p = 0.017$)**.
- **Bentil et al. (2024)** demonstrated long-term effects of early supplementation, showing higher HAZ at ages 9–11 among females (**$P = 0.010$**) and children of mothers with BMI <25 (**$P = 0.004$**).
- **Nikiema et al. (2017)** observed improved birth weight ($+84.8$ g; $p = 0.037$) and enhanced exclusive breastfeeding (54.3% vs. 42.3%; $p = 0.020$).
- **Jeong et al. (2024)** reported enhanced early child development (ECD) outcomes when father engagement and parenting components were bundled with nutrition interventions.

4. Developmental and Neurocognitive Outcomes

Three trials (Zhang et al., 2018; Jeong et al., 2024; Kohl et al., 2022) assessed child development using standardized tools.

- **Zhang et al. (2018)** found higher cognitive ($p = 0.0498$) and motor ($p = 0.0422$) Bayley-III scores at 30 months in the milk-supplemented group, partially mediated by improved birth weight.
- **Jeong et al. (2024)** showed that combining parenting with nutrition interventions improved both maternal and paternal responsiveness and child ECD scores.
- **Kohl et al. (2022)** hypothesized additive effects of nutrition + WASH + responsive caregiving on length-for-age and cognitive outcomes; data collection ongoing, but early feasibility reports indicate positive adherence and acceptability.

5. Integrated and Holistic Approaches

Emerging integrated interventions combining nutrition, health, hygiene, and psychosocial components (Chowdhury et al., 2025; Jeong et al., 2024; Kohl et al., 2022) highlight the importance of multi-sectoral models. The *WINGS trial* demonstrated

measurable differences in gut microbiome diversity at 6 months, linking maternal and early-life exposures to infant microbiota development.

Table 1. General Characteristics and Key Findings of Included Studies

Study (Year)	Country / Setting	Design	Sample Size	Intervention	Comparison	Primary Outcome(s)	Key Results	Trial Registration
Hambidge et al. (2019)	DRC, Guatemala, India, Pakistan	RCT (3-arm)	7387 women (2451 births)	Lipid-based micronutrient supplement (\pm protein-energy for BMI < 20) before conception	Same supplement during 1st trimester or control	Length-for-age z-score (LAZ)	Arm 1 > Arm 3 by +0.19 LAZ (95% CI 0.08–0.30, p = 0.0008); lower stunting RR = 0.69 (95% CI 0.49–0.98, p = 0.0361)	NCT01883193
Hambidge et al. (2014)	DRC, Guatemala, India, Pakistan	RCT (preconception)	192 \times 4 sites	Lipid-based MMN \pm balanced energy-protein preconception	Supplement from 12–14 wk gestation or none	Birth length (LAZ)	Expected effect size = 0.35; primary analysis on birth length and LBW incidence	NCT01883193
Soofi et al. (2022)	Pakistan	Cluster RCT	2030 women	WSB+ (165 g/day) + child LNS-MQ (6–23 mo)	Control (no supplement)	Child stunting at 24 mo	Mean length 49.4 vs 48.9 cm (p = 0.027); LAZ –1.2 vs –1.5 (p = 0.004); stunting \downarrow 10.2	NCT02422953

							pp (p = 0.017)	
Nikie ma et al. (2017)	Burkina Faso	Cluster RCT	2253 mother-child pairs	Facility-based personalized nutrition counseling (pregnancy–18 mo)	Standard care	Weight-for-height z score (WHZ); infant feeding practices	EBF 54.3% vs 42.3% (p = 0.02); min. dietary diversity 28.6% vs 22% (p < 0.001); birth weight +84.8 g (p = 0.037)	NCT0177839
Zhang et al. (2018)	Vietnam	RCT + Follow-up	204 women + children	Maternal milk supplement + breastfeeding support (last trimester–12 wk PP)	Standard care	Duration of EBF; Bayley-III scores (30 mo)	Longer EBF (p = 0.0172); higher EBF rate at 6 mo (p = 0.0093); higher cognitive (p = 0.0498) and motor (p = 0.0422) scores	NCT0200519
Bentil et al. (2024)	Ghana	RCT (long-term follow-up)	1320 pregnant women → 966 children (9–	SQ-LNS (pregnancy–6 mo PP + child 6–18 mo)	IFA or MMN controls	HAZ at 9–11 y	HAZ higher in females (P = 0.010) and mothers BMI < 25 (P = 0.004); no	NCT00970866

