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GLOBAL TRENDS AND EFFECTIVENESS OF NUTRITIONAL AND BEHAVIOURAL INTERVENTIONS ON BREASTFEEDING PRACTICES, HUMAN MILK COMPOSITION, AND NEONATAL HEALTH OUTCOMES: A REVIEW

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ABSTRACT

Optimal lactation and adequate neonatal nutrition are fundamental to infant growth, immune development, and long-term health. Despite sustained global efforts to promote exclusive breastfeeding, substantial disparities persist across regions, driven by sociocultural, economic and health-system factors. This systematic review aimed to synthesize evidence on the effectiveness of nutritional and behavioural interventions in improving breastfeeding practices, human milk composition, and neonatal health outcomes, and to characterize intervention strategies relevant to the global management of maternal and neonatal malnutrition. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) guided systematic review (2000–2025) search was conducted across PubMed, Scopus, Web of Science, and Cochrane Library for studies published to date. Randomized Controlled Trials (RCTs), quasi-experimental studies, and observational studies evaluating maternal supplementation, breastfeeding counselling and integrated neonatal nutrition interventions were included. A total of 421 records were identified through database searches. After the removal of 312 titles and abstracts, 109 unique studies remained for data associate screening. Articles with data associates were reviewed, resulting in the exclusion of 81 studies that did not meet the inclusion criteria. Subsequently, 28 full-text articles were assessed for eligibility and were found suitable for inclusion in the systematic review analysis. Behavioural interventions particularly structured breastfeeding counselling, peer-support programmes, and digital health strategies consistently and significantly increased exclusive breastfeeding rates at six months. Nutritional interventions, including maternal supplementation with vitamin D, docosahexaenoic acid (DHA), multivitamins and probiotics, demonstrated modest improvements in human milk composition and infant gut colonization but showed inconsistent effects on infant growth indicators. Subgroup analyses revealed stronger and more consistent benefits in low- and middle-income countries, where multimodal interventions combining counselling and supplementation were more effective in improving breastfeeding initiation and duration than in high-income settings. Overall heterogeneity was moderate, with evidence certainty rated high for exclusive breastfeeding outcomes and low to moderate for milk composition and growth outcomes. Behavioural and nutritional interventions enhance breastfeeding practices and selectively improve biological markers of neonatal nutrition, although effects on infant growth remain inconclusive. These findings underscore the need for integrated, context-specific strategies that combine community-based counselling, maternal nutritional support, and enabling policy environments to advance neonatal nutrition globally. Future research should prioritize standardized outcome measures, long-term follow-up, and evidence generation in underrepresented high-income settings to strengthen global applicability and policy translation.

Key words: neonatal-lactation, regional disparities, low and middle income countries

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INTRODUCTION

Optimal lactation and adequate neonatal nutrition are fundamental determinants of infant survival, growth, and long-term health. Exclusive breastfeeding during the first six months of life is strongly recommended by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), as it provides essential nutrients, enhances immune protection, and reduces the risk of infections and chronic diseases later in life [1, 2]. However, despite decades of global advocacy, adherence to optimal breastfeeding practices remains inconsistent. The 2022 Kenya Demographic and Health Survey (KDHS), for example, reported an exclusive breastfeeding prevalence of 60%, representing notable progress but still falling short of the global nutrition target of 70% by 2030 [3-5].

Globally, breastfeeding patterns reflect significant sociocultural, economic, and health-system disparities. While low- and middle-income countries (LMICs) have traditionally demonstrated higher breastfeeding rates due to cultural norms and economic constraints, they also face challenges related to maternal undernutrition, inadequate healthcare access, and limited maternity protections [6]. Conversely, in high-income countries (HICs), early cessation of breastfeeding is often driven by lifestyle demands, inadequate workplace lactation policies, and aggressive marketing of breast milk substitutes according to Alemu [7]. These disparities underscore the need for context-specific interventions tailored to distinct regional realities.

In response to these challenges, numerous interventions have been developed to promote breastfeeding and enhance milk quality. Behavioural strategies, such as structured lactation counselling, peer-support programs, and community-based education, have consistently demonstrated positive impacts on exclusive breastfeeding initiation and continuation [8]. Similarly, maternal nutritional supplementation including vitamin D, omega-3 fatty acids, and multivitamins has been explored as a means to improve human milk composition and, by extension, infant growth outcomes [9]. Despite these advances, evidence remains fragmented and inconclusive, particularly regarding the impact of maternal diet on milk macronutrients and the downstream effects on infant development. Furthermore, existing reviews have often focused on specific interventions or single outcomes, leaving gaps in understanding the integrated effects of nutritional and behavioural strategies on lactation and neonatal health globally. For instance, while some studies demonstrate improvements in exclusive breastfeeding through counselling, others report limited effects on biochemical milk composition or infant growth, indicating a need for a comprehensive synthesis of evidence [10].

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Considering existing inconsistencies and the urgent need to achieve Sustainable Development Goals related to child nutrition, this review synthesizes global evidence on behavioural and nutritional interventions that improve breastfeeding practices, human milk composition, and neonatal health outcomes. By comparing findings across different socioeconomic and geographic contexts, the review seeks to identify high-impact strategies, expose knowledge gaps, and inform evidence-based policies to optimize neonatal nutrition globally.

MATERIALS AND METHODS

Study Design and Reporting Framework

This systematic review followed the Preferred Reporting Items for Systematic Reviews (PRISMA) 2020 guidelines to ensure methodological rigor, transparency and reproducibility [11].

Eligibility Criteria (Inclusion and Exclusion Criteria)

Eligible studies included randomized controlled trials (RCTs) and quasi-experimental studies that examined nutritional or dietary interventions during lactation and their effects on maternal and neonatal outcomes. Primary outcomes were exclusive breastfeeding rates at six months, early initiation of breastfeeding, breast milk composition, infant growth parameters, and maternal micronutrient status. Exclusion criteria were studies with non-relevant outcomes, inappropriate study populations and insufficient data for extraction.

Information Sources

Comprehensive literature searches were conducted across the following electronic databases: PubMed, Cochrane Library, Scopus, and Web of Science for studies published between 2000 and 2025.

Search Strategy

The search strategy combined controlled vocabulary (for example, Medical Subject Headings) and free-text keywords related to breastfeeding, lactation, nutritional interventions, maternal diet, and infant health outcomes. Boolean operators ("AND," "OR") were used to refine searches according to database-specific syntax. Detailed search strategies for each database are provided in Supplementary Table 1.

Study Selection Process

A total of 421 records were identified through database and supplementary searches. After the removal of 312 articles associated with title and abstract, 109 unique studies remained for data screening. Data screening was done, resulting in the exclusion of 81 studies that did not meet the inclusion criteria.

