



LONG-TERM ASSOCIATION BETWEEN BREASTFEEDING DURATION AND NUTRITIONAL STATUS IN SCHOOL-AGED CHILDREN: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: Breastfeeding is a double-duty action proposed to protect simultaneously against undernutrition and overnutrition, yet the shape of the duration–response relationship between breastfeeding and nutritional status in early childhood remains contested, particularly in settings experiencing the double burden of malnutrition. This review aimed to synthesise primary evidence published in the last five years on the association between breastfeeding duration (≤ 1 , 3–5, 6, 6–11 and ≥ 12 months) and the full spectrum of nutritional status (stunting, underweight, normal weight, overweight and obesity) in children aged 2–6 years.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Randomised controlled trials (RCT), prospective and retrospective cohort, case-control and cross-sectional studies were eligible; systematic reviews and meta-analyses were excluded from the evidence tables but used in the discussion. Risk of bias

was appraised with a ROBINS-E-adapted domain tool and the Newcastle–Ottawa Scale (NOS) for observational studies and RoB 2 for randomised evidence. Where estimates were comparable, ratio measures were oriented as longer/any versus shorter/no breastfeeding and pooled using DerSimonian–Laird random-effects models, with subgroup, leave-one-out, cumulative, meta-regression and small-study analyses. Certainty was graded with GRADE.

Results: 41 studies from 25 countries met eligibility (40 observational, one secondary analysis of a cluster-RCT), comprising more than 161,000 children in the 37 studies that reported sample size. Twenty-seven studies addressed over-nutrition and 13 under-nutrition. Longer or any breastfeeding was associated with lower odds of overweight/obesity (10 estimates from 9 studies; pooled ratio 0.71, 95% CI 0.63–0.80; $I^2 = 60.8\%$; 95% prediction interval 0.50–1.01), robust to leave-one-out and trim-and-fill adjustment (0.73, 0.64–0.83). The association was stronger for exclusive breastfeeding (0.61, 0.53–0.71) than any/full breastfeeding (0.76, 0.66–0.86; P -between = 0.036) and for obesity (0.55, 0.43–0.71). All seven continuous estimates showed lower BMI z-scores with longer breastfeeding (–0.02 to –0.50). For stunting, pooling was dominated by extreme heterogeneity (0.49, 0.08–3.17; $I^2 = 98.4\%$) driven by a national survey showing higher stunting with breastfeeding into the third year; after its exclusion the association was protective and homogeneous (0.27, 0.19–0.38; $I^2 = 0\%$). Most observational studies had some concerns (65.0%) or high (35.0%) overall risk of bias, principally from confounding and recall-based exposure measurement.

Discussion: The evidence is compatible with a protective, approximately monotonic association between longer (particularly exclusive) breastfeeding and overweight/obesity at 2–6 years, with benefit already apparent after 3–5 months and extending beyond 12 months. For linear growth, exclusive breastfeeding to 6 months and continued breastfeeding into the second year are associated with less stunting, whereas the apparent harm of breastfeeding beyond 24 months in food-insecure settings is most plausibly explained by reverse causation and inadequate complementary feeding rather than by breast milk itself.

Conclusion: Longer breastfeeding is associated with a more favourable nutritional status in early childhood, particularly lower overweight and obesity, with low-certainty evidence; the association with stunting depends on complementary-feeding context and is of very low certainty. Programmes should protect exclusive breastfeeding for six months and continued breastfeeding with adequate complementary feeding, while future cohorts should use prospectively recorded duration categories and causal designs.

Keywords: breastfeeding duration; exclusive breastfeeding; stunting; underweight; childhood overweight; paediatric obesity; body mass index z-score; double burden of malnutrition; preschool children; systematic review

INTRODUCTION

Background

Malnutrition in early childhood has become bidirectional. Stunting, underweight and wasting continue to affect a large share of children in low- and middle-income countries (LMIC), while overweight and obesity are rising in the same populations, frequently within the same household or even the same child, a phenomenon termed the double burden of malnutrition (DBM). Early childhood, and particularly the first 1,000 days, has been described as a window of opportunity during which growth velocity programmes later body composition: subnormal weight and length gain before two years predict wasting and stunting, whereas excessive infant and toddler weight gain predicts later adiposity.¹⁻³

Breastfeeding is recognised as one of the few interventions that can act on both ends of this spectrum. Human milk supplies energy and nutrients, immunological factors and bioactive molecules that protect against infection, and breastfed infants follow a slower and more physiological growth trajectory than formula-fed infants. Nevertheless, fewer than half of infants and young children worldwide are breastfed as recommended; the 2023 *Lancet* Breastfeeding Series documented the pervasive influence of commercial milk formula (CMF) marketing and structural barriers such as inadequate maternity protection on breastfeeding duration.⁴⁻⁶

The burden attributable to suboptimal breastfeeding is inequitably distributed, with LMIC carrying a disproportionately greater share of mortality and disability-adjusted life years related to non-exclusive breastfeeding and early discontinuation. Women's exposure to CMF marketing is common across countries of all income levels, and health professionals remain the most frequent source of advice to start formula, underlining the importance of generating clinically interpretable evidence on how much breastfeeding matters, and for how long.⁷⁻⁹

Earlier syntheses support an inverse association between breastfeeding and later overweight/obesity: an updated meta-analysis commissioned by the World Health Organization reported a pooled odds ratio of 0.73 across 159 studies, with benefit persisting in studies less

susceptible to residual confounding. However, the 2020 Dietary Guidelines Advisory Committee review judged evidence on the *duration* of human-milk feeding, among infants who were ever breastfed, as insufficient to draw conclusions, and a systematic review of BMI trajectories found that 12 of 15 cohorts linked longer duration with lower BMI trajectories.^{10–12}

For undernutrition, a meta-analysis of 33 studies in developing countries found breastfeeding inversely associated with overall undernutrition and stunting, and regional syntheses from Ethiopia identified breastfeeding duration and non-exclusive breastfeeding as determinants of stunting and wasting. Conversely, several reports have observed higher stunting prevalence among children breastfed beyond 12–24 months, especially in poor households, a pattern that may reflect reverse causation or poor dietary diversity rather than a harmful effect of human milk.^{13–16}

Mechanistically, breastfeeding may lower adiposity through reduced protein intake and lower insulin-like growth factor-1 (IGF-1) and insulin secretion, infant-led self-regulation of intake, appetite-regulating hormones in milk (leptin, adiponectin, ghrelin), and human milk oligosaccharide (HMO)-mediated shaping of a *Bifidobacterium*-dominant gut microbiota; anti-infective factors reduce infection-related growth faltering (Figure 1).^{17–20}

Conceptual framework: pathways linking breastfeeding duration to nutritional status at 2-6 years

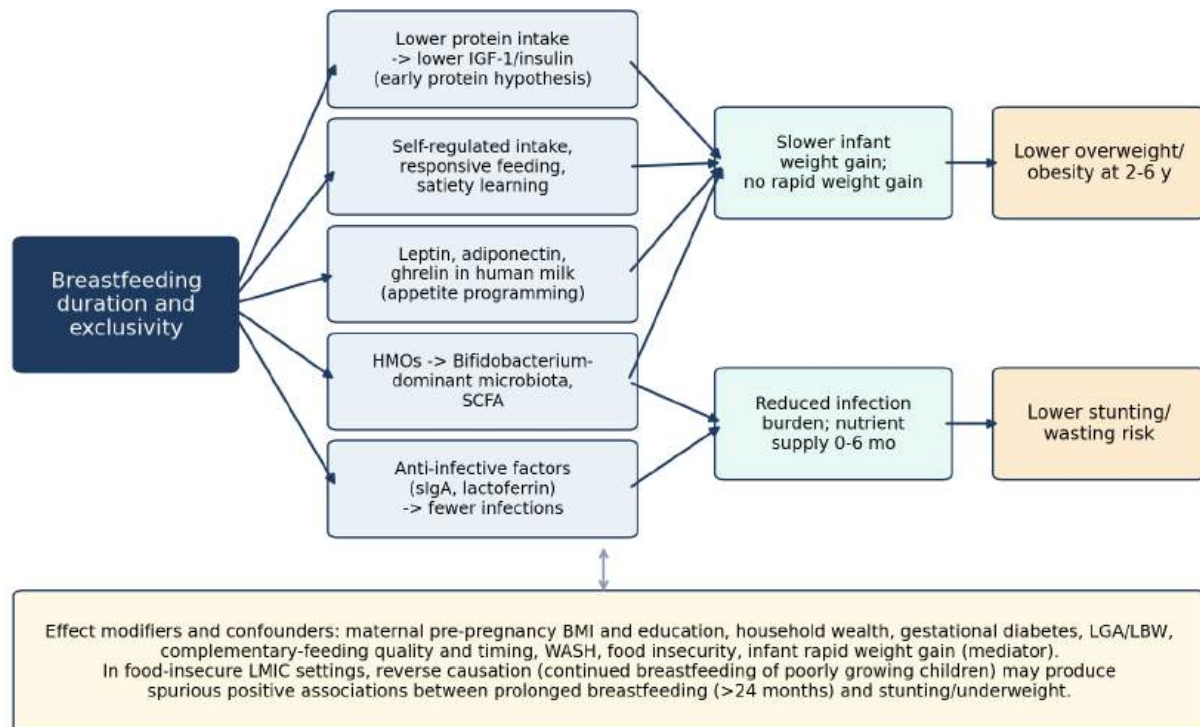


Figure 1. Conceptual framework of biological and behavioural pathways linking breastfeeding duration and exclusivity to nutritional status at 2–6 years, with principal confounders, effect modifiers and the possibility of reverse causation (developed for this review from the cited literature).^{1,17,18}

Research gap

Four gaps motivated this review. First, most existing reviews analyse breastfeeding as a binary exposure (ever versus never, or exclusive versus non-exclusive) and seldom map associations onto clinically meaningful duration categories such as ≤ 1 , 3–5, 6, 6–11 and ≥ 12 months. Second, over-nutrition and under-nutrition outcomes are typically reviewed separately, preventing an integrated view of whether a given duration is simultaneously favourable for stunting and for overweight. Third, a substantial volume of primary studies has been published since the most recent syntheses (2021–2026), including large birth cohorts from Asia, North America and

Europe and community studies from Indonesia and Africa. Fourth, the preschool window of 2–6 years, when adiposity rebound begins and stunting becomes largely established, has not been the explicit focus of previous reviews.^{10–13}

Novelty

This review is, to our knowledge, the first to (i) restrict inclusion to primary studies published in the most recent five-year window (2021–2026); (ii) examine the complete nutritional-status spectrum (stunting, underweight, wasting/thinness, normal weight, overweight and obesity, and BMI z-score) within the same framework; (iii) harmonise heterogeneous exposure definitions into the five duration categories requested by clinicians and programme managers; and (iv) combine exploratory random-effects meta-analysis with an effect-direction matrix and duration meta-regression to describe the shape of the duration–response relationship, including the paradoxical findings for prolonged breastfeeding in food-insecure settings.^{16,21,22}

Objectives

The primary objective was to evaluate the association between breastfeeding duration and nutritional status (stunting, underweight, normal weight, overweight and obesity) among children aged 2–6 years. Secondary objectives were to (a) compare exclusive and any/full breastfeeding; (b) describe the association across duration categories of ≤ 1 , 3–5, 6, 6–11 and ≥ 12 months; (c) explore effect modification by region, outcome definition and maternal/perinatal characteristics; (d) evaluate the risk of bias and certainty of evidence; and (e) situate findings within existing systematic reviews and the evidence on persistence into school age.^{21,23}

Hypotheses

H1 (over-nutrition): longer duration of breastfeeding, particularly exclusive breastfeeding, is associated with lower odds of overweight and obesity and lower BMI z-score at 2–6 years. **H2 (under-nutrition):** exclusive breastfeeding to about 6 months and continued breastfeeding into the second year are associated with lower odds of stunting and underweight. **H3 (duration–response):** the association with over-nutrition is graded across duration categories, whereas the association with stunting is context-dependent beyond 24 months. **H0:** breastfeeding duration is not associated with nutritional status at 2–6 years.^{10,13,22}

Benefits of the review

Clinical: the review provides paediatricians, family physicians and nutrition specialists with duration-specific estimates for counselling families and identifying children at risk (e.g., infants of mothers with obesity or gestational diabetes, large-for-gestational-age infants). **Public health and policy:** the synthesis informs national stunting- and obesity-prevention programmes, including Indonesian first-1,000-days initiatives, and supports regulatory action on CMF marketing and maternity protection. **Academic:** the review identifies methodological weaknesses (recall bias, residual confounding, reverse causation) and defines priorities for future cohorts and trials.^{4,7,24}

METHODS

Protocol and reporting

The review was designed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. The protocol was not prospectively registered; this is acknowledged as a limitation, and the eligibility criteria, synthesis plan and exposure harmonisation rules below were fixed before data extraction.²¹

Eligibility criteria (PECOS)

Eligibility was defined using the population, exposure, comparator, outcome and study-design (PECOS) framework (Figure 2; Table 1). Studies were eligible if nutritional status was assessed in children aged 2–6 years or if repeated measures spanned this window; cohorts with outcomes at 5–9 years or beyond were eligible when at least one assessment fell within or at the boundary of the window. Only original primary studies published between January 2021 and September 2026 were included.^{21,23}

PECO framework and eligible study designs

P Population	I/E Exposure	C Comparator	O Outcomes
Children aged 2-6 years (pre-school to early school age), any setting; outcome measured within 2-6 y window (or cohort spanning it)	Duration of any or exclusive breastfeeding; feeding pattern in infancy (EBF, full BF, continued BF 12-24 mo)	Shorter or no breastfeeding; duration categories: <=1 mo 3-5 mo 6 mo 6-11 mo >=12 mo	Nutritional status: stunting, underweight, (wasting/thinness), normal weight, overweight, obesity; BMI/BMI z-score

Designs: RCT (incl. secondary analyses), prospective/retrospective cohort, case-control, cross-sectional/observational | Publication window 2021-2026

Figure 2. PECO framework and eligible study designs.

Table 1. Eligibility criteria according to the PECOS framework.