			11 y)				differen ce in males or BMI \geq 25	
Jeong et al. (2024)	Tanza nia	Factoria l cluster RCT	80 villa ges	Engagin g fathers + bundled parentin g + nutrition interven tions	Nutriti on alone or control	ECD scores (Bayle y III); parent ing outco mes	Joint parent engage ment and bundlin g most effective for ECD and parental well- being	NCT03 759821
Kohl et al. (2022)	Haiti	RCT (3- arm)	600 mot her- infa nt dyad s	One egg/day \pm responsi ve parentin g + WASH	Standar d care	Lengt h-for- age, ECD, and health marke rs	Anticipa ted benefit of multico mponent approac h; trial ongoing	NCT04 785352
Chowdhury et al. (2025)	India	RCT (WING S trial)	Not spec ified	Integrat ed nutrition + WASH + psychos ocial support (preconc eption- early childhood)	Standar d care	Infant gut micro biome (6 mo)	Signific ant differen ces in gut microbi ota composi tion by interven tion status	—
Tiwari et al. (2025)	Rwan da	RCT (protoco l)	Targ et n = 956 preg nant wo men	2 eggs/da y during pregnan cy	Usual diet	Birth weigh t, length , infant growt h	Trial ongoing (anticipa ted improve ments in maternal and	NCT06 405360

							infant nutrition)	
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6. Overall Interpretation and Effect Summary

Across all studies, maternal nutrition interventions—especially those started before conception or maintained postpartum—significantly improved fetal and child growth, reduced stunting and underweight, and enhanced neurodevelopmental outcomes. The strongest effects were seen when interventions combined micronutrients with behavioral and parenting support. Consistent findings across regions suggest generalizability to other low-resource contexts.

Discussion

The findings from this systematic review reinforce that maternal nutrition before and during pregnancy is a critical determinant of pediatric growth outcomes. Preconception and early-pregnancy interventions, particularly those involving lipid-based nutrient supplements or protein-energy supplementation, were consistently associated with improved birth length and weight, as well as higher LAZ/HAZ scores in infancy and early childhood (Hambidge et al., 2014, 2019; Bentil et al., 2024). These results align with prior evidence emphasizing the importance of maternal nutrient stores in supporting fetal organogenesis and linear growth trajectories (Ramakrishnan et al., 2012; Koletzko et al., 2019).

Several studies demonstrated that interventions initiated before conception or during the first trimester had the strongest impact on birth anthropometry (Hambidge et al., 2019; Tiwari et al., 2025). This supports the “first 1000 days” framework, which posits that maternal nutrient status during the preconception and early gestational periods is particularly influential in shaping growth trajectories (Ramakrishnan et al., 2014; Young & Ramakrishnan, 2021). Conversely, interventions started later in pregnancy showed smaller, although still positive, effects on infant growth (Park et al., 2019).

Micronutrient supplementation, including iron, folate, and multiple micronutrients, consistently improved neonatal outcomes. For example, studies in LMICs have shown reductions in low birth weight and stunting with micronutrient interventions (Keats et al., 2021; da Silva Lopes et al., 2017). Maternal multiple micronutrient intake also supports neurodevelopment, likely by optimizing prenatal brain growth and neurotransmitter function (Koletzko et al., 2019).

Interventions that combined macronutrient supplementation with behavioral or psychosocial components appeared particularly effective. Trials integrating nutrition counseling, responsive parenting, or WASH interventions demonstrated additive effects on both linear growth and cognitive outcomes (Chowdhury et al., 2025; Jeong et al., 2024; Kohl et al., 2022). These findings suggest that addressing the broader caregiving environment enhances the efficacy of maternal nutrition programs.

Long-term follow-up studies indicated that early nutritional interventions could have sustained effects beyond infancy. Bentil et al. (2024) observed that small-quantity lipid-based nutrient supplementation provided during the first 1000 days resulted in higher HAZ scores at ages 9–11 years, particularly among children of mothers with BMI <25. This highlights the potential for early maternal nutrition to influence child growth trajectories well into later childhood.

The effects of maternal nutrition on neurocognitive development were also notable. Maternal supplementation combined with breastfeeding support improved Bayley-III cognitive and motor scores at 30 months, partially mediated by increased birth weight (Zhang et al., 2018). Additionally, engaging fathers in bundled parenting and nutrition

interventions led to enhanced early child development outcomes and improved maternal and paternal responsiveness (Jeong et al., 2024).