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Subsequently, 28 full-text articles were assessed for eligibility and were found suitable for inclusion in the systematic review and meta-analysis. The full selection process is summarized in Figure 1, which depicts the stages of identification, screening, eligibility, and inclusion in accordance with the PRISMA 2020 guidelines.

Data Extraction

Data were extracted independently by three reviewers using pre-defined extraction templates. Extracted variables included author, year of publication, country, study design, sample size, population characteristics, intervention type, and duration and outcome measures. Primary outcomes included exclusive breastfeeding rates at six months, early initiation of breastfeeding, breast milk composition, infant growth metrics, and maternal micronutrient status.

All extracted data were cross-checked for accuracy by a second and third reviewer. Any discrepancies were resolved through discussion, and when consensus could not be reached, a fourth reviewer adjudicated. Uncertainties were resolved through discussion or consultation with a fourth reviewer.

Risk of Bias Assessment

Risk of bias for randomized controlled trials was assessed using the Cochrane Risk of Bias Tool, while observational studies were evaluated using appropriate domain-based criteria [12]. Each domain random sequence generation, allocation concealment, blinding of participants, incomplete outcome data and selective reporting was rated as low, high, or unclear risk of bias.

The assessments were performed independently by two reviewers, with disagreements resolved through discussion or consultation with a third and fourth reviewer. The results of the risk of bias assessment are summarized in Table 3, which highlights variability in methodological quality across studies.

Most studies demonstrated low to moderate risk of bias, particularly in areas of randomization, allocation concealment, and completeness of data. However, blinding of participants and allocation concealment were common sources of potential bias, particularly in behavioural and nutritional intervention trials where blinding is challenging.

The results of the bias assessment also informed sensitivity analyses, in which studies with a high overall risk of bias were excluded to test the robustness of pooled estimates.

The full selection process is summarized in Figure 1, which depicts the identification, screening, eligibility, and inclusion stages in accordance with PRISMA 2020 guidelines.

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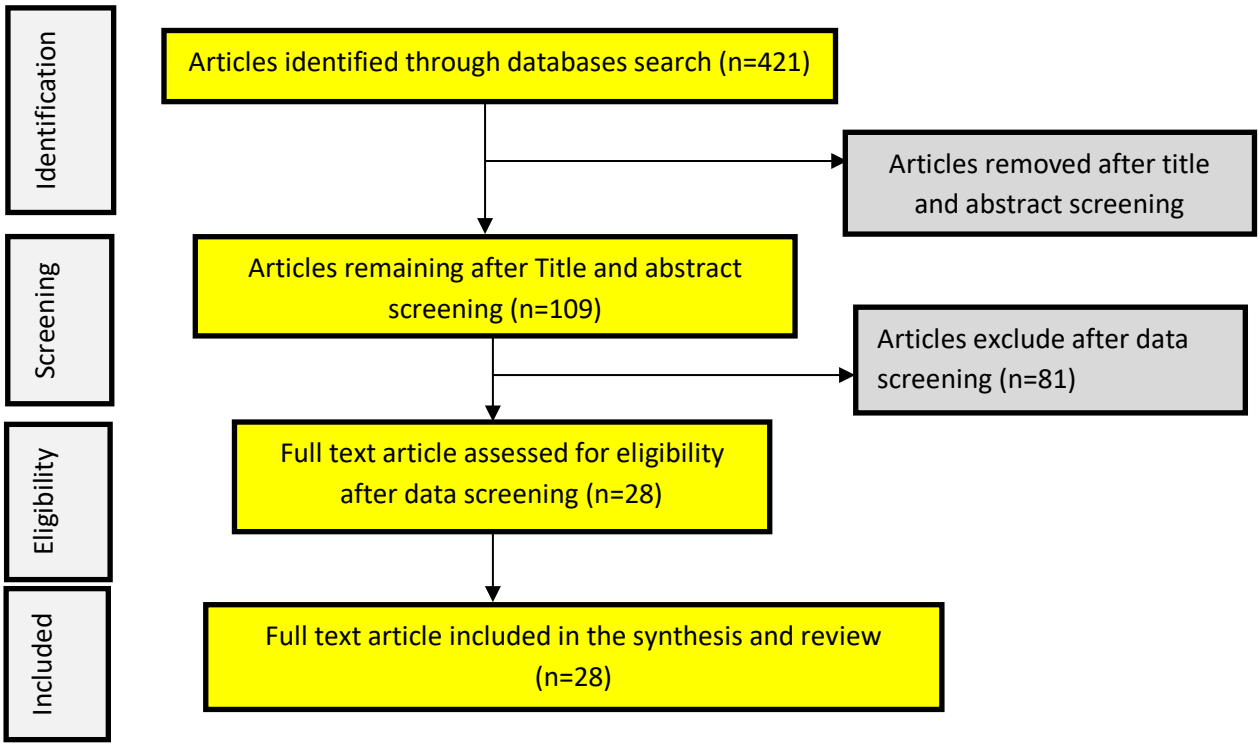

Figure 1: PRISMA 2020 flowchart illustrating inclusion process

RESULTS AND DISCUSSION

A total of 28 studies met the inclusion criteria for review and synthesis analysis. The interventions assessed included high-energy supplementation, lipid-based nutrient supplements (LNS), probiotic administration, breastfeeding counselling, dietary pattern modification, and micronutrient supplementation.

Dietary Pattern Shifts and Ketogenic/Carbohydrate Restricted Diets (Caution Required)

Evidence on the effects of maternal dietary pattern shifts during lactation remains limited and is largely derived from observational studies and small interventional trials, rather than well-powered randomized controlled trials. Available primary data suggest that high-fat, low-carbohydrate dietary patterns can alter breast milk fatty acid composition and total milk fat, although findings are inconsistent and based on small samples with heterogeneous dietary assessment methods [13]. To date, no randomized trials have evaluated the safety or efficacy of ketogenic or severely carbohydrate-restricted diets during lactation, particularly with respect to infant growth and metabolic outcomes.

Importantly, reports from clinical settings describe maternal metabolic complications associated with extreme carbohydrate restriction during lactation, including

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
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lactational ketoacidosis, raising concerns about maternal safety in the absence of clear benefit to the infant. While infant outcomes in these contexts remain poorly characterized, the absence of randomized evidence and the potential for maternal harm warrant caution.

The clinical implication is that in the absence of RCT evidence supporting safety or benefit, population-level dietary guidance during lactation should avoid recommending strict carbohydrate restriction. Clinicians should actively screen for extreme dietary practices during the postnatal period and counsel lactating women on maintaining a balanced macronutrient intake to support maternal metabolic health and breastfeeding sustainability.