Element	Inclusion criteria	Exclusion criteria
Population	Children aged 2–6 years (pre-school/early school age) in any setting; cohorts with at least one assessment in this window	Outcome assessed only <2 years; only school-age/adolescent outcomes (≥ 7 years); hospitalised or disease-specific populations
Exposure	Duration of any, full or exclusive breastfeeding (months or categories); infant feeding pattern over a defined period (EBF, mixed, formula); continued breastfeeding to 12–24 months; randomised breastfeeding promotion	Exposure limited to early initiation, prelacteal feeding or formula composition without a breastfeeding-duration contrast
Comparator	Shorter or no breastfeeding; harmonised to ≤ 1 , 3–5, 6, 6–11 and ≥ 12 months	No comparison group

Outcomes	Stunting (HAZ < -2 SD), underweight (WAZ < -2 SD), wasting/thinness, normal weight, overweight, obesity (WHO, CDC, IOTF or ISO-BMI references), BMI or BMI z-score, child-level DBM	Household-level DBM only; neurodevelopmental, infectious or metabolic outcomes only
Study design	RCT (including follow-up or secondary analyses), prospective or retrospective cohort, case-control, cross-sectional and other observational designs	Systematic reviews, meta-analyses, narrative/scoping reviews, editorials, protocols, preprints duplicating a published record
Time/language	Published 2021–2026; English or Indonesian with English abstract	Published before 2021

Search Strategy

The keywords used for this research based PICO :

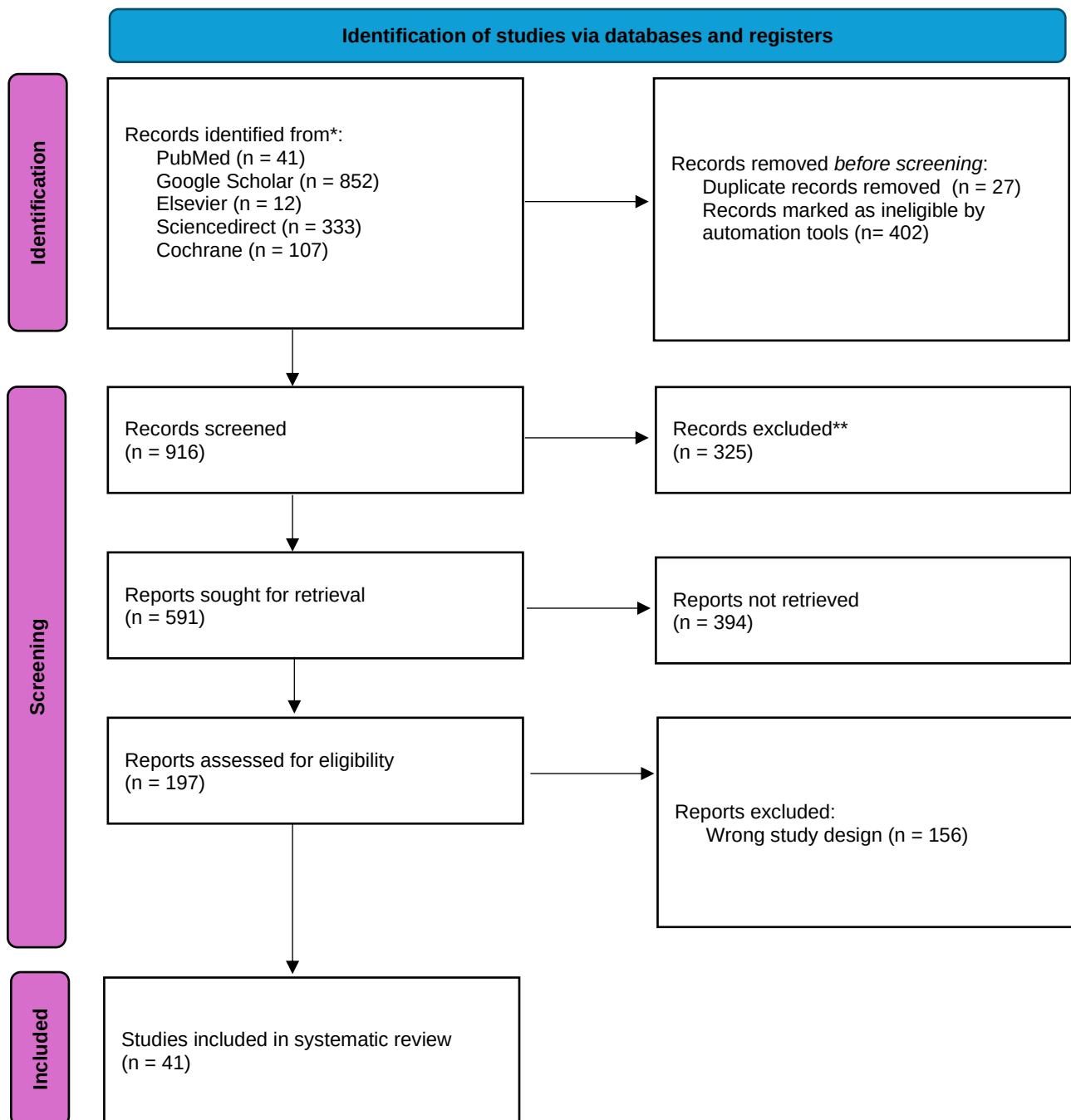
PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Children aged 2–6 years	School-aged children	Preschool children in LMICs
I (Intervention)	Breastfeeding duration	Exclusive breastfeeding	Prolonged breastfeeding
C (Comparison)	Shorter or no breastfeeding	Formula feeding	Early weaning
O (Outcome)	Nutritional status	Stunting and underweight	Overweight and obesity

The Boolean MeSH keywords inputted on databases for this research are: (*"Children aged 2–6 years"* OR *"School-aged children"* OR *"Preschool children in LMICs"*) AND (*"Breastfeeding duration"* OR *"Exclusive breastfeeding"* OR *"Prolonged breastfeeding"*) AND (*"Shorter or no*

breastfeeding" OR "Formula feeding" OR "Early weaning") AND ("Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")

Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Children aged 2–6 years" OR "School-aged children" OR "Preschool children in LMICs") AND ("Breastfeeding duration" OR "Exclusive breastfeeding" OR "Prolonged breastfeeding") AND ("Shorter or no breastfeeding" OR "Formula feeding" OR "Early weaning") AND ("Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")</i>	41
Google Scholar	<i>("Children aged 2–6 years" OR "School-aged children" OR "Preschool children in LMICs") AND ("Breastfeeding duration" OR "Exclusive breastfeeding" OR "Prolonged breastfeeding") AND ("Shorter or no breastfeeding" OR "Formula feeding" OR "Early weaning") AND ("Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")</i>	852
Elsevier	<i>("Children aged 2–6 years" OR "School-aged children" OR "Preschool children in LMICs") AND ("Breastfeeding duration" OR "Exclusive breastfeeding" OR "Prolonged breastfeeding") AND ("Shorter or no breastfeeding" OR "Formula feeding" OR "Early weaning") AND ("Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")</i>	12
Science-direct	<i>("Children aged 2–6 years" OR "School-aged children" OR "Preschool children in LMICs") AND ("Breastfeeding duration" OR "Exclusive breastfeeding" OR "Prolonged breastfeeding") AND ("Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")</i>	333
Cochrane	<i>("Children aged 2–6 years" OR "School-aged children" OR "Preschool children in LMICs" AND "Breastfeeding duration" OR "Exclusive breastfeeding" OR "Prolonged breastfeeding" AND "Nutritional status" OR "Stunting and underweight" OR "Overweight and obesity")</i>	107



Article search flowchart

Data items and extraction

A standardised extraction template captured: first author, year, country and region, design, data source, analytic sample size, age at outcome assessment, exposure definition (any, full or exclusive breastfeeding; duration categories; method of ascertainment), comparator, outcome definition and growth reference, adjustment set, effect measure with 95% confidence interval (CI), and the direction of association. Adjusted estimates were preferred over crude estimates; when several adjusted models were reported, the fully adjusted model was extracted. When multiple non-overlapping strata were reported (e.g., sex-specific estimates), strata were entered as separate estimates. Where only a subgroup estimate was reported in the published abstract (e.g., large-for-gestational-age infants), that estimate was used and its influence tested in sensitivity analyses.^{21,23}

Harmonisation of breastfeeding-duration categories

To address the comparator specified for this review, each exposure contrast was mapped to one of five duration categories using the midpoint of the exposed group (Table 3). Estimates reported with shorter breastfeeding as the exposed group (e.g., breastfeeding <12 months versus ≥ 12 months) were inverted (1/ratio; CI limits inverted and swapped) so that all ratios express longer/any versus shorter/no breastfeeding; a ratio below 1 therefore indicates lower risk with longer breastfeeding. Regression coefficients were sign-inverted when necessary so that negative values indicate lower BMI z-score with longer breastfeeding.^{23,25}

Table 2. Harmonisation rules mapping reported breastfeeding exposures to the five duration categories of the review.

Review category	Typical exposure definitions mapped	Midpoint used for meta-regression	Examples among included studies
≤ 1 month (reference)	Never breastfed; any/full breastfeeding <1 month; exclusive formula feeding	Reference	Huang Y 2024 (<1 mo); Blanco 2023 (<1 mo); formula-fed groups

3–5 months	Breastfeeding during the first 4 months; EBF >4 mo vs ≤4 mo; any BF 3–7 mo; 3 mo increments	4–5 months	Huang H 2022; Leth-Møller 2025; Park 2025 (boys); Shipp 2024; Ong 2023
6 months	EBF 6 months; EBF within the first 6 months vs formula; <6 vs ≥6 mo	6 months	Hildebrand 2021; Li 2022; Izzah 2022; Martín-Ramos 2024
6–11 months	Full BF >6 mo; any BF ≥8 mo; 6–12 vs 0–3 mo	7.5–10 months	Huang Y 2024; Park 2025 (girls); Maskarinec 2021
≥12 months	Continued BF 12–23 mo; ≥12 vs <12 mo; ≥24 mo; BF into third year	15–30 months	Clayton 2024; Yigezu 2024; Paramashanti 2026; Adnyana 2026; Tefera 2025

Outcome definitions

Outcomes were accepted as defined by the primary authors and recorded with the growth reference used: stunting as height/length-for-age z-score (HAZ) below -2 SD, underweight as weight-for-age z-score below -2 SD, wasting/thinness as weight-for-height or BMI-for-age below -2 SD (or IOTF thinness cut-offs), and overweight/obesity according to WHO z-score thresholds, CDC percentiles (85th/95th), IOTF or ISO-BMI cut-offs, or BMI z-score >1 . Child-level DBM (coexisting stunting with under- or overweight) was retained as a composite outcome. Continuous BMI and BMI z-score were analysed separately.^{1,26}

Risk of bias and methodological quality

Risk of bias of observational estimates was appraised using a seven-domain tool adapted from ROBINS-E: D1 confounding (including reverse causation), D2 selection of participants, D3 classification of the exposure (breastfeeding duration), D4 post-exposure interventions/co-exposures, D5 missing data, D6 measurement of the outcome (anthropometry), and D7 selection of

the reported result; each domain was judged low, some concerns or high according to pre-specified criteria (Table 4), and the overall judgement equalled the most severe domain. Methodological quality was additionally scored with the Newcastle–Ottawa Scale (NOS; selection 0–4, comparability 0–2, outcome/exposure 0–3; ≥ 7 good, 5–6 fair, ≤ 4 poor), using the cross-sectional adaptation where applicable. Randomised evidence was appraised with RoB 2.^{23,25,27}

Table 3. Pre-specified signalling criteria for the ROBINS-E-adapted risk-of-bias domains.

Domain	Low	Some concerns	High
D1 Confounding	Randomised or sibling/causal design, or adjustment for maternal BMI, SES/education, birth weight and infant growth	Multivariable adjustment for key confounders but residual confounding plausible	Unadjusted (bivariate/chi-square) analysis, or strong reverse-causation potential (current BF status in poorly growing children)
D2 Selection	Population-based, random or complete sampling	Facility-based random sampling; modest case–control sampling	Convenience hospital sample; outcome-restricted sample (e.g., stunted children only)
D3 Exposure	Prospectively recorded feeding (registers, repeated interviews in infancy)	Maternal recall over 2–5 years or proxy exposure	Recall with evidence of differential misclassification
D4 Co-exposures	No post-exposure intervention differing between groups	Differential complementary-feeding programme exposure	Major co-intervention linked to exposure
D5 Missing data	<10% missing or appropriate handling	10–30% attrition, complete-case analysis	>30% attrition without handling

D6 Outcome	Anthropometry measured by trained staff with standard references	Registry/record-based anthropometry or unclear reference	Self- or parent-reported height and weight
D7 Reporting	Pre-specified analysis; complete reporting	Selected subgroup/model presented	Selective p-value-only or significance-only reporting

Risk of bias and methodological quality

No observational study was judged at low overall risk of bias: 26 of 40 (65.0%) had some concerns and 14 (35.0%) were at high risk. Confounding was the dominant limitation (some concerns in 31 and high risk in 9 studies), the latter comprising small studies with only bivariate analyses and survey analyses in which current or prolonged breastfeeding status is prone to reverse causation. Exposure classification raised some concerns in 26 studies because breastfeeding duration was recalled two to six years after the event, whereas 14 studies used prospectively recorded feeding data (e.g., health-care registers or infancy interviews). Outcome measurement was generally robust (measured anthropometry in 37 studies), and selection bias was high in four hospital- or outcome-restricted samples.^{22,23,34}

Risk-of-bias traffic-light plot (ROBINS-E-adapted), observational studies (n = 40)



All = overall judgement. D1 confounding; D2 selection of participants; D3 exposure (BF duration) classification; D4 post-exposure interventions/co-exposures; D5 missing data; D6 outcome (anthropometry) measurement; D7 selection of reported result. + low - some concerns x high

Figure 3. Risk-of-bias traffic-light plot for the 40 observational studies using the ROBINS-E-adapted seven-domain tool.²³

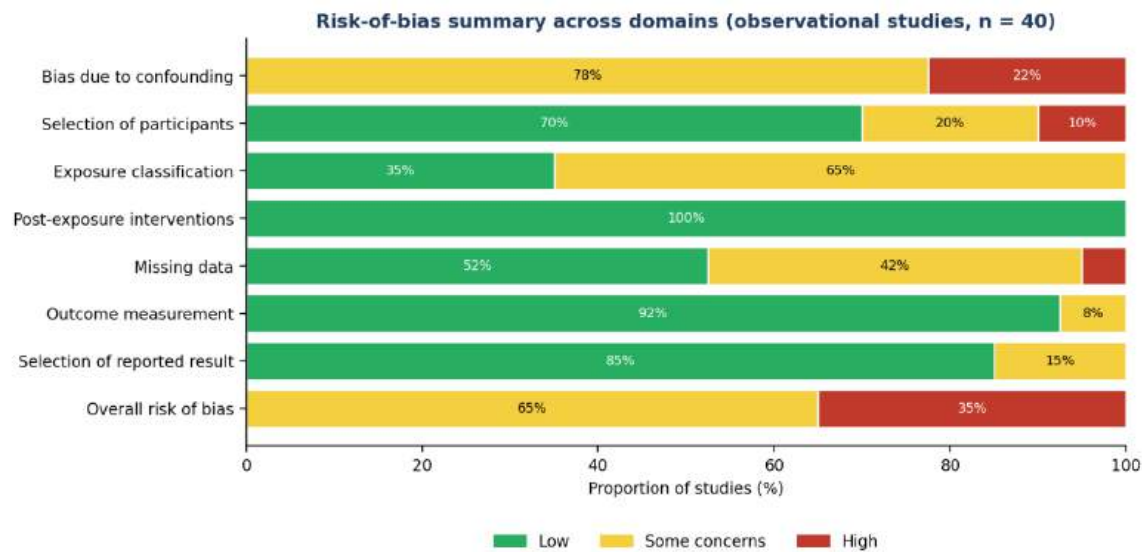


Figure 4. Weighted summary of risk-of-bias judgements across domains (proportion of observational studies).²³

Table 4. Domain-level risk-of-bias judgements for observational studies (ROBINS-E-adapted).