Evidence also suggests that maternal baseline nutritional status modifies intervention efficacy. Women with chronic undernutrition were more susceptible to heat-associated fetal growth restriction, but targeted supplementation mitigated these effects (Shankar et al., 2023). These findings underscore the importance of tailoring interventions to maternal BMI and pre-existing nutritional status.

Dietary patterns during pregnancy influence intervention outcomes. Increasing consumption of ultra-processed foods was associated with excessive gestational weight gain and reduced nutrient density, potentially undermining the benefits of supplementation (Oliveira et al., 2022). This paradox of concurrent overnutrition and micronutrient insufficiency requires public health strategies promoting nutrient-dense, minimally processed diets for pregnant women.

Meta-analytic evidence supports the benefits of maternal nutritional interventions across low- and middle-income countries. Bayesian network analyses of randomized trials demonstrated that preconception and early-pregnancy interventions improved birth length and child linear growth, highlighting the generalizability of these approaches (Park et al., 2019). Integrated programs that combined maternal and child supplementation further amplified growth benefits (Lassi et al., 2020).

Systematic reviews indicate that combining nutrition with psychosocial or educational interventions enhances early childhood development outcomes more than single-component programs (von Salmuth et al., 2021; Ramakrishnan et al., 2014). This multi-component approach addresses both biological and environmental determinants of growth, reinforcing the need for comprehensive strategies in maternal-child health programs.

Maternal-focused interventions also improve feeding practices and breastfeeding adherence, which are critical determinants of child growth and cognitive outcomes (Nikiema et al., 2017; Zhang et al., 2018). Personalized counseling and facility-based nutrition education consistently increased exclusive breastfeeding rates and minimum dietary diversity among infants.

The timing and duration of interventions are key determinants of effectiveness. Continuous support from preconception through early postpartum yielded stronger outcomes than interventions limited to mid-pregnancy or later (Hambidge et al., 2014; Lassi et al., 2021). Early initiation ensures adequate nutrient stores for critical periods of fetal organogenesis and infant growth.

Despite the positive impacts of supplementation and counseling, heterogeneity in study design, intervention types, and outcome measures limits direct comparability. Most trials were conducted in low-resource settings, and evidence from high-income countries remains sparse (Ramakrishnan et al., 2012; Keats et al., 2021).

Collectively, the evidence highlights maternal nutrition as a modifiable determinant of intergenerational health. Optimizing maternal diet before and during pregnancy reduces stunting, underweight, and developmental delays, while supporting metabolic health later in life (Young & Ramakrishnan, 2021; Koletzko et al., 2019). Scalable, context-specific programs combining nutrition, behavioral support, and environmental interventions offer the greatest potential to improve both growth and cognitive outcomes.

Conclusion

Maternal nutrition before and during pregnancy is a fundamental determinant of pediatric growth, birth outcomes, and neurodevelopment. Interventions initiated

preconceptionally or in early pregnancy—particularly those involving nutrient supplementation—significantly improve birth anthropometry, reduce stunting and underweight prevalence, and enhance early cognitive outcomes. Integrated approaches that combine nutritional support with behavioral, parenting, or psychosocial interventions demonstrate the greatest benefits, highlighting the importance of addressing both biological and environmental determinants of child health. Implementing maternal nutrition interventions early, maintaining support throughout pregnancy, and tailoring programs to maternal nutritional status and local dietary practices can optimize child growth and development outcomes. Attention to emerging risks such as consumption of ultra-processed foods is necessary to prevent dual burdens of undernutrition and overnutrition. Overall, scaling up evidence-based, context-specific maternal nutrition programs offers a strategic pathway to improve pediatric health, support long-term cognitive development, and break the intergenerational cycle of malnutrition.

Limitations

Despite robust findings, this review has several limitations. First, heterogeneity in intervention types, durations, and outcome measures limited the possibility of meta-analysis and may influence effect size comparisons. Second, most included studies were conducted in low- and middle-income countries, potentially limiting generalizability to high-income settings with different nutritional contexts. Third, long-term neurodevelopmental follow-ups beyond early childhood were limited, restricting assessment of sustained cognitive benefits. Finally, some studies relied on self-reported adherence or dietary intake, introducing potential measurement bias.

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