Maternal Micronutrients Status

Randomized controlled trial evidence indicates that maternal micronutrient supplementation improves maternal and infant micronutrient status primarily in settings where baseline deficiencies exist. In a postpartum randomized controlled trial conducted in India, Manapurath *et al.* [14] demonstrated that six months of multiple micronutrient supplementations significantly improved maternal and infant micronutrient concentrations, including iron and selected vitamins, compared with standard care. These findings confirm that targeted supplementation during lactation can effectively replenish maternal nutrient stores and enhance micronutrient transfer to the infant.

However, RCT evidence also suggests that benefits are context-dependent, with greater effects observed among women with documented or probable deficiencies at baseline [14]. Data remain limited regarding optimal dosing, duration of supplementation, and the efficacy of universal supplementation strategies in nutritionally adequate populations, as few trials have directly evaluated these questions using growth or functional infant outcomes as primary endpoints.

Overall, available randomized evidence supports a targeted approach to micronutrient supplementation during lactation, prioritizing populations with a high burden of maternal undernutrition or dietary inadequacy. Integration of supplementation with breastfeeding support interventions may further enhance maternal–infant nutritional outcomes, but additional RCTs are needed to determine whether universal postpartum micronutrient supplementation confers meaningful benefits beyond deficiency correction. However, the benefits are contingent on maternal baseline status and adherence to supplementation. As highlighted by Chapman and Nommsen-Rivers [18], over-supplementation without dietary assessment may pose risks of metabolic imbalance.

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Energy and Macronutrient Supplementation Benefits

High-energy Evidence from randomized and quasi-experimental studies indicate that high-energy macronutrient supplementation primarily benefits lactating women with underlying caloric insufficiency, rather than well-nourished populations. Trials providing approximately 2.1–2.2 MJ/day of additional energy to undernourished mothers reported increases in breast milk volume and infant milk or energy intake, with some extension of exclusive breastfeeding duration; however, effects on infant growth outcomes were inconsistent (Table 1) [15, 18]. This pattern suggests that energy supplementation improves breastfeeding performance largely by correcting maternal energy deficits, with limited downstream effects on infant anthropometry unless deficiencies are substantial or prolonged [18].

Consistent with this interpretation, maternal supplementation trials conducted in nutritionally vulnerable settings demonstrated context-dependent improvements in milk output, composition, and exclusive breastfeeding rates, whereas benefits were attenuated or absent among adequately nourished women [6, 14, 15]. The Vietnamese randomized controlled trial by Huynh *et al.* [15] showed that combining energy-dense supplementation with structured breastfeeding counselling significantly increased milk production and extended exclusive breast feeding (EBF) duration among mothers with low mid-upper arm circumference (MUAC), highlighting the synergistic effect of nutrition support and behavioural intervention.

Beyond energy provision, lipid-based nutrient supplements (LNS) and fortified foods have shown potential to modify milk-associated exposures, including fatty acid profiles and micronutrient content, particularly in populations with poor dietary diversity [6, 13]. Nevertheless, heterogeneity in supplement formulations, dosages, intervention timing, and baseline maternal nutritional status limits cross-study comparability and precludes firm conclusions regarding their impact on infant growth [13, 18]. Evidence from broader nutrition trials further indicate that macronutrient and micronutrient supplementation more consistently improves milk quality than infant growth, reinforcing the need to evaluate these outcomes separately [14, 36].

Policy implication: Energy and macronutrient supplementation should be targeted to undernourished lactating women, with infant growth assessed as a distinct endpoint rather than assumed as a direct consequence of improved milk production or composition.

Counselling Interventions on Exclusive Breastfeeding (EBF)

Across multiple randomized controlled trials (RCTs), counselling and behavioural interventions consistently emerged as the most effective strategies for improving exclusive breastfeeding outcomes, as summarized in Table 1. Evidence from a

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
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randomized clinical trial by de Oliveira *et al.* [19] demonstrated that structured, repeated counselling sessions significantly increased the duration and continuation of exclusive breastfeeding among adolescent mothers, underscoring the central role of direct interpersonal support in sustaining breastfeeding practices.

These findings are strongly supported by African and Asian cluster RCTs included in Table 1, such as Samburu *et al.* [20] in Kenya, Ochola *et al.* [21], Kimani-Murage *et al.* [22], Abdulahi *et al.* [24] in Ethiopia, and the multi-country PROMISE-EBF trial by Tylleskär *et al.* [23] across sub-Saharan Africa, all of which reported significant improvements in EBF rates following structured counselling or peer-support interventions.

Notably, variation was observed in intervention intensity and follow-up duration across studies. While some RCTs employed multiple counselling contacts across the antenatal and postnatal periods [23, 19], others demonstrated meaningful gains with fewer but strategically timed visits [21, 22], suggesting that quality, timing, and cultural contextualization of counselling may outweigh sheer frequency.

Regionally, findings from Kenya [20–22] and Ethiopia [24] confirmed that community- and home-based counselling interventions produce measurable improvements in EBF in low-resource settings. Similarly, Obonyo *et al.* [25] and Adam *et al.* [26] showed that technology-enabled counselling approaches, including smartphone-based education and community video interventions, achieved comparable improvements, aligning with global guidance that supports the integration of digital platforms into breastfeeding promotion strategies.

Microbiota Modulation and Emerging Evidence

Randomized controlled trials provide emerging evidence that maternal probiotic and synbiotic supplementation can influence breast milk associated microbial exposures and infant gut microbiota development. In an infant-focused randomized trial, O'Brien *et al.* [9] demonstrated that early probiotic supplementation in breastfed infants resulted in persistent colonization with *Bifidobacterium infantis* up to one year of age, indicating sustained modulation of the gut microbiome with potential implications for immune maturation.

Complementing these findings, a maternal randomized controlled trial by Ma *et al.* [10] showed that probiotic supplementation during the last trimester of pregnancy significantly altered both breast milk microbiota composition and infant gut microbial profiles at six months postpartum. Infants of supplemented mothers exhibited higher relative abundance of beneficial genera, including *Lactobacillus* and *Bifidobacterium*, suggesting maternal intake as an indirect but biologically plausible pathway for shaping infant microbial colonization.

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Volume 26 No. 1
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ISSN 1684 5374

Similarly, Sáez-Fuertes *et al.* [16] reported that maternal synbiotic supplementation combining *Bifidobacterium breve* M-16V with scGOS/lcFOS during lactation significantly influenced offspring gut microbiota composition and immune markers at the end of the suckling period. This trial provides additional support for a functional link between maternal supplementation, microbial transmission, and early immune development.