Study	D1	D2	D3	D4	D5	D6	D7	Overall
Usheva et al. 2021	Some	Low	Some	Low	Some	Low	Low	Some concerns
Hildebrand et al. 2021	Some	Low	Some	Low	Low	Low	Low	Some concerns
Maskarinec et al. 2021	Some	Low	Low	Low	High	Low	Low	High
Sata et al. 2021	Some	Low	Some	Low	High	Some	Low	High
Huang H et al. 2022	Some	Low	Some	Low	Low	Low	Low	Some concerns
Li et al. 2022	Some	Low	Low	Low	Some	Low	Low	Some concerns
Mantzorou et al.	Some	Low	Some	Low	Low	Some	Low	Some

2022								concerns
Chen et al. 2022	Some	Low	Some	Low	Low	Low	Low	Some concerns
Dubois et al. 2022	Some	Low	Low	Low	Some	Low	Low	Some concerns
Ong et al. 2023	Some	Low	Low	Low	Some	Low	Low	Some concerns
Michael et al. 2022	Some	Low	Low	Low	Some	Low	Low	Some concerns
Zheng et al. 2023	Some	Low	Low	Low	Some	Low	Low	Some concerns
Matias et al. 2023	Some	Low	Some	Low	Low	Low	Low	Some concerns
Blanco et al. 2023	Some	Low	Low	Low	Some	Low	Low	Some concerns
Shipp et al. 2024	Some	Low	Some	Low	Some	Low	Low	Some concerns
Huang Y et al. 2024	Some	Low	Low	Low	Some	Low	Low	Some concerns
Sun et al. 2024	Some	Low	Some	Low	Low	Low	Low	Some concerns
AlTarrah et al. 2024	Some	Some	Some	Low	Low	Low	Low	Some concerns
Clayton et al. 2024	Some	Low	Low	Low	Some	Some	Low	Some concerns
Martín-Ramos et al. 2024	Some	Low	Low	Low	Some	Low	Low	Some concerns

Park et al. 2025	Some	Low	Some	Low	Some	Low	Low	Some concerns
Leth-Møller et al. 2025	Some	Low	Low	Low	Some	Low	Low	Some concerns
Haahr Vad et al. 2025	Some	Low	Low	Low	Some	Low	Low	Some concerns
Nagore González et al. 2025	Some	Low	Low	Low	Some	Low	Low	Some concerns
Sámano et al. 2025	High	Some	Some	Low	Low	Low	Some	High
Liu Y et al. 2025	Some	High	Some	Low	Low	Low	Some	High
Teotia et al. 2026	High	High	Some	Low	Low	Low	Some	High
Izzah et al. 2022	Some	Some	Some	Low	Low	Low	Low	Some concerns
Yigezu et al. 2024	Some	Low	Some	Low	Low	Low	Low	Some concerns
Tefera et al. 2025	High	Low	Some	Low	Low	Low	Low	High
Andarusukma et al. 2025	High	Low	Some	Low	Low	Low	Low	High
Khomisah et al. 2025	High	Low	Some	Low	Low	Low	Some	High
Wulandari et al. 2024	High	Some	Some	Low	Some	Low	Some	High
Paramashanti et al. 2026	Some	Some	Some	Low	Low	Low	Low	Some concerns
Adnyana et al. 2026	High	Some	Some	Low	Low	Low	Low	High
Feriani et al. 2026	High	Some	Some	Low	Low	Low	Low	High

Indrasari et al. 2026	High	Some	Some	Low	Low	Low	Some	High
Balapou et al. 2026	Some	High	Some	Low	Low	Low	Low	High
Alajajian et al. 2026	Some	High	Low	Low	Some	Low	Low	High
Alghofaili et al. 2026	Some	Low	Some	Low	Low	Low	Low	Some concerns

D1 confounding; D2 selection of participants; D3 exposure classification; D4 post-exposure interventions/co-exposures; D5 missing data; D6 outcome measurement; D7 selection of reported result. Some, some concerns.

NOS scores ranged from 2 to 9 (mean 7.2); 28 studies were rated good quality (≥ 7 stars), seven fair (5–6) and five poor (≤ 4) (Figure 8; Table 11). Poor-quality studies were small, facility-based analyses without multivariable adjustment. The single randomised source, a secondary analysis of the PROBIT cluster-randomised breastfeeding-promotion trial, was judged to have some concerns overall under RoB 2, reflecting reliance on mediation analysis and long-term follow-up.^{27,31}

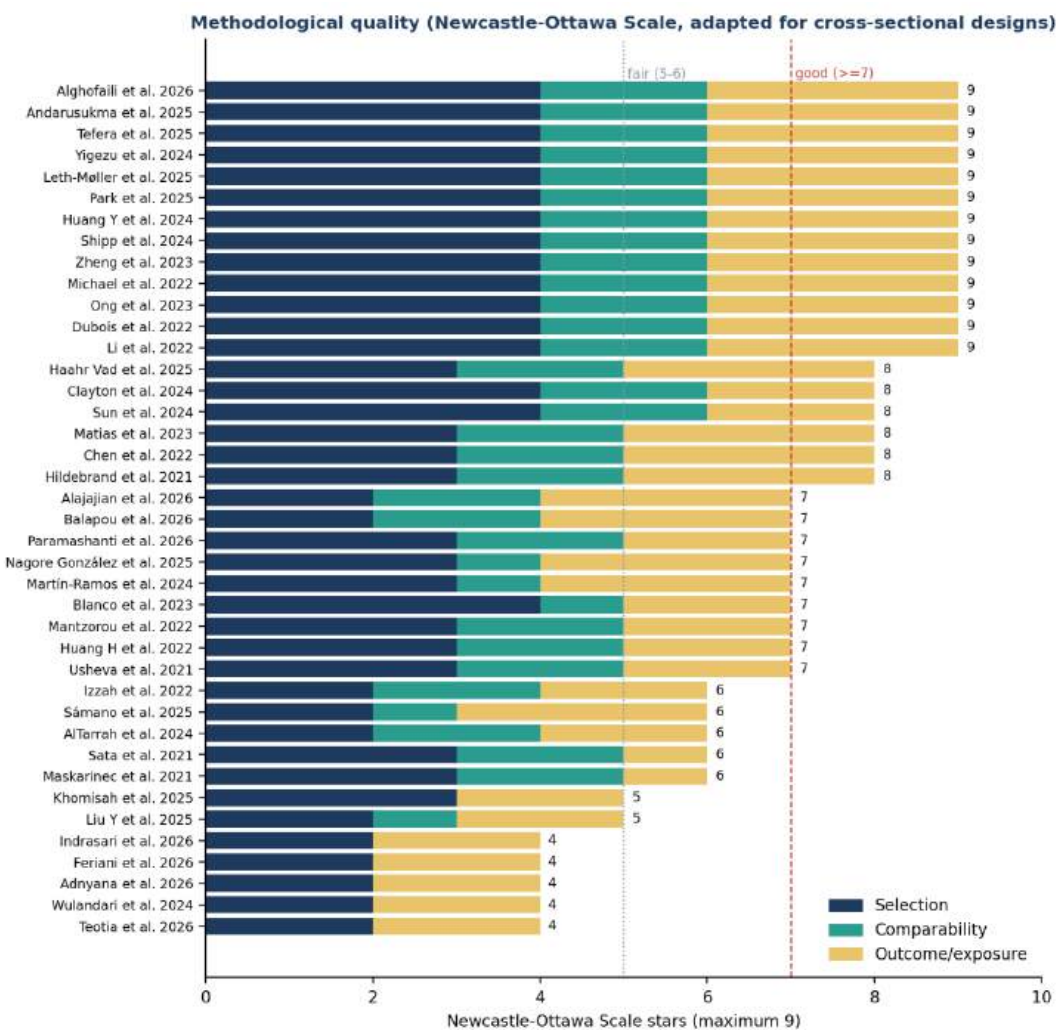


Figure 5. Newcastle–Ottawa Scale scores by domain (selection, comparability, outcome/exposure) for the 40 observational studies.

Table 5. Newcastle–Ottawa Scale scores of observational studies.

Study	Design	Selectio n (0–4)	Comparabilit y (0–2)	Outcome/exposur e (0–3)	Tota l (0– 9)	Qualit y
Usheva et al. 2021	Cross-sectional (ToyBox)	3	2	2	7	Good

Hildebrand et al. 2021	Cross-sectional within cohort (ECHO/NICH D Fetal Growth)	3	2	3	8	Good
Maskarinec et al. 2021	Prospective follow-up cohort	3	2	1	6	Fair
Sata et al. 2021	Prospective cohort (IBACHIL)	3	2	1	6	Fair
Huang H et al. 2022	Retrospective cohort (fitness surveillance)	3	2	2	7	Good
Li et al. 2022	Retrospective population birth cohort (repeated measures)	4	2	3	9	Good
Mantzorou et al. 2022	Cross-sectional (9 regions)	3	2	2	7	Good
Chen et al. 2022	Retrospective registry cohort (LGA infants)	3	2	3	8	Good
Dubois et al. 2022	Prospective cohort (3D Cohort)	4	2	3	9	Good

Ong et al. 2023	Prospective multi-ethnic birth cohort (GUSTO)	4	2	3	9	Good
Michael et al. 2022	Prospective birth cohort (GUSTO) - trajectory modelling	4	2	3	9	Good
Zheng et al. 2023	Pooled analysis of 7 cohorts (GSEM)	4	2	3	9	Good
Matias et al. 2023	Retrospective cohort (programme data)	3	2	3	8	Good
Blanco et al. 2023	Prospective infancy cohort	4	1	2	7	Good
Shipp et al. 2024	Pooled prospective cohorts (ECHO)	4	2	3	9	Good
Huang Y et al. 2024	Prospective cohort (GEE)	4	2	3	9	Good
Sun et al. 2024	Cross-sectional (national survey)	4	2	2	8	Good

AlTarrah et al. 2024	Cross-sectional (kindergarten)	2	2	2	6	Fair
Clayton et al. 2024	Prospective population-based cohort	4	2	2	8	Good
Martín-Ramos et al. 2024	Prospective longitudinal cohort (LAyDI)	3	1	3	7	Good
Park et al. 2025	Nationally representative birth cohort	4	2	3	9	Good
Leth-Møller et al. 2025	Population-based cohort (routine records)	4	2	3	9	Good
Haahr Vad et al. 2025	Observational cohort (primary/school care records)	3	2	3	8	Good
Nagore González et al. 2025	Observational longitudinal cohort	3	1	3	7	Good
Sámano et al. 2025	Retrospective cohort (daycare records)	2	1	3	6	Fair
Liu Y et al.	Hospital-based	2	1	2	5	Fair

2025	cross-sectional (obese vs non- obese)					
Teotia et al. 2026	Hospital-based case-control	2	0	2	4	Poor
Izzah et al. 2022	Case-control	2	2	2	6	Fair
Yigezu et al. 2024	Community- based cross- sectional	4	2	3	9	Good
Tefera et al. 2025	Pooled cross- sectional DHS (multilevel)	4	2	3	9	Good
Andarusukma et al. 2025	Cross-sectional national survey	4	2	3	9	Good
Khomisah et al. 2025	Cross-sectional	3	0	2	5	Fair
Wulandari et al. 2024	Retrospective cohort	2	0	2	4	Poor
Paramashanti et al. 2026	Case-control (multistage random)	3	2	2	7	Good
Adnyana et al. 2026	Cross-sectional	2	0	2	4	Poor
Feriani et al. 2026	Cross-sectional	2	0	2	4	Poor
Indrasari et	Cross-sectional	2	0	2	4	Poor

al. 2026	correlational					
Balapou et al. 2026	Hospital-based cross-sectional	2	2	3	7	Good
Alajajian et al. 2026	Clinical cohort (stunted children; mixed models)	2	2	3	7	Good
Alghofaili et al. 2026	Cross-sectional (PHC, multistage)	4	2	3	9	Good

Table 6. RoB 2 assessment of the randomised evidence (PROBIT secondary analysis).