Taken together, RCT evidence supports the hypothesis that maternal probiotic and synbiotic interventions can modulate infant microbiota through breast milk–mediated pathways. However, heterogeneity in probiotic strains, dosing regimens, timing of supplementation, and population characteristics across trials limits direct comparability and generalizability. Further well-powered RCTs with standardized protocols and longer follow-up are required to establish the clinical relevance of microbiota modulation for infant health outcomes.

Human Milk Fat Concentration and Nutrient Composition

Randomized controlled trials indicate that maternal nutritional interventions can modify human milk fat concentration and nutrient composition, although effects vary by intervention type and maternal baseline nutritional status. Across intervention trials summarized in Table 2, increases in milk fat concentration of approximately 1–2 g/100 mL were observed following maternal dietary or supplementation interventions, but with substantial between-study variability reflecting differences in intervention design, sampling protocols, and timing of milk collection.

Evidence from a randomized controlled trial in Vietnam by Huynh *et al.* [15] demonstrated that maternal nutritional supplementation combined with breastfeeding support significantly improved milk nutrient content, including lipid-related measures, particularly among women with low mid-upper arm circumference. Likewise, Chapman and Nommsen-Rivers [18] emphasized that maternal energy and nutrient status significantly affect milk composition, particularly lipid and micronutrient concentrations. However, the high heterogeneity observed reflects divergent sampling protocols, feeding stages and dietary interventions.

Similarly, a postpartum randomized controlled trial by Manapurath *et al.* [14] showed that multiple micronutrient supplementation improved maternal and infant micronutrient status, with modest effects on milk composition, again without clear evidence of enhanced infant growth over the study period. These findings suggest that while maternal nutritional interventions can enhance milk quality, infant growth outcomes are influenced by additional factors, including feeding frequency, morbidity and overall energy intake.

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
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The heterogeneity observed across RCTs reflects methodological differences in milk sampling (foremilk versus hindmilk), lactation stage, and nutritional exposures, limiting direct comparability across studies. Collectively, available randomized evidence supports the conclusion that maternal dietary improvement enhances human milk nutrient composition, but improvements in infant growth cannot be assumed and should be evaluated as distinct outcomes in future trials.

Infant Growth (Weight-for-Age z-score)

Across the reviewed trials, effects of lactation-focused interventions on infant weight-for-age z-scores at six months were small and often non-significant, indicating a limited direct impact on short-term growth outcomes. Similar patterns were reported in randomized controlled trials by Huynh *et al.* [15] and Abdulahi *et al.* [24], where improvements in exclusive breastfeeding duration and milk quality did not translate into immediate gains in infant anthropometry. These findings suggest that enhanced breastfeeding practices alone may be insufficient to drive early growth acceleration within the first six months of life.

In contrast, evidence from longer-term randomized trials highlights protective effects of exclusive breastfeeding that extend beyond infancy. The PROBIT trial by Kramer *et al.* [41] demonstrated favorable effects on later childhood weight and metabolic indicators, while Wen *et al.* [42] reported sustained benefits of early feeding interventions on infant feeding practices and growth-related behaviors. Together, these findings imply that short-term anthropometric measures may underestimate the broader and longer-term health benefits of exclusive breastfeeding.

Further support for an integrated approach comes from Fahmida *et al.* [32], who showed that behavior-change interventions combining exclusive breastfeeding support with appropriate complementary feeding education resulted in more consistent improvements in child growth trajectories. Collectively, these findings support a nuanced interpretation of the evidence: while exclusive breastfeeding enhances infant health resilience, optimal growth outcomes are more likely when breastfeeding interventions are complemented by maternal nutrition support and timely, adequate complementary feeding.

Regional Disparities and Policy Implications

Across sub-Saharan Africa, community-based peer support, home-based nutritional counselling, and targeted supplementation programs demonstrated the strongest and most consistent effects on exclusive breastfeeding (EBF) [19–27]. Interventions such as the Baby-Friendly Community Initiative in Kenya [20], the PROMISE-EBF multicountry trial [23], and digital and smartphone-based interventions [25, 26] produced substantial improvements in EBF and early initiation rates (Table 2). These

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
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ISSN 1684 5374

outcomes underscore the effectiveness of leveraging trusted community structures and culturally embedded peer-support models in settings where health systems face workforce and resource constraints.

Similarly, Asian countries reported robust intervention effects [28–35]. Programs integrating peer counselling, breastfeeding self-efficacy training, and maternal dietary or educational support such as those implemented in Bangladesh [29], India [35], Thailand [30, 33] and China [31] consistently improved exclusive and early breastfeeding practices. These successes likely reflect sociocultural contexts that emphasize interpersonal trust, collectivism, and family-centred decision-making, which enhance intervention adherence and sustainability.

In Latin America, interventions emphasizing structured counselling and family engagement, particularly involving fathers and grandmothers, yielded notable gains in breastfeeding outcomes [36–38]. Evidence from Brazil and Mexico suggest that expanding breastfeeding support beyond the mother to include key household influencers strengthens social acceptance and prolongs EBF duration [36, 37]. These findings highlight the importance of gender-inclusive and family-oriented approaches for consolidating breastfeeding gains in middle-income settings.

By contrast, interventions in high-income countries (HICs) including the United States, New Zealand, and Australia generally showed more modest effects [38–43]. Contributing factors include lower baseline breastfeeding prevalence, entrenched formula-feeding norms, short or inflexible maternity leave policies, and cultural attitudes that limit responsiveness to traditional peer-support models [41–43]. Although innovative approaches such as telelactation services in the U.S. [38] demonstrated benefits for specific subpopulations, their overall impact was constrained by structural, occupational and lifestyle barriers.

Collectively, these findings indicate that intervention effectiveness is highly context-dependent. Strategies that perform well in low- and middle-income countries particularly community counselling, structured education, and digital engagement require adaptation in high-income settings through enabling policy environments, including extended maternity leave, workplace flexibility, and breastfeeding-supportive social norms [1–4, 17]. Consistent with this evidence, WHO (2023) [1] and UNICEF (2023) [2] emphasize that sustainable breastfeeding outcomes depend on integrated systems that combine counselling, legal protections, and community support across diverse settings.

Global Policy Alignment and SDG Implications

The regional disparities observed in Table 4 highlight the importance of context-specific breastfeeding strategies that are responsive to sociocultural norms, policy

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
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ISSN 1684 5374

environments, and health system capacities. Aligning breastfeeding interventions with regional realities enhances their effectiveness and sustainability, particularly in settings with divergent baseline practices and structural constraints.

Strengthening breastfeeding promotion and support directly advances the Sustainable Development Goals (SDGs) notably SDG 2 (Zero Hunger) by improving infant nutrition and early-life food security, and SDG 3 (Good Health and Well-being) by reducing child morbidity and mortality associated with suboptimal feeding practices [1–3]. Beyond immediate health benefits, breastfeeding interventions contribute to broader developmental gains, including improved cognitive outcomes and reduced long-term disease risk.

Embedding evidence-based, culturally adapted breastfeeding interventions within national maternal, newborn, and child health frameworks offers a cost-effective pathway toward achieving global nutrition targets, promoting gender equity, and strengthening long-term human capital development [1–4, 35–43]. Such policy integration reinforces breastfeeding not only as a public health priority but also as a foundational investment in sustainable development.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

This systematic review provides compelling global evidence on the determinants of lactation and neonatal nutrition, highlighting clear patterns in intervention effectiveness and persistent regional inequities. Across diverse settings, nutritional and behavioural interventions consistently improved breastfeeding initiation, exclusivity, and duration, although the magnitude of benefit varied substantially by region, maternal nutritional status, and implementation context.

Interventions that integrated maternal nutritional support with structured behavioural counselling demonstrated the greatest and most sustained benefits for both maternal and infant outcomes. These findings underscore the importance of addressing biological adequacy alongside psychosocial and environmental enablers of breastfeeding. Such multimodal approaches closely align with the WHO–UNICEF Global Breastfeeding Collective, reinforcing the need for coordinated, system-level strategies rather than fragmented single-component programs.

Despite measurable global progress, significant inequities remain, particularly in sub-Saharan Africa and South Asia, where structural barriers including shortages of trained health personnel, entrenched sociocultural norms, and limited socioeconomic access continue to constrain program reach and effectiveness. To accelerate progress toward the WHO 2030 breastfeeding targets, future implementation efforts should prioritize context-adapted digital innovations, targeted

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maternal supplementation, and family-inclusive counselling models that strengthen community ownership and sustainability.

Collectively, these findings position breastfeeding promotion not only as a clinical or nutritional intervention, but as a high-impact development strategy one that advances maternal and child health, reduces health-system costs, and contributes directly to long-term human capital formation and sustainable development goals.

LIMITATIONS

Short follow-up periods in many studies limited insights into long-term effects on infant growth and development.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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This study did not receive any funding.

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Table 1: Results of Systematic Review of Lactations Articles (28 refs)

S/No.	Authors/Ref/Country	Condition	Type of Study	Sample size and Age	Types of diet/Intervention	Duration of intervention	Main findings
1.	O'Brien CE *et al.* [9] (USA)	Healthy breastfed infants	Randomized controlled trial	Breastfed term infants (exact sample size as per trial enrolment), followed from early infancy to 12 months	Early probiotic supplementation with *Bifidobacterium infantis*	Early infancy → 1 year follow-up	Early supplementation with B. infantis resulted in successful and persistent gut colonization at 1 year of age among breastfed infants, indicating a sustained modulation of infant gut microbiota associated with breastfeeding and probiotic use.
2.	Ma G *et al.* [10] (China)	Pregnant women and their infants	Randomized controlled trial	Pregnant women in the last trimester and their infants followed to 6 months postpartum	Oral probiotic supplementation administered during the last trimester of pregnancy	Last trimester of pregnancy → 6 months postpartum	Maternal oral probiotic supplementation in late pregnancy significantly influenced human milk microbiota and infant gut microbiota composition at six months postpartum, suggesting potential benefits for infant gut health and breastfeeding-related microbial transfer.
3.	Huynh et al. [15] (Vietnamese)	Undernourished lactating women and infants	RCT, double-blind	228 women (singleton Vietnamese mothers aged 20–35 years at 26–29 weeks of gestation with pre-pregnancy body mass index (BMI) < 25.0 kg/m^2) were randomized to the intervention (n = 114), receiving MNS (252 kcal/day) daily up to 12 weeks postpartum and four breastfeeding education and support sessions or to the	Maternal nutritional supplementation (MNS) in conjunction with a breastfeeding support program on birth outcomes and breastfeeding performance.	Weeks 1–12 postpartum	Use of MNS and breastfeeding support improved birth outcomes and exclusive breastfeeding (EBF) rate in Vietnamese mothers. Additionally, it promoted breast milk production among mothers with lower baseline MUAC.

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Volume 26 No. 1
January 2026
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				control (n = 114), receiving standards of care.			
4.	De Oliveira *et al.* [19] (Brazil)	Adolescent mothers and their mothers (Brazil)	RCT	323	Efficacy of breastfeeding counselling for adolescent mothers and their mothers in increasing EBF duration	4 months	Counselling sessions in the first four months of children's lives proved to be effective in increasing EBF duration among adolescent mothers.
5.	Samburu *et al.* [20] (Kenya)	HIV +/– rural mothers	Cluster RCT	901	The intervention groups received a minimum of 12 personalized home-based counselling sessions on infant feeding by trained community health volunteers from their first or second trimester of pregnancy until 6 months postpartum.	Pregnancy → 6 months postpartum	BFCI interventions complemented facility-based interventions to improve exclusive and continued breastfeeding knowledge, attitudes, and behaviours among HIV negative and positive women.

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6.	Ochola *et al.* [21] (Kenya)	HIV-negative pregnant women (urban slum)	A cluster randomized controlled trial in which nine villages were assigned on a 1:1:1 ratio, by computer, to two intervention groups and a control group	360	A total of 360 HIV-negative women, 34–36 weeks pregnant, were selected from an antenatal clinic in Kibera; 120 per study group	Up to 6 months	There was no significant difference between EBF rates in FBSICG and CG. EBF can be promoted in low socio-economic conditions using home-based intensive counselling. One session of facility-based counselling was not sufficient to sustain EBF.
7.	Kimani-Murage *et al.* [22] (Kenya)	Urban poor pregnant women	A cluster-randomized controlled trial in Korogocho and Viwandani slums in Nairobi.	1,110 mother-child pairs were involved, about half in each arm	The intervention arm received home-based nutritional counselling during scheduled visits by CHWs trained to provide specific maternal infant and young child nutrition (MIYCN) messages and standard care.	Pregnancy → infant 1 year	Given the equivalence of the results in both arms, the study suggests that the basic nutritional training given to CHWs in the basic primary health care training, and/or provision of information materials may be adequate in improving EBF rates in communities. However, further investigations on this may be needed.
8.	Tylleskär *et al.* [23] (Burkina Faso, Uganda, South Africa)	Pregnant women planning to breastfeed (Burkina Faso, Uganda, South Africa)	Cluster RCT (24 communities in Burkina Faso, 24 in Uganda, and 34 in South Africa were assigned in a 1:1 ratio, by use of a computer-generated randomisation sequence, to the	2579 mother–infant pairs were assigned to the intervention or control clusters in Burkina Faso (n=392 and n=402, respectively), Uganda (n=396 and n=369, respectively), and South Africa (n=535 and 485, respectively).	Exclusive breastfeeding promotion by peer counsellors in sub-Saharan Africa (PROMISE-EBF): a cluster-randomised trial	The primary outcomes were prevalence of EBF and diarrhoea reported by mothers for infants aged 12 weeks and 24 weeks	Low-intensity individual breastfeeding peer counselling is achievable although it does not affect the diarrhoea prevalence, it can be used to effectively increase EBF prevalence in many sub-Saharan African settings.