Domain	Judgement	Support for judgement
1. Randomisation process	Low	Cluster randomisation of maternity hospitals and affiliated clinics to breastfeeding promotion or usual care
2. Deviations from intended interventions	Some concerns	Effect of assignment estimated; mediation of weight effects via dietary intake requires untestable no-confounding assumptions
3. Missing outcome data	Some concerns	Long-term follow-up through adolescence with probable attrition; handling not detailed in abstract
4. Measurement of the outcome	Low	Weight-for-age measured with standardised anthropometry
5. Selection of the reported result	Some concerns	Secondary econometric analysis without a pre-registered analysis plan
Overall	Some concerns	Randomised comparison robust; mechanism (nutrition-mediated) inferences less certain

Effect measures and synthesis methods

Adjusted odds ratios (aOR), risk ratios, prevalence ratios and hazard ratios were treated as approximating the same relative measure because the outcomes of interest (overweight/obesity in most high-income cohorts) were of low to moderate prevalence; this assumption was tested by stratifying by effect measure. Log-transformed ratios and their standard errors (derived from 95% CI as $[\ln(\text{upper}) - \ln(\text{lower})]/3.92$) were pooled with DerSimonian–Laird random-effects models when at least three comparable estimates were available. Heterogeneity was quantified with Cochran's Q, I^2 and τ^2 , and 95% prediction intervals were calculated. Continuous BMI z-score coefficients were displayed in a coefficient plot but not pooled because contrasts (per month, per 3 months, categorical) were not commensurable.^{21,23}

Pre-specified subgroup analyses examined exposure type (exclusive versus any/full), outcome definition (obesity versus overweight or combined), region, effect measure and duration category, with between-subgroup Q tests. Sensitivity analyses included restriction to adjusted estimates, odds ratios only, cohort designs only, exclusion of subgroup-only estimates, substitution of alternative strata, a fixed-effect model, leave-one-out analysis and cumulative meta-analysis by year. Duration–response was explored by random-effects meta-regression of the log ratio on the duration midpoint and by an effect-direction (vote-count) matrix across the five duration categories and seven outcome categories. Small-study effects were examined with contour-enhanced funnel plots, Egger's regression and Begg's rank correlation, and Duval–Tweedie trim-and-fill; Galbraith plots were inspected for outliers. Analyses were performed in Python (NumPy/SciPy) with independently coded estimators.^{21,23}

Certainty of evidence

Certainty of evidence for each outcome was rated with the GRADE approach, starting at low certainty for observational evidence and considering risk of bias, inconsistency, indirectness, imprecision and publication bias, with possible upgrading for a large effect or a dose–response gradient.²⁵

Ethical considerations

The review used published aggregate data only; ethical approval and informed consent were therefore not required. All included studies reported ethical approval in their original publications or were analyses of publicly available survey data.²¹

RESULTS

Characteristics of included studies

The 41 included studies were published between 2021 and 2026 and were conducted in 25 countries across Asia (n = 17), North America (n = 8), Europe (n = 7), Africa (n = 3), Latin America (n = 3), the Middle East (n = 2) and Oceania (n = 1). Designs comprised prospective or pooled cohorts, retrospective cohorts, case-control studies, cross-sectional studies and one secondary analysis of a cluster-randomised trial. Analytic samples ranged from 83 to 59,564 children, with a combined 161,633 children in the 37 studies reporting sample size (Figure 5). Twenty-seven studies primarily examined over-nutrition (overweight, obesity, BMI or BMI z-score), 13 examined under-nutrition (stunting, underweight, wasting or child-level DBM) and one provided randomised evidence.^{22,28–31}

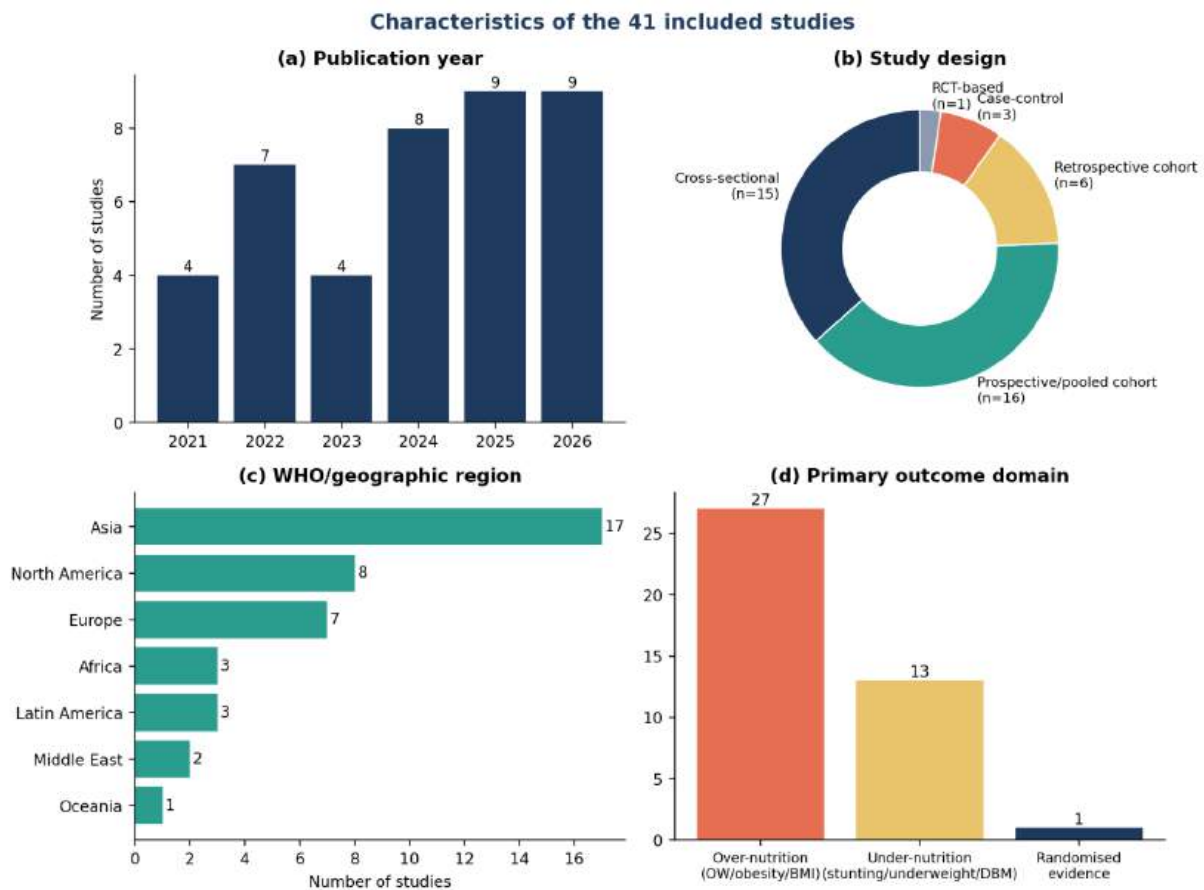


Figure 6. Characteristics of the 41 included studies: (a) year of publication, (b) study design, (c) geographic region and (d) primary outcome domain.

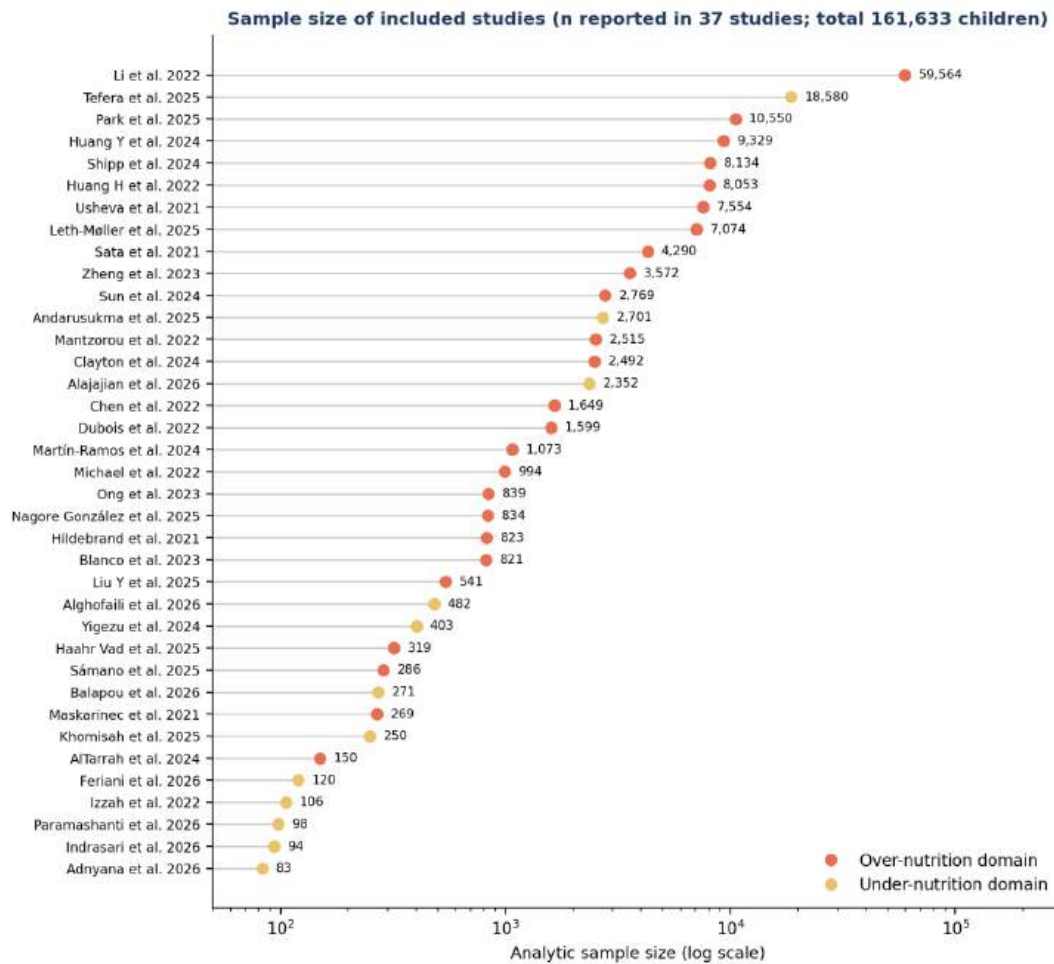


Figure 7. Analytic sample size of each included study (log scale), coloured by outcome domain.

Table 7. Characteristics of included studies: over-nutrition domain (n = 27).

Study	Country	Design	N	Age at outcome	Exposure and duration categories	Outcome [growth reference]
Usheva et al. 2021 ²⁸	Belgium, Bulgaria, Germany, Greece, Poland,	Cross-sectional (ToyBox)	7,554	3.5-5.5 y	Any BF and EBF duration (parental recall); Never; EBF 4-6 mo; median any BF 5 mo	Overweight, obesity (measured) [NR in abstract]

	Spain					
Hildebrand et al. 2021 ³²	USA	Cross-sectional within cohort (ECHO/NI CHD Fetal Growth)	823	4-8 y	Duration of EBF and total BF; None; <6 mo; ≥6 mo EBF	Overweight (85th- <95th pct), obesity (≥95th pct), %BF by BIA [BMI percentiles]
Maskarinec et al. 2021 ³³	USA	Prospective follow-up cohort	269	Birth-6 y	Duration of human-milk feeding at breast/expressed; 0-3 mo; 6-12 mo (months, z-continuous)	Ever excess weight (WAZ, WHZ, BMIZ); BMIZ trajectory [z-scores]
Sata et al. 2021 ³⁴	Japan	Prospective cohort (IBACHIL)	4,290	3, 6, 12, 22 y	Feeding type in infancy (BF, mixed, formula); Breastfed vs formula-fed	Overweight (self/parent-reported height, weight) [NR in abstract]
Huang H et al. 2022 ³⁵	China (Jiangsu)	Retrospective cohort (fitness surveillance)	8,053	3-6 y	Feeding pattern in first 4 mo; BF, mixed, formula	Thinness, overweight, obesity (measured) [IOTF]
Li et al. 2022 ²⁹	China (Tianjin)	Retrospective population birth	59,564	1-6 y	Feeding modality within first 6 mo (health records); EBF, mixed, exclusive formula	Underweight, normal weight, obesity (6 repeated measures) [NR in

		cohort (repeated measures)				abstract]
Mantzorou et al. 2022 ³⁶	Greece	Cross- sectional (9 regions)	2,515	2-5 y	EBF for ≥ 4 mo (questionnaire); EBF ≥ 4 mo vs < 4 mo	Overweight/obesity [NR in abstract]
Chen et al. 2022 ³⁷	China (Xiamen)	Retrospect ive registry cohort (LGA infants)	1,649	1-4 y	BF vs no BF; BF vs no- BF	BMI z-score; overweight [NR in abstract]
Dubois et al. 2022 ³⁸	Canada (Quebec)	Prospectiv e cohort (3D Cohort)	1,599	2 y	Total and exclusive BF duration; < 6 mo; $6-12$ mo; ≥ 12 mo; EBF < 3 vs ≥ 6 mo	Rapid weight gain (RWG); excess weight at 2 y [NR in abstract]
Ong et al. 2023 ³⁹	Singapore	Prospectiv e multi- ethnic birth cohort (GUSTO)	839	6 y	Any BF duration and timing of complementary feeding; Short (≤ 4 mo) vs long (> 4 mo) BF	BMIZ, skinfolds, cardiometabolic markers [z-scores]
Michael et al. 2022 ⁴⁰	Singapore	Prospectiv e birth cohort (GUSTO) - trajectory	994	Birth-6 y	BF duration (determinant of BMI trajectories); Shorter vs longer BF	Obesogenic BMIZ trajectories (early/late acceleration) [z- scores]

		modelling				
Zheng et al. 2023 ⁴¹	Australia and New Zealand (7 cohorts)	Pooled analysis of 7 cohorts (GSEM)	3,572	3-5 y	BF duration ≥ 6 mo; < 6 mo vs ≥ 6 mo	BMIz, overweight status [NR in abstract]
Matias et al. 2023 ⁴²	USA (Southern California, WIC)	Retrospective cohort (programme data)	NR	2-4 y	Fully breastfeeding duration (WIC formula package proxy); Per additional month of full BF	Obesity (BMIz ≥ 95 th pct) [BMI-for-age]
Blanco et al. 2023 ⁴³	Chile (Santiago)	Prospective infancy cohort	821	1, 5, 10, 16, 23 y	Duration of EBF; type of BF at 6 mo; < 1 mo; 1- < 3 mo; 3- < 6 mo; ≥ 6 mo	BMI z-score [NR in abstract]
Shipp et al. 2024 ⁴⁴	USA (21 ECHO cohorts)	Pooled prospective cohorts (ECHO)	8,134	2-6 y	Any and exclusive BF duration, stratified by maternal BMI; Per 3 mo any/exclusive BF	BMI-for-age z-score [z-scores]
Huang Y et al. 2024 ⁴⁵	China (Hangzhou)	Prospective cohort (GEE)	9,329	12-36 mo	Full (exclusive+predominant) BF duration; < 1 mo; 1-2 mo; 3-5 mo; > 6 mo	Overweight/obesity (BMI > 1 SD) [BMI z > 1 SD]
Sun et al. 2024 ⁴⁶	USA (NHANES 2009-2018)	Cross-sectional (national survey)	2,769	2-6 y	BF duration (tertiles; recall); Short, medium, long-term BF	BMI (kg/m ²) [BMI]
AlTarrh et al. 2024 ⁴⁷	United Arab Emirates	Cross-sectional	150	2-6 y	Any BF duration (months); age at CF;	BMI z-score [z-scores]

	(Al Ain)	(kindergarten)			Continuous (per month)	
Clayton et al. 2024 ⁴⁸	USA (Upstate KIDS)	Prospective population-based cohort	2,492	2-3 y and 7-9 y	BF type/duration reported 4-12 mo; Formula; EBF; any BF ≥ 12 mo	BMIz, WAZ; overweight/obesity [z-scores]
Martín-Ramos et al. 2024 ⁴⁹	Spain (PAPenRed)	Prospective longitudinal cohort (LAYDI)	1,073	12 and 24 mo	BF duration; <6 mo vs ≥ 6 mo	WFA, BMI-for-age, WFL/H; overweight/obesity [NR in abstract]
Park et al. 2025 ⁵⁰	USA (ECLS-B)	Nationally representative birth cohort	10,550	9 mo-7 y	Any BF duration; Never; ≤ 2 mo; 3-7 mo; ≥ 8 mo	Entry to/exit from elevated body mass (OW, obesity) [NR in abstract]
Leth-Møller et al. 2025 ⁵¹	Denmark (Aarhus)	Population-based cohort (routine records)	7,074	5-9 y	EBF duration; Never; ≤ 4 mo; >4 mo	Overweight (BMIz >1) [BMIz >1]
Haahr Vad et al. 2025 ⁵²	Sweden	Observational cohort (primary/school care records)	319	~4, 7, 10, 13, 16 y	BF duration (months); <6 mo vs ≥ 6 mo	BMI, overweight/obesity (ISO-BMI) [ISO-BMI]
Nagore	Spain	Observatio	834	Birth-6	Feeding type in first 4	BMIz, obesity at 6

González et al. 2025 ⁵³		nal longitudinal cohort		y	mo; EBF vs formula	y; mediation by RWG [NR in abstract]
Sámano et al. 2025 ⁵⁴	Mexico (Mexico City daycare)	Retrospective cohort (daycare records)	286	<5 y	BF practices and EBF duration; EBF vs partial; EBF duration (months)	BMI percentile change; OW/OB [WHO protocol]
Liu Y et al. 2025 ⁵⁵	China (Suzhou)	Hospital-based cross-sectional (obese vs non-obese)	541	3-16 y	BF duration and lifestyle score; Categories of BF duration; recommended 4-12 mo	Obesity vs non-obesity [NR in abstract]
Teotia et al. 2026 ⁵⁶	India (Greater Noida)	Hospital-based case-control	NR	2-5 y	BF duration, EBF, timing of top feeds; Shorter vs longer BF	Obesity vs normal BMI [WHO growth standards]

BF, breastfeeding; EBF, exclusive breastfeeding; CF, complementary feeding; GDM, gestational diabetes mellitus; LGA, large for gestational age; BIA, bioelectrical impedance; IOTF, International Obesity Task Force; NR, not reported in the accessible record.