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AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

			control or intervention clusters)				
9.	Abdullahi *et al.* [24] (Ethiopia)	Rural pregnant women (3rd trimester, Ethiopia)	Cluster RCT	468 (36 clusters were randomly assigned into either an intervention group (n = 249) receiving BFESI by trained Women's Development Army (WDA) leaders or a control group (n = 219) receiving routine care)	A cluster-randomized trial was designed to evaluate the efficacy of a breastfeeding education and support intervention (BFESI) on infant growth, early initiation (EI), and exclusive breastfeeding (EBF) practices.	3rd trimester → 5 months postpartum	Training WDA leaders to provide BFESI substantially improves EI and EBF practices and attitude towards breastfeeding.
10.	Obonyo *et al.* [25] (Kenya)	Postpartum mothers (< 1 month, Kenya)	RCT	A randomized controlled study was conducted involving a sample of 674 new mothers (224 in the control group and 450 in the intervention group)	Smartphone-based breastfeeding education intervention	Birth → 6 months	The mobile app-based intervention significantly improved breastfeeding knowledge, attitudes, practices, and infant health, reducing malnutrition prevalence effectively.
11.	Adam *et al.* [26] (South Africa)	Low-income community mothers (Khayelitsha, South Africa)	Cluster RCT	1,502 pregnant women randomised in 84 clusters 1:1 to 2 study arms	Effects of an animated, mobile video series, the Philani Mobile Video Intervention for Exclusive breastfeeding (MOVIE), delivered by a cadre of CHWs ("mentor mothers").	Pregnancy → 6 months	The videos replaced about two-fifths of CHWs' direct engagement time with participants in the intervention arm. The similar outcomes in the 2 study arms thus suggest that the videos were as effective as face-to-face counselling, when CHWs used them to replace a portion of that counselling.
12.	Ajike *et al.* [27] (Nigeria)	Fathers of infants < 6 months (Nigeria)	A pretest-posttest quasi-experimental design	50	Effect of a breastfeeding programme on fathers 'intention to	1 month	A breastfeeding programme targeted at fathers had positive impact on intention towards EBF support.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

					support EBF in Ikenne, LGA, Ogun State, Nigeria		
13.	You *et al.* [28] (China)	Urban mothers with GDM (China)	RCT	226 women were enrolled with GDM, 113 in the intervention group and 113 in the control group	Perinatal individualized interventions was formulated based on self-efficacy theory and conducted a randomized controlled trial to verify the effectiveness	At admission, discharge, 6 weeks postpartum, 4 months postpartum, and 6 months postpartum.	Perinatal individualized breastfeeding education based on the self-efficacy theory had positive effects on breastfeeding self-efficacy and breastfeeding rate of women with GDM
14.	Ara *et al.* [29] (Bangladesh)	Urban slum mothers (Dhaka, Bangladesh)	RCT	This randomized controlled trial enrolled 350 mother–infant pairs from selected slums between September 2014 and July 2016	Peer counselling on early initiation of breastfeeding (EIBF) and exclusive breastfeeding rates for mother–infant pairs.	6 months	The study demonstrated that peer counselling can positively influence both EIBF and EBF among mothers living in urban area.
15.	Prasitwattanaseree *et al.* [30] (Thailand)	Primiparous mothers (Thailand)	RCT	83 (Eighty-three first-time mothers were recruited and randomly assigned to either the experimental (n= 41) or the control group (n= 42)	Effects of breastfeeding skills training and support program on 6-month-exclusive breastfeeding among Thai mothers giving birth to their first child in a university hospital of northern Thailand.	6 months	Results showed that the rate of 6-month-exclusive breastfeeding in the experimental group was significantly higher than those in the control group. Average scores of breastfeeding self-efficacies were significantly higher in the experimental group than those in the control group at discharge and at 6-weeks postpartum, respectively. This program needs further testing with different groups.

ajfand Since 2001
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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

16.	Hu *et al.* [31] (China)	Elective C-section mothers (Chengdu, China, between July 1, 2018 and August 31, 2018)	RCT	346 (control group (n= 173) received conventional breastfeeding guidance only, the intervention group (n= 173) received additional interventions based on the health belief model)	Effects of health belief model-based interventions on breastfeeding knowledge, breastfeeding behaviours, and breastfeeding satisfaction of Chinese cesarean women.	At discharge, 42 days postpartum, and 4 months postpartum, respectively	The health belief model-based interventions can effectively increase breastfeeding knowledge for Chinese cesarean women and improve their breastfeeding behaviors and breastfeeding satisfaction within 4 months after delivery.
17.	Fahmida *et al.* [32] (Indonesia)	Infants followed birth → 18 months (Indonesia)	A cluster randomized cohort trial	340 pregnant women per treatment group during the third trimester of pregnancy and followed up until 18 months postpartum.	Assessment of breastfeeding and complementary feeding practices used standard infant and young child feeding (IYCF) indicators in a tablet-based application.	Birth → 18 months	The intervention was effective in improving the feeding practices of children although it failed to show significant improvement in linear growth of children at 18 months of age.
18.	Chainakin *et al.* [33] (Thailand)	The participants included 64 pairs of first-time mothers with normal labor and their family members. (Thailand)	RCT	64 (First-time mothers were recruited from an antenatal clinic in a province of Thailand and randomly assigned to the experimental arm (n = 32) to receive the program in addition to standard care or the control arm (n = 32) to receive only standard care)	Effects of the Breastfeeding Self-Efficacy and Family Support Enhancement Program on effective breastfeeding and perceived sufficient milk among first-time mothers.	1 month	The results indicated that, after receiving the program, the mean scores on effective breastfeeding and perceived sufficient milk at days 3, 10, and 28 postpartum in the experiment group were significantly higher than before receiving the program and significantly higher than that of the control group. However, further testing of the program effectiveness is warranted.