Table 8. Characteristics of included studies: under-nutrition domain (n = 13) and randomised evidence (n = 1).

Study	Country	Design	N	Age at outcome	Exposure and duration categories	Outcome [growth reference]
Izzah et al. 2022 ⁵⁷	Indonesia (Aceh)	Case-control	106	Under-five	EBF, early initiation, BF	Stunting (HAZ < -2 SD) [HAZ z-

	Besar)				duration; EBF vs non-EBF	score]
Yigezu et al. 2024 ⁵⁸	Ethiopia (Gedeo)	Community-based cross-sectional	403	6-59 mo	Total BF duration; <12 mo vs ≥12 mo	Stunting, underweight, wasting [WHO Anthro z-scores]
Tefera et al. 2025 ²²	Ethiopia (EDHS 2000-2019)	Pooled cross-sectional DHS (multilevel)	18,580	<3 y	BF duration (year of life); First year; second year; third year	Stunting, underweight, wasting [NR in abstract]
Andarusukma et al. 2025 ⁵⁹	Indonesia (IFLS-5)	Cross-sectional national survey	2,701	6-59 mo	EBF and BF duration; <12; 12-23; >24 mo	Stunting and severe stunting [NR in abstract]
Khomisah et al. 2025 ⁶⁰	Indonesia (Sampang, coastal)	Cross-sectional	250	12-59 mo	Colostrum, EBF <6 mo, continued BF 12-23 mo; EBF 6 mo vs <6 mo; continued BF 12-23 mo	Stunting [NR in abstract]
Wulandari et al. 2024 ⁶¹	Indonesia (Aceh Besar)	Retrospective cohort	NR	24-59 mo	History of EBF; EBF vs non-EBF	Stunting [NR in abstract]
Paramashanti	Indonesia	Case-control	98	24-59 mo	Any BF	Stunting (HAZ <-

et al. 2026 ⁶²	(Bantul, Yogyakarta)	(multistage random)			duration; <12; 12-23; >24 mo	2 SD) [HAZ z-score]
Adnyana et al. 2026 ³⁰	Indonesia (North Lombok)	Cross-sectional	83	0-59 mo	Immunisation, EBF, BF duration; <2 y vs ≥ 2 y	Stunting [NR in abstract]
Feriani et al. 2026 ⁶³	Indonesia (Kutai Kartanegara)	Cross-sectional	120	7-59 mo	EBF history; EBF vs non-EBF	Stunting/severe stunting; normal status [NR in abstract]
Indrasari et al. 2026 ⁶⁴	Indonesia	Cross-sectional correlational	94	24-59 mo	Early initiation, EBF, BF until 24 mo; BF to 24 mo vs <24 mo	Stunting [NR in abstract]
Balapou et al. 2026 ²⁶	Ghana (urban)	Hospital-based cross-sectional	271	Under-five	BF history and exclusivity; Never; non-EBF; EBF	Child-level double burden (stunting + under/overweight) [WHO standards]
Alajajian et al. 2026 ⁶⁵	Guatemala	Clinical cohort (stunted children; mixed)	2,352	0.5-5 y	Continued BF, IYCF indicators; Continued BF 12-23 mo vs	Linear growth (HAZ) [WHO z-scores]

		models)			not	
Alghofaili et al. 2026 ⁶⁶	Saudi Arabia (Taif)	Cross-sectional (PHC, multistage)	482	Under-five	Early feeding before 6 mo (non-EBF); Early feeding <6 mo vs EBF	Stunting, wasting, underweight, overweight, obesity [WHO standards]
Randomised evidence						
Brenøe et al. 2026 ³¹	Belarus (PROBIT)	Secondary analysis of cluster-RCT (PROBIT)	NR	Infancy-adolescence	Randomised BF promotion (prolonged EBF); Intervention vs control hospitals	Weight-for-age; mediation by diet [NR in abstract]

HAZ, height/length-for-age z-score; DHS, Demographic and Health Survey; IFLS, Indonesia Family Life Survey; DBM, double burden of malnutrition; PROBIT, Promotion of Breastfeeding Intervention Trial; PHC, primary health care.

Table 9. Principal findings and effect estimates: over-nutrition domain.

Study	Principal findings	Effect estimate (95% CI)	NOS	Overall RoB
Usheva et al. 2021 ²⁸	Overweight 8.0%, obesity 2.8%; no significant BF-obesity association after adjustment (p>0.05)	Adjusted: NS (no estimate in abstract)	7	Some concerns
Hildebrand et al. 2021 ³²	6 mo EBF vs none: 60% lower odds of obesity; adjusted %BF 16.8, 14.5, 13.4 for none, <6, ≥6	aOR 0.40 (0.18-0.91)	8	Some concerns

	mo EBF			
Maskarinec et al. 2021 ³³	Duration unrelated to ever excess weight; 6-12 vs 0-3 mo any human milk -> lower BMIZ	beta BMIZ -0.50 (-0.99 to -0.01)	6	High
Sata et al. 2021 ³⁴	At 3 y overweight lower in breastfed boys (6.3% vs 9.3%) and girls (10.4% vs 13.6%); no difference at 6-22 y	Adjusted prevalence difference (p=0.03 boys)	6	High
Huang H et al. 2022 ³⁵	BF lowered overweight and OW/OB vs formula; no difference for thinness or obesity	OW aOR 0.652 (0.533-0.797); OW/OB aOR 0.721 (0.602-0.862)	7	Some concerns
Li et al. 2022 ²⁹	BF inversely associated with obesity 2-6 y with dose trend; formula feeding may increase underweight at 3 and 5 y	Obesity at 3 y: EBF aOR 0.57 (0.44-0.74); mixed 0.62 (0.49-0.80)	9	Some concerns
Mantzorou et al. 2022 ³⁶	EBF ≥ 4 mo associated with about two-fold lower risk of childhood OW/OB, independent of SES and smoking	~2-fold lower risk (p<0.0001)	7	Some concerns
Chen et al. 2022 ³⁷	BF associated with lower BMIz 1-4 y; OW risk lower (significant in model 1 only)	OW OR 0.87 (0.74-1.03), fully adjusted	8	Some concerns
Dubois et al. 2022 ³⁸	Shorter BF -> more RWG; no direct association with excess weight at 2 y; RWG main predictor	RWG OR 2.45 (<6 vs ≥ 12 mo); excess weight NS	9	Some concerns

Ong et al. 2023 ³⁹	Short BF associated with higher BMIz and skinfolds; long BF attenuated cardiometabolic risk of early CF	beta BMIz +0.18 (-0.01 to 0.38) short vs long	9	Some concerns
Michael et al. 2022 ⁴⁰	Shorter BF duration common risk factor for both early- and late-acceleration obesogenic trajectories	Direction: shorter BF -> obesogenic trajectory	9	Some concerns
Zheng et al. 2023 ⁴¹	Association of BF ≥ 6 mo with lower overweight fully mediated by rapid weight gain in infancy	Indirect (mediated) effect only	9	Some concerns
Matias et al. 2023 ⁴²	Each additional month of full BF -> 3-5% lower obesity risk; strongest in high gestational weight gain tertile	3-5% risk reduction per month	8	Some concerns
Blanco et al. 2023 ⁴³	EBF 3-<6 vs <1 mo associated with lower BMIz at 1 and 5 y; null later	Lower BMIz at 5 y (p<0.05)	7	Some concerns
Shipp et al. 2024 ⁴⁴	3 mo any BF -> lower BMIz in children of overweight and obese mothers; 3 mo EBF -> lower BMIz across strata	beta -0.04 (-0.07 to -0.006) [maternal obesity]	9	Some concerns
Huang Y et al. 2024 ⁴⁵	Longer full BF reduced OW/OB vs <1 mo; stronger among GDM-exposed and LGA infants	LGA: 3-5 mo aOR 0.66 (0.57-0.76); >6 mo 0.70 (0.56-0.88); GDM >6 mo 0.58 (0.44-0.78)	9	Some concerns
Sun et al. 2024 ⁴⁶	Long-term BF negatively associated with BMI; stronger in	beta -0.21 kg/m ² (P<0.05)	8	Some concerns

	low-income households			
AlTarrah et al. 2024 ⁴⁷	Each month of any BF associated with lower BMIz after adjustment	beta -0.02 (-0.05 to 0.00) per month	6	Some concerns
Clayton et al. 2024 ⁴⁸	EBF -> lower BMIz; BF ≥ 12 mo -> lower overweight risk at 2-3 y	aRR 0.33 (0.18-0.59)	8	Some concerns
Martín-Ramos et al. 2024 ⁴⁹	BF <6 mo associated with more OW/OB at 12 and 24 mo; maternal pre-pregnancy BMI effect modifier at 24 mo	Significant association (no estimate in abstract)	7	Some concerns
Park et al. 2025 ⁵⁰	Girls: ≥ 8 mo reduced entry into OW/obesity; boys: 3-7 mo protective; dose-response exit in girls	Girls OW aHR 0.76 (0.64-0.89); boys OW aHR 0.79 (0.67-0.92)	9	Some concerns
Leth-Møller et al. 2025 ⁵¹	No EBF or ≤ 4 mo EBF associated with overweight vs >4 mo; >4 mo EBF neutralised risk of accelerated infant growth	≤ 4 mo aOR 1.54 (1.28-1.85); never 1.61 (1.27-2.03)	9	Some concerns
Haahr Vad et al. 2025 ⁵²	No association of BF duration with BMI trajectory or OW/OB up to 16 y	OR 1.46 (0.69-3.08), unadjusted	8	Some concerns
Nagore González et al. 2025 ⁵³	Formula-fed higher BMIz and obesity at 6 y; partly mediated by RWG to 6 mo	p=0.012 (BMIz); p=0.003 (obesity)	7	Some concerns
Sámano et al. 2025 ⁵⁴	EBF duration, birth BMI and maternal education explained 54% of BMI-percentile change 0-2 y	Model R ² 0.54 (p=0.001)	6	High
Liu Y et al.	Prolonged BF and healthy lifestyle	Protective	5	High

2025 ⁵⁵	protective, synergistic	(logistic; ROC/SHAP)		
Teotia et al. 2026 ⁵⁶	Shorter BF, lack of EBF and early top feeds more common among obese children	Chi-square $p < 0.05$ (unadjusted)	4	High

aOR, adjusted odds ratio; aRR, adjusted risk ratio; aHR, adjusted hazard ratio; OW, overweight; OB, obesity; BMIz, BMI-for-age z-score; RWG, rapid weight gain; NS, not significant.

Table 10. Principal findings and effect estimates: under-nutrition domain and randomised evidence.

Study	Principal findings	Effect estimate (95% CI)	NOS	Overall RoB
Izzah et al. 2022 ⁵⁷	Non-EBF and LBW independent risk factors for stunting	Non-EBF aOR 4.57 (1.57-13.27)	6	Some concerns
Yigezu et al. 2024 ⁵⁸	Stunting 49%; BF <12 mo predictor of stunting	BF <12 mo aOR 4.0 (2.55-6.43)	9	Some concerns
Tefera et al. 2025 ²²	BF into third year -> higher stunting and underweight but lower wasting	Stunting aOR 5.45 (4.83-6.15); underweight 1.55 (1.41-1.70); wasting 0.50 (0.43-0.60)	9	High
Andarusukma et al. 2025 ⁵⁹	BF 12-23 and >24 mo associated with higher stunting risk ($P < 0.001$)	$P < 0.001$ (no estimate in abstract)	9	High
Khomisah et al. 2025 ⁶⁰	No EBF (<6 mo) associated with stunting; continued BF 12-23 mo not associated	OR 2.77 (no CI); continued BF NS	5	High
Wulandari et	EBF history associated with lower	OR 0.285 ($p = 0.01$;	4	High

al. 2024 ⁶¹	stunting	no CI)		
Paramashanti et al. 2026 ⁶²	BF 12-23 and >24 mo less likely to be stunted; short birth length and wealth also associated	12-23 mo aOR 0.14 (0.02-0.82); >24 mo 0.21 (0.05-0.87)	7	Some concerns
Adnyana et al. 2026 ³⁰	BF <2 y associated with higher stunting; EBF not significant	PR 2.62 (1.23-5.59), unadjusted	4	High
Feriani et al. 2026 ⁶³	Severe stunting 22.0% non-EBF vs 5.7% EBF (P=0.01)	Chi-square P=0.01 (unadjusted)	4	High
Indrasari et al. 2026 ⁶⁴	Optimal BF practices -> 98.1% lower stunting risk	BF to 24 mo OR 0.089 (no CI)	4	High
Balapou et al. 2026 ²⁶	DBM 31.4%; no BF and non-EBF strongly associated with DBM	No BF aOR 11.79 (2.68-51.84); non-EBF 5.46 (2.13-14.00)	7	High
Alajajian et al. 2026 ⁶⁵	Continued BF 12-23 mo positively associated with linear growth; food insecurity negative	Positive association (LME)	7	High
Alghofaili et al. 2026 ⁶⁶	Stunting 29.5%, OW 7.7%, obesity 11.6%; early feeding <6 mo associated with stunting	Significant (logistic regression)	9	Some concerns
Randomised evidence				
Brenøe et al. 2026 ³¹	Intervention increased WFA in infancy with effects persisting through adolescence; mediated by caloric density	Positive WFA effect (mediation)	RoB 2	Some concerns

PR, prevalence ratio; WFA, weight-for-age; LME, linear mixed-effects model. Estimates are shown as reported (not re-oriented); orientation for pooling is described in Section 2.6.

Breastfeeding duration and over-nutrition

Meta-analysis of overweight and obesity

Ten comparable estimates from nine studies (Asia 4, North America 4, Europe 2) were pooled. Longer or any breastfeeding was associated with 29% lower odds of overweight/obesity (pooled ratio 0.71 (95% CI 0.63–0.80); $Z = 5.53$, $P < 0.001$). Heterogeneity was moderate to substantial ($Q = 22.97$, $df = 9$, $P = 0.006$; $I^2 = 60.8\%$; $\tau^2 = 0.020$), and the 95% prediction interval (0.50–1.01) indicates that a new study in a similar setting would most likely observe a protective or null association. Nine of the ten estimates lay below unity; only the small Swedish cohort, which reported an unadjusted estimate, pointed in the opposite direction with a wide CI.^{29,32,35,37,45,48,50–52}

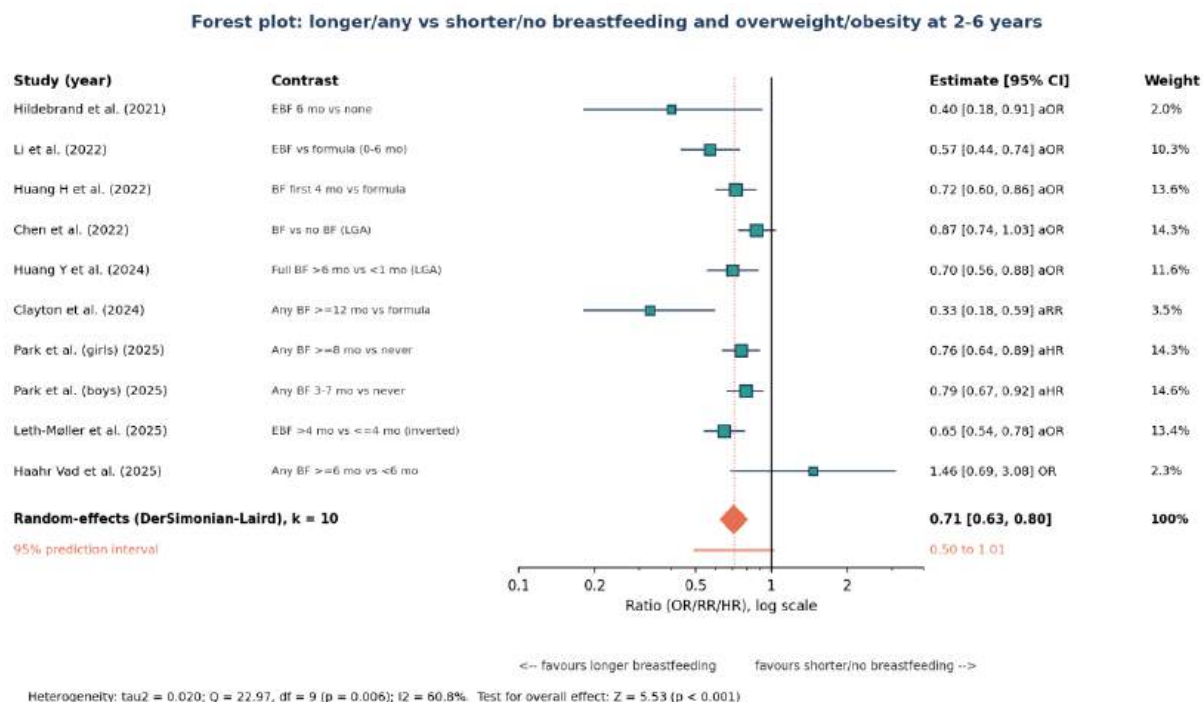


Figure 8. Forest plot of the association between longer/any breastfeeding and overweight/obesity in early childhood (random-effects, DerSimonian–Laird). Squares are sized by weight; the diamond is

the pooled estimate and the orange bar the 95% prediction interval. Leth-Møller et al. was inverted to express >4 versus ≤ 4 months of exclusive breastfeeding.^{29,32,35,37,45,48,50–52}

Table 11. Meta-analysis input data by outcome category (numbers only; oriented as longer versus shorter breastfeeding).

Author	Year	Effect	LowerCI	UpperCI
A. Overweight/obesity (ratio; longer/any vs shorter/no breastfeeding)				
Hildebrand et al.	2021	0.400	0.180	0.910
Li et al.	2022	0.570	0.440	0.740
Huang H et al.	2022	0.721	0.602	0.862
Chen et al.	2022	0.870	0.740	1.030
Huang Y et al.	2024	0.700	0.560	0.880
Clayton et al.	2024	0.330	0.180	0.590
Park et al. (girls)	2025	0.760	0.640	0.890
Park et al. (boys)	2025	0.790	0.670	0.920
Leth-Møller et al.	2025	0.649	0.541	0.781
Haahr Vad et al.	2025	1.460	0.690	3.080
B. Stunting (ratio; longer/exclusive vs shorter/non-exclusive breastfeeding)				
Izzah et al.	2022	0.219	0.075	0.637
Yigezu et al.	2024	0.250	0.156	0.393
Tefera et al.	2025	5.450	4.830	6.150
Paramashanti et al.	2026	0.210	0.050	0.870
Adnyana et al.	2026	0.382	0.179	0.816
C. BMI z-score (coefficient; negative = lower BMIz with longer breastfeeding)				
Maskarinec et al.	2021	-0.500	-0.990	-0.010
Ong et al.	2023	-0.180	-0.380	0.010
Shipp et al. (maternal healthy weight)	2024	-0.020	-0.040	0.001

Shipp et al. (maternal overweight)	2024	-0.040	-0.070	-0.004
Shipp et al. (maternal obesity)	2024	-0.040	-0.070	-0.006
AlTarrah et al.	2024	-0.020	-0.050	0.000
Clayton et al.	2024	-0.230	-0.420	-0.050

Table 12. Summary of pooled estimates (random-effects).

Outcome / analysis	k (studies)	Pooled ratio (95% CI)	P	I ² (%)	τ^2	95% PI	Small- study effects
Overweight/obesity (all)	10 (9)	0.71 (0.63– 0.80)	<0.001	60.8	0.020	0.50– 1.01	Egger P = 0.24; Begg P = 0.07
Overweight/obesity, trim-and-fill	11 (1 imputed)	0.73 (0.64– 0.83)	<0.001	–	–	–	Adjusted for asymmetry
Stunting (all)	5	0.49 (0.08– 3.17)	0.45	98.4	4.347	0.00– >100	Egger P = 0.05
Stunting, excluding BF >24 mo DHS estimate	4	0.27 (0.19– 0.38)	<0.001	0.0	0.000	0.12– 0.59	Too few studies
Stunting, Asian studies only	3	0.30 (0.17– 0.52)	<0.001	0.0	–	–	Too few studies
BMI z-score (continuous)	7 (5)	Not pooled; range	–	–	–	–	7/7 negative

		-0.02 to -0.50					
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Subgroup analyses

The association was significantly stronger for exclusive breastfeeding (0.61 (95% CI 0.53–0.71); $I^2 = 0\%$) than for any/full breastfeeding (0.76 (95% CI 0.66–0.86); P-between = 0.036) and for obesity (0.55 (95% CI 0.43–0.71)) than for overweight or combined overweight/obesity (0.74 (95% CI 0.66–0.83); P-between = 0.037). Estimates did not differ by region (North America 0.65, Asia 0.72, Europe 0.89; P-between = 0.67) or by effect measure (P-between = 0.83), supporting the pooling of odds, risk and hazard ratios. By duration category, the single estimate for ≥ 12 months (Clayton et al.) showed the largest association (0.33, 0.18–0.60), followed by 6–11 months (0.68, 0.59–0.80) and < 6 months (0.76, 0.67–0.85).^{29,32,48,51}

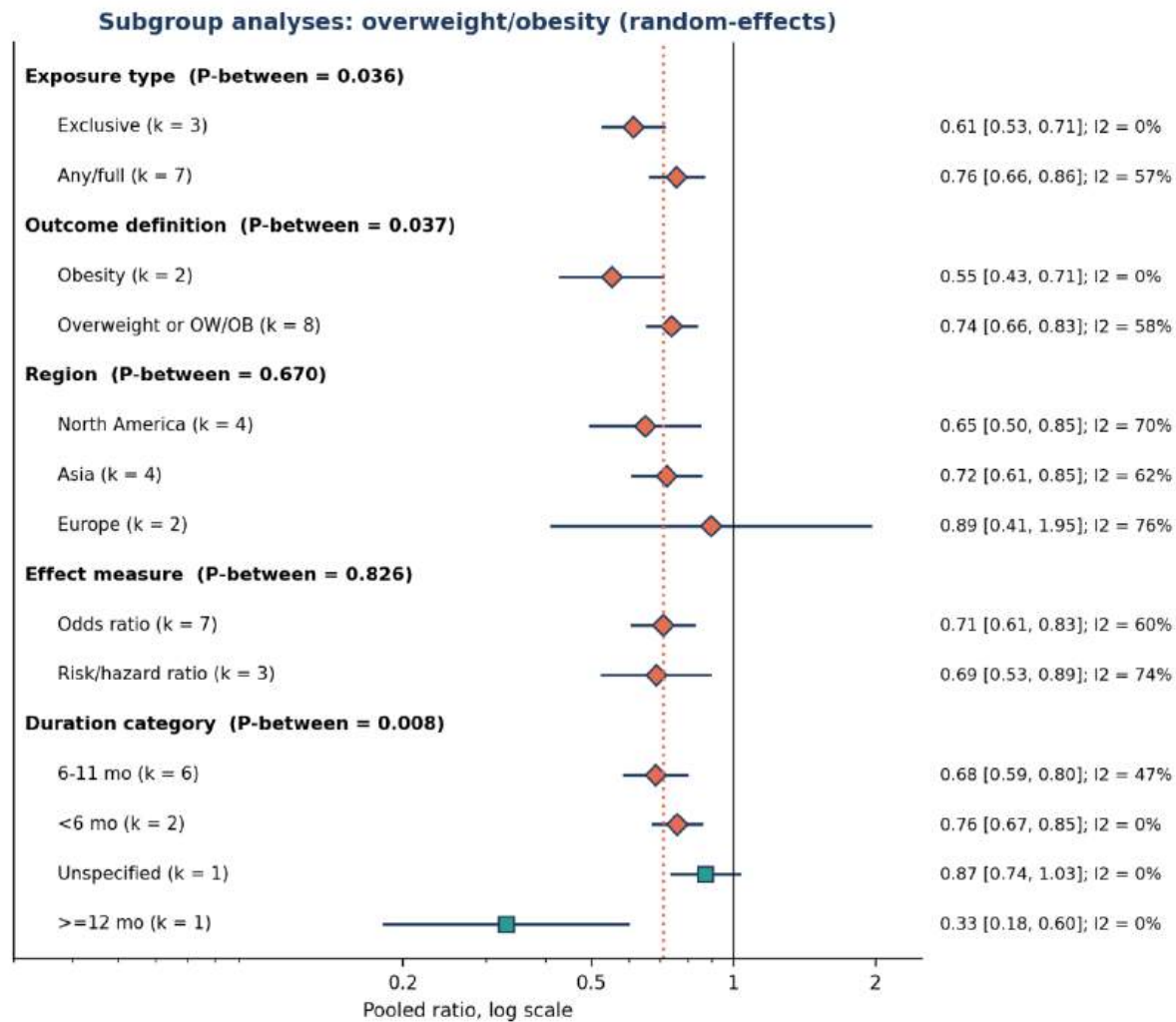


Figure 9. Subgroup analyses of the overweight/obesity meta-analysis by exposure type, outcome definition, region, effect measure and duration category.

Table 13. Subgroup analyses for overweight/obesity.

Subgroup	k	Pooled ratio (95% CI)	I ² (%)
Exposure type (Q-between = 4.40, df = 1, P = 0.036)			
Exclusive	3	0.61 (0.53–0.71)	0.0
Any/full	7	0.76 (0.66–0.86)	57.3
Outcome definition (Q-between = 4.35, df = 1, P = 0.037)			

Obesity	2	0.55 (0.43–0.71)	0.0
Overweight or OW/OB	8	0.74 (0.66–0.83)	58.4
Region (Q-between = 0.80, df = 2, P = 0.670)			
North America	4	0.65 (0.50–0.85)	70.2
Asia	4	0.72 (0.61–0.85)	61.9
Europe	2	0.89 (0.41–1.95)	76.5
Effect measure (Q-between = 0.05, df = 1, P = 0.826)			
Odds ratio	7	0.71 (0.61–0.83)	59.6
Risk/hazard ratio	3	0.69 (0.53–0.89)	74.3
Duration category (Q-between = 11.95, df = 3, P = 0.008)			
6-11 mo	6	0.68 (0.59–0.80)	46.9
<6 mo	2	0.76 (0.67–0.85)	0.0
Unspecified	1	0.87 (0.74–1.03)	0.0
≥12 mo	1	0.33 (0.18–0.60)	0.0

Sensitivity and influence analyses

The pooled estimate was stable across all sensitivity analyses (range 0.68–0.73; Table 16). Leave-one-out estimates ranged from 0.69 to 0.73 with every CI excluding unity; omission of Clayton et al. reduced I^2 to 49.8%, identifying this estimate (the only ≥12-month contrast) as the main contributor to heterogeneity (Figure 11). The cumulative meta-analysis showed that the direction and significance of the association were established by 2022 and that subsequent studies progressively narrowed the CI around 0.71 (Figure 12). The Galbraith plot showed no estimate outside the ± 2 standardised limits other than the ≥12-month estimate at the lower boundary.^{21,48}

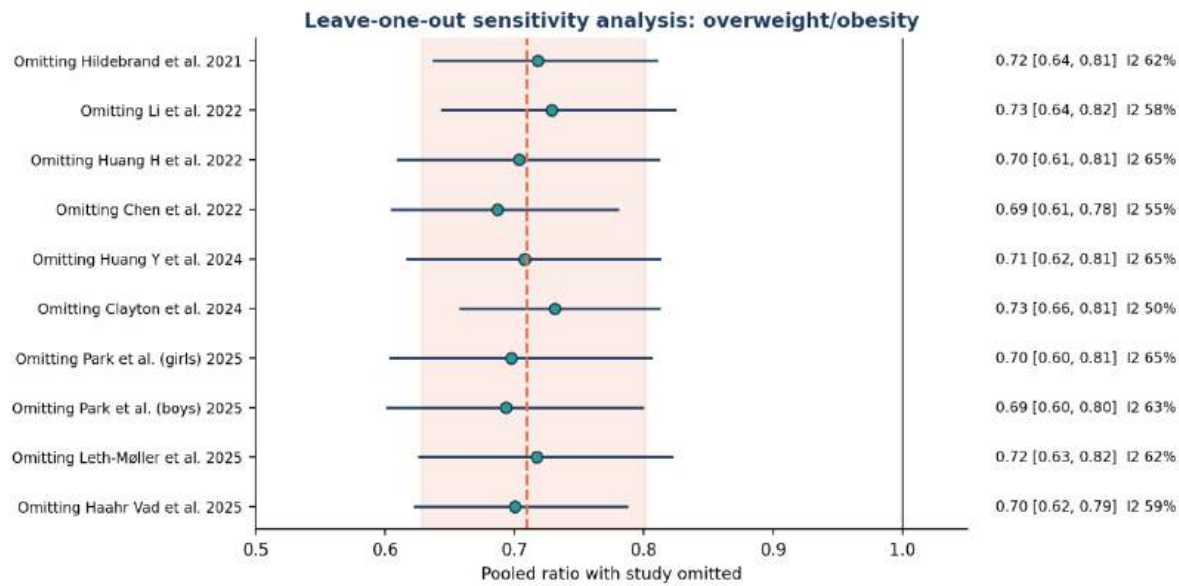


Figure 10. Leave-one-out sensitivity analysis for overweight/obesity; shaded band shows the 95% CI of the full model.