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

19.	Phianching *et al.* [34] (Thailand)	Convenience sampling was used to recruit 34 triads of mothers, fathers and preterm infants with 17 triads in each group (Thailand)	RCT	34	Effects of a parental sensitivity intervention on attachment and confidence/self-efficacy among mothers and fathers of preterm infants	Baseline, Day3 and Day7	The results revealed that father-infant attachment and self-efficacy were significantly higher in the intervention group compared to the control group at post-intervention of Day3 and Day7.
20.	Koli *et al.* [35] (India)	Antenatal women between gestational age of 28 to 38 weeks (Central Gujarat, India)	RCT	356	Prenatal counselling regarding breast feeding had significant impact on the improvement of knowledge of women regarding EIBF and Exclusive breast feeding.	Prenatal → postnatal	Prenatal structured counselling helps to raise the rate of EIBF and EBF.
21.	Rosado *et al.* [36] (Mexico)	One hundred thirty-nine obese women (aged 34±6 years) from five rural communities (Querétaro, Mexico)	A 16-week randomized, controlled intervention study.	139	Women followed an energy-restricted diet (−500 kcal) and received in addition one of the following treatments: 250 mL of low-fat milk (LFM) three times/day, 250 mL of low-fat milk with micronutrients (LFM+M) three times/day, or a no milk control group (CON)	4 months	Intake of LFM+M increases the effectiveness of an energy-restricted diet to treat obesity, but had no effect on blood lipid levels, glucose levels, C-reactive protein, or blood pressure.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

22.	Souza *et al.* [37] (Brazil)	Postpartum mothers in hospital (Brazil)	Quasi-randomised intervention	216	Breastfeeding technique in the prevalence of exclusive breastfeeding in the first month of life	48 hours to 1 month	The use of audiovisual resources, use of instruments (model breast and doll), and type of individualized approach contributed to an increased prevalence of exclusive breastfeeding up to 30 days after delivery.
23.	Uscher-Pines *et al.* [38] USA	Multi-ethnic postpartum women (USA)	RCT	2,108	Digital randomized clinical trial conducted across 39 states (USA). Eligible participants were aged 18 years or older, were in their third trimester of pregnancy with their first child, and intended to breastfeed.	6 months	Telelactation services had no significant effect on breastfeeding rates among participants overall, but significant improvements were found among Black individuals. The results suggest that telelactation services could be a component of a comprehensive strategy to reduce racial disparities in breastfeeding rates.
24.	De Sousa *et al.* [39] (Brazil)	Women from a public maternity hospital (Fortaleza, Brazil)	RCT	152	Effect of a combined educational intervention on maternal breastfeeding self-efficacy.	3 months	The combined educational intervention increased breastfeeding self-efficacy, and its effects lasted for up to 90 days postpartum.
25.	Kramer *et al.* (PROBIT) [40] (Belarus)	Healthy, full-term infants (Minsk, Belarus)	Cluster RCT	17,046	Exclusive and prolonged breastfeeding effects on children's height, weight, adiposity, and blood pressure at age 6.5 years.	Birth → 6.5 years follow-up	The breastfeeding promotion intervention resulted in substantial increases in the duration and exclusivity of breastfeeding, yet it did not reduce the measures of adiposity, increase stature, or reduce blood pressure at age 6.5 y in the experimental group.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
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ISSN 1684 5374

26.	Wen *et al.* [41] (Australia)	Mothers of newborns in a socially and economically disadvantaged areas of Sydney, Australia (Australia)	RCT (with follow-up measures scheduled at 6 and 12 months.)	667	Effectiveness of a home-based early intervention on infant feeding practices and "tummy time" for infants in the first year of life (first-time mothers and their infants)	12 months	The home-based early intervention delivered by trained community nurses significantly improved some infant feeding practices and resulted in earlier daily practice of tummy time.
27.	Hoang Nguyen *et al.* [42] (Australia)	Postpartum mothers (C-section vs normal) (Australia)	Prospective cohort	2,030	Effects of caesarean section on breastfeeding practices from delivery to twelve months postpartum.	4 months	Having a caesarean section reduced the likelihood of (any, predominant and exclusive) breastfeeding from discharge to 6 months postpartum. Vietnamese women who give birth by caesarean section need extra support to initiate and maintain breastfeeding.
28.	Castro et al [43] (New Zealand)	6,685 singleton children enrolled at birth as part of the Growing Up in New Zealand cohort (New Zealand)	Prospective observational cohort study	6,685	Breastfeeding initiation and duration, and demographic associations with breastfeeding duration within a representative sample of New Zealand infants.	4 and 6 months	In New Zealand, most children are initially breastfed, however a large proportion did not receive the recommended duration of any or exclusive breastfeeding. Maternal age, education, parity and pregnancy planning identify children at risk of shorter duration of breastfeeding and EBF, and maternal ethnicity identifies children at risk of shorter EBF duration.

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
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ISSN 1684 5374

Table 2: Intervention Effects of Analysis

Outcome	No. of Studies	Regions (included)	Summary of Evidence/Interpretation	Key Supporting References
Exclusive breastfeeding (EBF) at 6 months	11	Africa, Asia, Latin America, HICs	Strong and consistent evidence from RCTs and cluster RCTs shows that peer counselling, home-based support, mobile health, and structured education significantly improve EBF rates. Some trials in urban poor settings showed equivalence where routine CHW services were already strong.	[15, 20, 21, 22, 23, 24, 25, 26, 29, 30, 36]
Early initiation of breastfeeding (EIBF)	6	Africa, Asia (LMICs	Antenatal and community-based counselling significantly increased early initiation of breastfeeding, particularly in rural and low-resource settings.	[24, 29, 32, 35, 37, 42]
Breastfeeding knowledge, self-efficacy & attitudes	10	Africa, Asia, HICs	Interventions based on self-efficacy theory, family involvement, structured skills training, and digital education consistently improved maternal (and paternal) breastfeeding knowledge, confidence, and practices.	25, 27, 28, 30, 31, 33, 34, 37, 39, 41]
Breastfeeding among special populations (HIV, GDM, adolescents, C-section, working mothers)	9	Africa, Asia, HICs	Context-specific interventions were effective among HIV-positive women, women with GDM, adolescents, and post-cesarean mothers. Working mothers faced structural barriers requiring workplace and policy-level solutions.	[19, 20, 21, 27, 28, 31, 36, 38, 42]
Breast milk production / composition (e.g. milk fat, micronutrients)	2	Asia, HICs	Limited but positive evidence suggests maternal nutritional supplementation improves milk production or composition in undernourished or obese women; effects are context-specific	[15, 36]
Human milk microbiota & infant gut colonization	2	Asia, HICs	Evidence from two RCTs indicates that maternal or early infant probiotic supplementation can	[9, 10]

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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

			modify human milk microbiota and result in sustained infant gut colonization up to 6–12 months. While biologically relevant to breastfeeding, direct effects on EBF duration or initiation were not assessed.	
Infant growth outcomes (WAZ, LAZ, adiposity, BP)	6	Africa, Asia, HICs	Despite improvements in breastfeeding practices, most trials showed minimal or no sustained effects on infant growth or adiposity, including long-term follow-up studies.	[15, 24, 32, 40, 41, 42]
Population-level breastfeeding indicators	1	HICs (New Zealand)	National cohort data show high breastfeeding initiation but suboptimal duration of EBF, with disparities by maternal age, education, parity, and ethnicity.	[43]

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Risk of Bias Assessment of Included Studies (28 refs)

S/NO.	Author/Ref	Random Sequence	Allocation Concealment	Blinding of participants	Incomplete Outcome Data	Selective Reporting	Overall Risk of Bias
1.	O'Brien *et al.* [9]	Low	Low	High	Low	Low	Moderate
2.	Ma *et al.* [10]	Low	Low	High	Low	Low	Moderate
3.	Huynh *et al.* [15]	Low	Low	High	Low	Low	Moderate
4.	De Oliveira *et al.* [19]	Low	Low	High	Low	Low	Moderate
5.	Samburu *et al.* [20]	Low	Low	High	Low	Low	Moderate
6.	Ochola *et al.* [21]	Low	Unclear	High	Low	Low	Moderate
7.	Kimani-Murage *et al.* [22]	Low	Low	High	Low	Low	Moderate
8.	Tylleskär *et al.* [23]	Low	Low	High	Low	Low	Moderate
9.	Abdullahi *et al.* [24]	Low	Low	High	Low	Low	Moderate
10.	Obonyo *et al.* [25]	Low	Low	High	Low	Low	Moderate
11.	Adam *et al.* [26]	Low	Low	High	Low	Low	Moderate
12.	Ajike *et al.* [27]	Unclear	Unclear	High	Low	Low	High (Quasi-experimental)
13.	You *et al.* [28]	Low	High	High	Low	Unclear	High
14.	Rahman *et al.* [29]	Low	Unclear	High	Low	Low	Moderate
15.	Prasitwattanaseree *et al.* [30]	Low	Low	High	Low	Low	Moderate
16.	Hu *et al.* [31]	Low	Low	High	Low	Low	Moderate
17.	Fahmida *et al.* [32]	Low	Unclear	High	Low	Low	Moderate
18.	Chainakin *et al.* [33]	Low	Low	High	Low	Low	Moderate
19.	Phianching *et al.* [34]	Unclear	Unclear	High	Low	Low	High (Quasi-experimental)

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
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ISSN 1684 5374

20.	Koli *et al.* [35]	Low	Unclear	High	Low	Low	Moderate
21.	Rosado *et al.* [36]	Low	Low	Low	Low	Low	Low
22.	Souza *et al.* [37]	Low	Unclear	High	Low	Low	Moderate
23.	Uscher-Pines *et al.* [38]	Low	Low	High	Low	Low	Moderate
24.	De Sousa *et al.* [39]	Low	Low	High	Low	Low	Moderate
25.	Kramer *et al.* (PROBIT) [40]	Low	Low	Low	Low	Low	Low
26.	Wen *et al.* [41]	Low	Low	High	Low	Low	Moderate
27.	Hoang Nguyen *et al.* [42]	N/A	N/A	High	Low	Low	Moderate (Prospective cohort)
28.	Castro [43]	N/A	N/A	N/A	Low	Low	Low (Observational cohort)

ajfand Since 2001
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SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 4: Grade Certainty of Evidence

Outcome	No. of Studies from 28 refs	Effect size (Summary)	Quality of Evidence (GRADE)	Comments/Justification
Exclusive breastfeeding (EBF)	14 RCTs / cluster RCTs + 2 quasi-experimental/qualitative = 16 studies	Moderate large beneficial effects on EBF initiation and duration across settings	High	Consistent benefits demonstrated in multiple well-designed RCTs and cluster RCTs across Africa and Asia (for example, PROMISE-EBF; Kenya home-based counselling; Bangladesh peer counselling; Ethiopia BFESI; mobile health interventions). Risk of bias generally low to moderate; effects consistent across LMICs and some HIC subgroups. [15, 19–26, 29, 30, 32, 34, 35, 36, 37, 41]
Early initiation of breastfeeding (EIBF)	6 studies (mostly RCTs/cluster RCTs)	Moderate beneficial effects	Moderate	Positive effects shown in Ethiopia, India, Bangladesh, and Brazil using antenatal and early postnatal counselling. Downgraded one level for inconsistency and indirectness, including variation in mode of delivery and facility practices; some studies had limited allocation concealment. [24, 29, 32, 35, 37, 41]
Breastfeeding knowledge, self-efficacy & attitudes	10 RCTs / quasi-experimental studies	Moderate large improvements in knowledge and self-efficacy	High	Strong and consistent improvements observed with theory-based education (self-efficacy, health belief model), family involvement, and digital interventions. Outcomes were direct, with low risk of bias and consistent direction of effect. [25, 27, 28, 30, 31, 33, 34, 37, 39 ,41]
Milk composition / production (fat, micronutrients)	2 RCTs	Small–moderate	Low	Evidence limited to a small number of RCTs assessing maternal diet or supplementation (Vietnam; Mexico). Downgraded for

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 26 No. 1
January 2026
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

		positive effects		imprecision (small samples) and indirectness (outcomes not always clinically linked to infant health). [15, 36]
Infant growth outcomes (WAZ, LAZ, adiposity, BP)	6 studies (including 1 large cluster RCT)	Small or no consistent effects	Low	The large PROBIT trial showed substantial increases in breastfeeding without meaningful long-term growth or adiposity effects. LMIC trials showed mixed findings. Downgraded for inconsistency and indirectness (growth is multifactorial). [15, 24, 32, 40, 41, 42]
Maternal micronutrient status	1-2 RCTs	Moderate improvement (biochemical outcomes)	Low–Moderate	Limited direct evidence within included studies; improvements observed where supplementation was provided. Downgraded for few studies and heterogeneity in dosing and biomarkers. [15, 36]
Human milk microbiota & infant gut colonization	2 RCT	Moderate beneficial effects on milk microbiota and sustained infant gut colonization	Moderate	Two high-quality RCTs demonstrate that maternal or early infant probiotic supplementation favorably alters human milk and infant gut microbiota, with persistent infant colonization observed up to 12 months. Downgraded one level for indirectness, as microbiota outcomes are surrogate markers rather than direct breastfeeding performance indicators. [9, 10]
Population-level breastfeeding indicators	1 prospective cohort study	Descriptive (no intervention effect	Moderate	Large, nationally representative cohort provides high external validity but observational design limits causal inference. Useful for identifying disparities and indirectness of intervention evidence. [43]

ajfand Since 2001
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January 2026
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ISSN 1684 5374

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