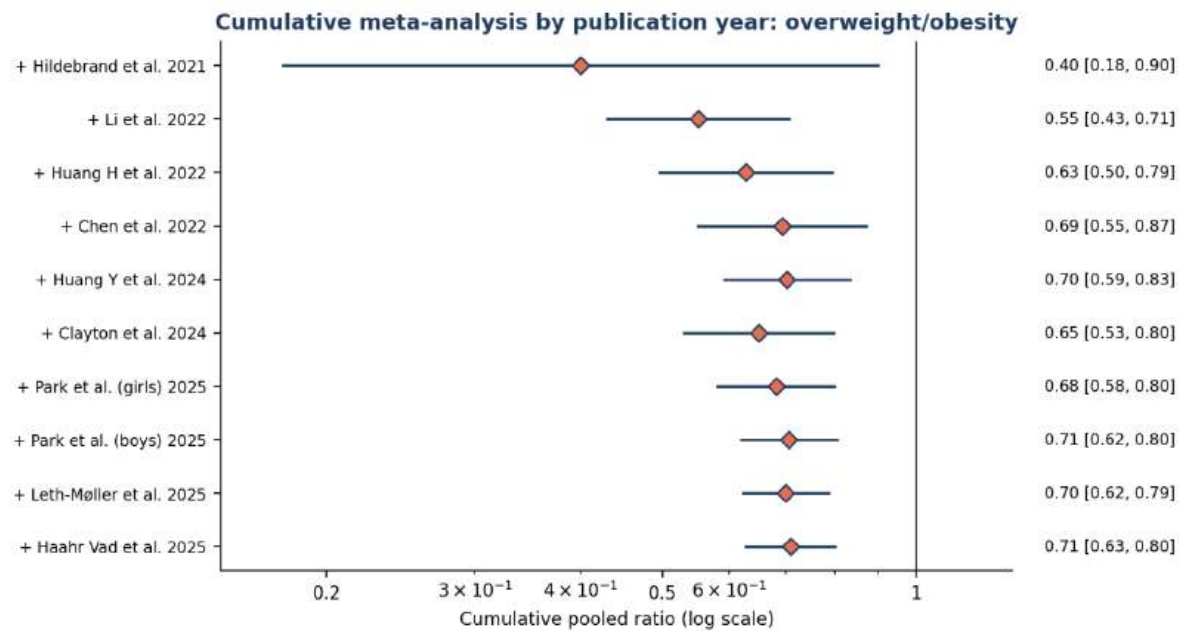


Figure 11. Cumulative random-effects meta-analysis for overweight/obesity ordered by year of publication.

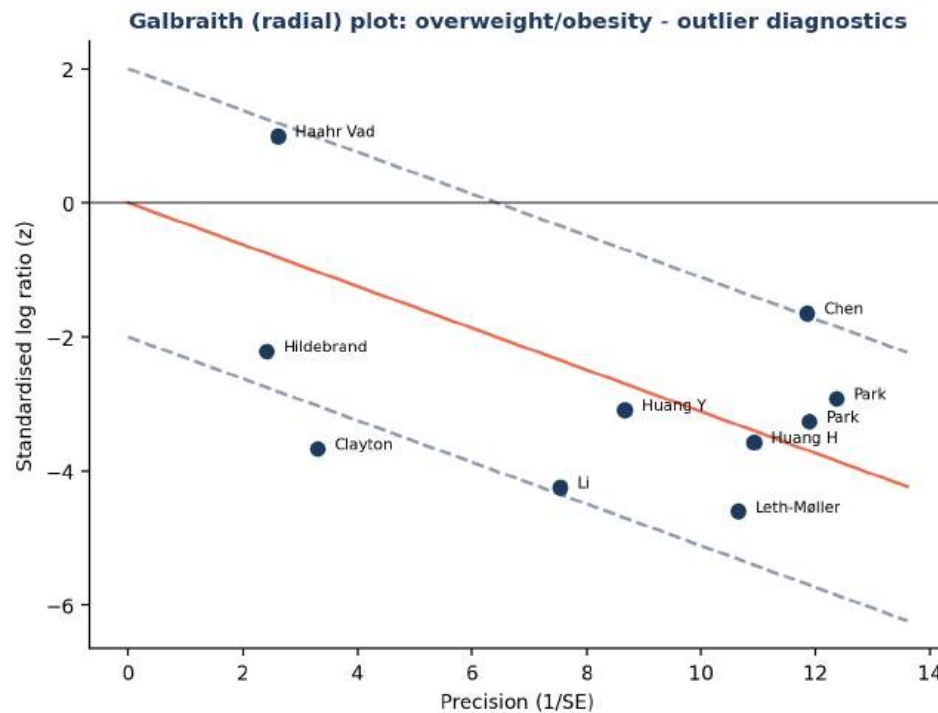


Figure 12. Galbraith (radial) plot for overweight/obesity estimates; dashed lines indicate ± 2 standardised units around the fixed-effect regression line.

Table 14. Sensitivity analyses for the overweight/obesity meta-analysis.

Analysis	k	Pooled ratio (95% CI)	I ² (%)
Adjusted estimates only	9	0.70 (0.62–0.79)	59.3
Odds ratios only	7	0.71 (0.61–0.83)	59.6
Excluding subgroup-only estimates (Chen, Huang Y)	8	0.68 (0.59–0.79)	61.0
Prospective/retrospective cohorts only	9	0.72 (0.64–0.81)	61.6
Huang Y et al. GDM stratum substituted	10	0.69 (0.61–0.79)	64.4
Fixed-effect (inverse-variance) model	10	0.73 (0.68–0.78)	60.8
Leave-one-out range	9 each	0.69–0.73	49.8–65.1

Trim-and-fill (1 study imputed right of mean)	11	0.73 (0.64–0.83)	—
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Small-study effects

The contour-enhanced funnel plot showed mild asymmetry, with the two smallest protective estimates (Hildebrand et al., Clayton et al.) located in the region of statistical significance. Neither Egger's test (intercept -1.48, SE 1.16; $P = 0.24$) nor Begg's test (Kendall $\tau = -0.47$; $P = 0.07$) was significant, although power with ten estimates is limited. Trim-and-fill imputed one estimate on the null side and yielded an adjusted ratio of 0.73 (0.64–0.83), leaving the conclusion unchanged.^{32,48}

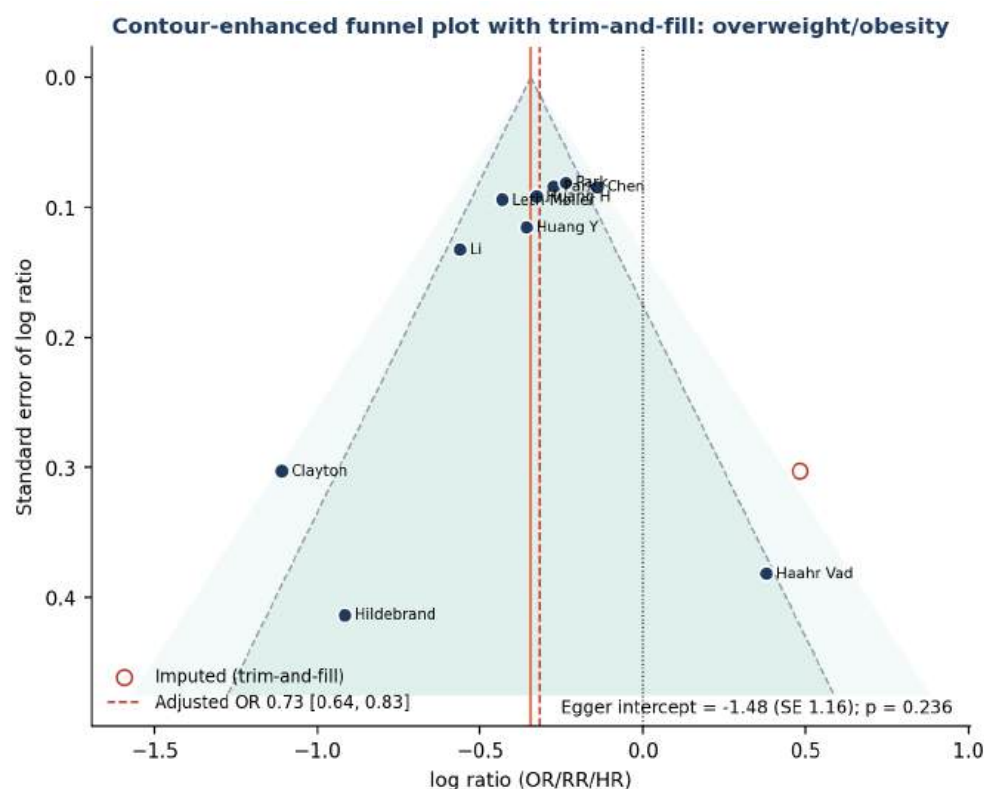


Figure 13. Contour-enhanced funnel plot with Duval–Tweedie trim-and-fill for overweight/obesity (shaded contours: $P < 0.05$ and $P < 0.01$ regions; open red circle: imputed estimate).

BMI and BMI z-score

All seven continuous estimates from five studies indicated lower BMI z-score with longer breastfeeding. The largest difference was reported for 6–12 versus 0–3 months of human-milk

feeding (-0.50 SD; Maskarinec et al.), and the smallest for per-month increments (-0.02 SD per month; AlTarrah et al.). In 8,134 dyads from 21 ECHO cohorts, three months of any breastfeeding was associated with lower BMI z-score among children of mothers with overweight (-0.04) or obesity (-0.04), and three months of exclusive breastfeeding with lower BMI z-score in children of mothers with healthy weight (-0.06) or obesity (-0.08). In GUSTO, short (≤ 4 months) breastfeeding was associated with higher BMI z-score ($+0.18$ SD) and skinfolds at 6 years, and short breastfeeding combined with early complementary feeding synergistically increased diastolic blood pressure and the metabolic-syndrome score. In NHANES, long-term breastfeeding was associated with 0.21 kg/m^2 lower BMI at 2–6 years, with larger differences in low-income households (-0.57).^{33,39,44,46–48}

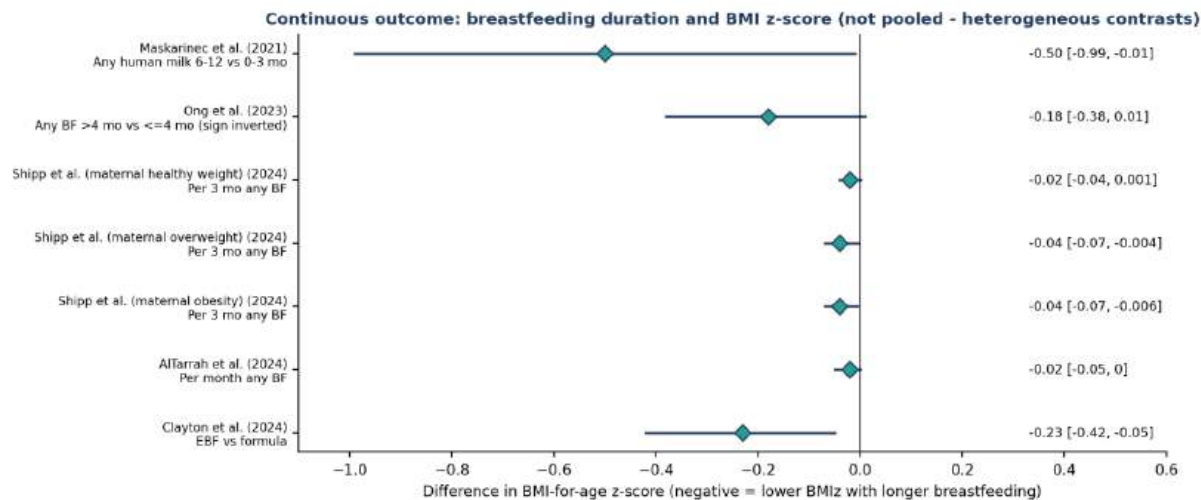


Figure 14. Coefficient plot of BMI z-score differences associated with longer breastfeeding (not pooled because contrasts differ).^{33,39,44,47,48}

Narrative synthesis of the remaining over-nutrition studies

Among studies not included in the pooled analysis, eight reported favourable associations: exclusive breastfeeding for at least four months halved overweight/obesity risk at 2–5 years in 2,515 Greek children; exclusive breastfeeding to four months lowered BMI z-score and obesity at six years, partly mediated by infant rapid weight gain; each additional month of full breastfeeding reduced obesity at 2–4 years by 3–5% among WIC participants, particularly after excessive

gestational weight gain; shorter breastfeeding predicted both early- and late-accelerating obesogenic BMI trajectories in Singapore; 3 to <6 months of exclusive breastfeeding was associated with lower BMI z-score at five years in Chile; breastfeeding for less than six months was associated with more overweight/obesity at 24 months in Spain; and longer breastfeeding was protective in Chinese and Indian clinical samples.^{36,40,42,43,49,53,55,56}

Four studies reported null or attenuated associations. In the six-country ToyBox study (n = 7,554; 3.5–5.5 years), associations disappeared after adjustment for socio-demographic and lifestyle factors; in the 3D Cohort, breastfeeding duration was associated with less rapid weight gain but not directly with excess weight at two years; in seven pooled Australian and New Zealand cohorts, the association of breastfeeding ≥ 6 months with lower overweight at 3–5 years was fully mediated by rapid infant weight gain; and in the Japanese IBACHIL cohort breastfed children had lower overweight prevalence at three years, but differences were not significant at six years. Collectively, these findings position infant rapid weight gain as a principal pathway, and they indicate that part of the crude association is explained by socioeconomic confounding.^{28,34,38,41,54}

Breastfeeding duration and under-nutrition

Meta-analysis of stunting

Five estimates were pooled. The overall random-effects estimate (0.49 (95% CI 0.08–3.17); $P = 0.45$) was accompanied by extreme heterogeneity ($Q = 244.6$, $df = 4$, $P < 0.001$; $I^2 = 98.4\%$; $\tau^2 = 4.35$) and an uninformative prediction interval. Four estimates — exclusive breastfeeding (Aceh Besar, Indonesia), breastfeeding ≥ 12 months (Southern Ethiopia), breastfeeding > 24 months (Yogyakarta, Indonesia) and breastfeeding ≥ 2 years (North Lombok, Indonesia) — were protective, whereas the pooled Ethiopian Demographic and Health Survey (EDHS 2000–2019; $n = 18,580$) found that breastfeeding into the third year was associated with markedly higher stunting (aOR 5.45, 4.83–6.15). Excluding this estimate, which compares children still breastfed at 24–36 months with those weaned earlier and is therefore susceptible to reverse causation, yielded a homogeneous protective association (0.27 (95% CI 0.19–0.38); $I^2 = 0\%$; 95% PI 0.12–0.59). Restriction to the three Indonesian studies gave 0.30 (95% CI 0.17–0.52) ($I^2 = 0\%$).^{22,30,57,58,62}

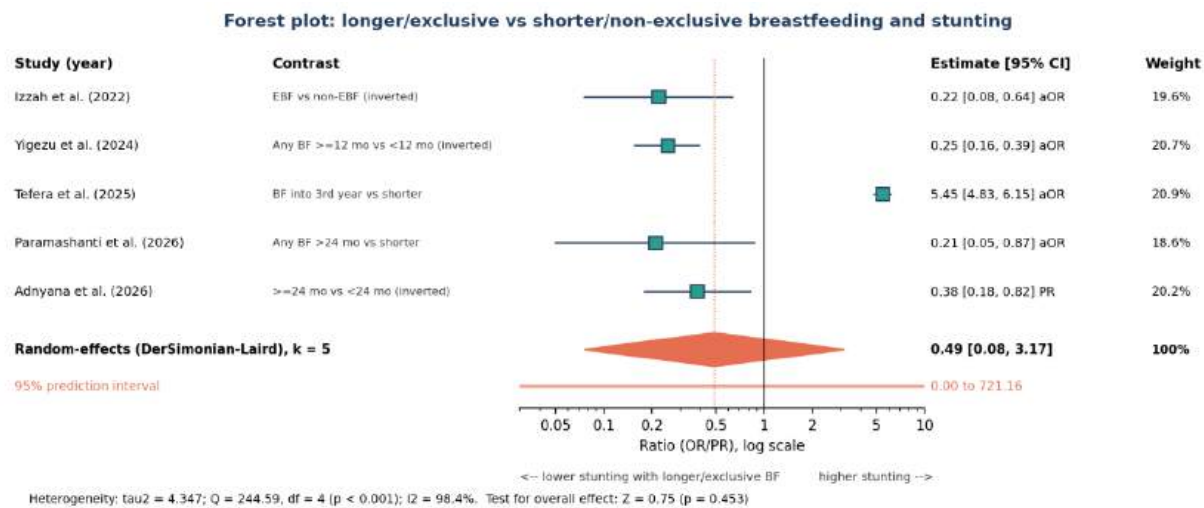


Figure 15. Forest plot of breastfeeding exposure and stunting (random-effects). Estimates from Izzah, Yigezu and Adnyana were inverted to express longer/exclusive versus shorter/non-exclusive breastfeeding.^{22,30,57,58,62}

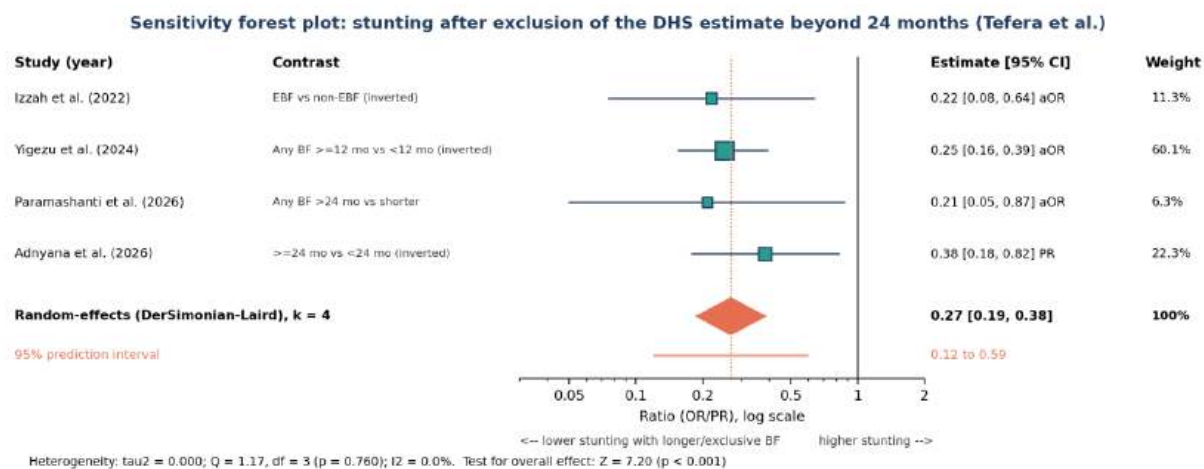


Figure 16. Sensitivity forest plot for stunting after exclusion of the Ethiopian DHS estimate for breastfeeding into the third year of life.^{30,57,58,62}

Leave-one-out analysis confirmed that heterogeneity was entirely attributable to the EDHS estimate (I² fell from 98.4% to 0% on its removal, whereas omission of any other study left I² above 96%). Substituting the 12–23-month estimate for the > 24 -month estimate from Paramashanti et al. did not materially change the overall estimate (0.46, 0.07–3.05). The funnel plot was markedly

asymmetric (Egger $P = 0.05$), but with five estimates this reflects between-study heterogeneity in design and context rather than interpretable publication bias.^{22,62}

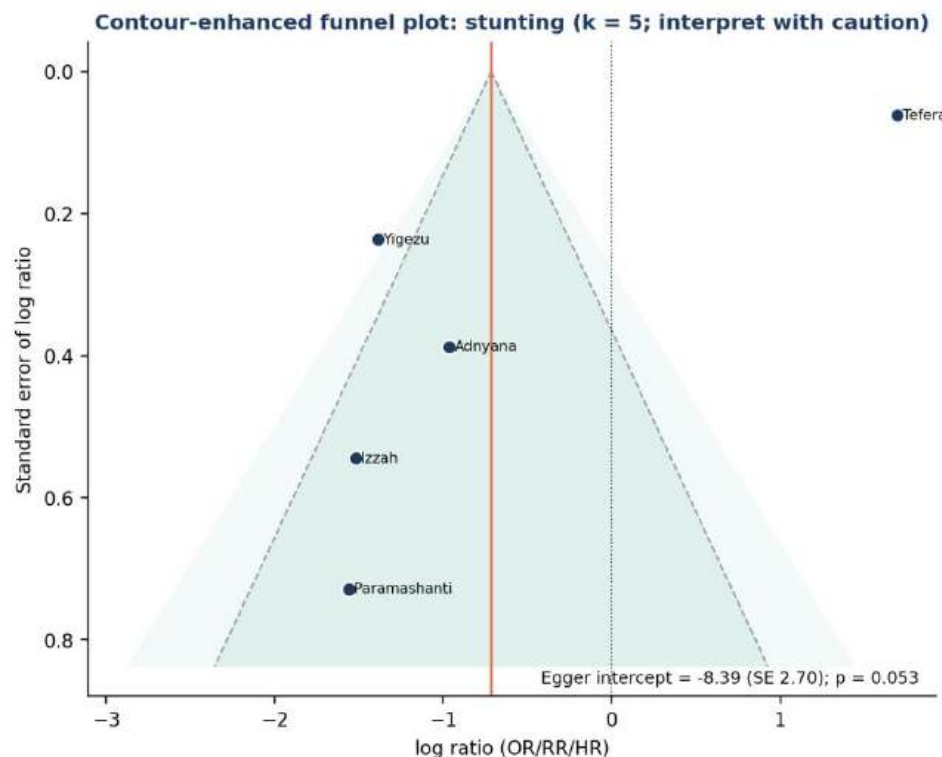


Figure 17. Contour-enhanced funnel plot for stunting (k = 5; tests for asymmetry are underpowered).

Narrative synthesis of stunting, underweight, wasting and double burden

Five further Indonesian studies of children aged 7–59 months consistently associated exclusive breastfeeding or breastfeeding to 24 months with less stunting: severe stunting was 22.0% versus 5.7% in non-exclusively versus exclusively breastfed children in East Kalimantan; exclusive breastfeeding history was associated with lower stunting in Aceh Besar (OR 0.285); breastfeeding until 24 months was strongly protective in a reproductive-health framework study (OR 0.089); and absence of exclusive breastfeeding to six months was associated with stunting in coastal East Java, where continued breastfeeding at 12–23 months was not. In contrast, the Indonesia Family Life Survey (IFLS-5; n = 2,701) found higher stunting among children breastfed 12–23 and >24 months,

mirroring the EDHS paradox. In Guatemala, continued breastfeeding from 12 to 23 months was among the factors most strongly associated with better linear growth in a clinical cohort of 2,352 stunted children, and in Saudi Arabia early introduction of other feeds before six months was associated with stunting.^{59–61,63–66}

For weight-based outcomes, the Tianjin birth cohort (n = 59,564) suggested that exclusive formula feeding might increase underweight at three and five years compared with exclusive breastfeeding, whereas breastfeeding in the first four months was unrelated to thinness in 8,053 Jiangsu children aged 3–6 years. In the EDHS, breastfeeding into the third year was associated with more underweight (aOR 1.55) but less wasting (aOR 0.50 for the third year; 0.75 for the second year). In urban Ghana, never breastfeeding (aOR 11.79) and non-exclusive breastfeeding (aOR 5.46) were strongly associated with child-level double burden of malnutrition.^{22,26,29,35}

Table 15. Evidence for underweight, wasting/thinness, normal weight and child-level double burden of malnutrition.

Outcome	Study	Exposure contrast	Result	Direction
Underweight	Li et al. 2022 ²⁹	Exclusive formula vs EBF (0–6 mo)	Higher underweight risk at 3 and 5 y with formula	Favours BF
Underweight	Tefera et al. 2025 ²²	BF into 3rd year vs 1st year	aOR 1.55 (1.41–1.70)	Unfavourable (reverse causation likely)
Thinness	Huang H et al. 2022 ³⁵	BF first 4 mo vs formula	No difference (P > 0.05)	Null
Wasting	Tefera et al. 2025 ²²	BF in 2nd / 3rd year	aOR 0.75 (0.67–0.83) / 0.50 (0.43–0.60)	Favours BF

Normal nutritional status	Feriani et al. 2026 ⁶³	EBF vs non-EBF	58.6% vs 38.0% normal status	Favours BF
Child-level DBM	Balapou et al. 2026 ²⁶	Never BF; non-EBF vs EBF	aOR 11.79 (2.68–51.84); 5.46 (2.13–14.00)	Favours EBF
Multiple forms	Alghofaili et al. 2026 ⁶⁶	Feeding other foods <6 mo	Associated with stunting; overweight linked to diet/lifestyle	Favours EBF (stunting)
Weight-for-age (RCT)	Brenøe et al. 2026 ³¹	Randomised BF promotion vs usual care	Higher WFA in infancy persisting to adolescence	Favours BF promotion

Synthesis across breastfeeding-duration categories

For overweight, obesity and BMI z-score, favourable associations were already apparent for 3–5 months (five of five overweight estimates and four of four BMI z-score estimates favourable) and persisted for 6, 6–11 and ≥ 12 months, with the largest single estimate for ≥ 12 months; null findings were concentrated in studies with smaller samples, unadjusted estimates or mediation by infant weight gain. The exploratory meta-regression suggested a decline of -0.026 log-units per additional month of breastfeeding (approximately 2.5% lower odds per month), which did not reach statistical significance ($P = 0.32$) (Figure 19a). For stunting, exclusive breastfeeding to six months was consistently favourable (five of five studies), whereas findings for ≥ 12 months diverged: five studies were favourable, two national surveys unfavourable and one null.^{22,45,48,50,59}

Table 16. Synthesis of effect estimates by harmonised breastfeeding-duration category.

Duration category	Stunting	Underweight / wasting / thinness	Overweight	Obesity	BMI / BMIz
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≤1 month	Reference in most studies	Reference	Reference (<1 mo: Huang Y)	Reference	Reference (<1 mo: Blanco)
3–5 months	No estimate	Thinness NS (Huang H)	Huang H 0.65 (0.53–0.80); Huang Y-LGA 0.66 (0.57–0.76); Park-boys 0.79 (0.67–0.92); Leth-Møller 0.65 (0.54–0.78); Mantzorou ~0.5	Nagore sig.; Usheva NS; Huang H NS	Shipp –0.04/3 mo; Ong –0.18; Blanco lower at 5 y; Michael favourable
6 months	Izzah 0.22 (0.08–0.64); Feriani, Wulandari (0.29), Khomisah, Alghofaili favourable	Li: formula ↑ underweight	Martín-Ramos favourable; Haahr Vad 1.46 (0.69–3.08); Zheng mediated	Hildebrand 0.40 (0.18–0.91); Li 0.57 (0.44–0.74)	No estimate
6–11 months	No estimate	No estimate	Huang Y-LGA 0.70 (0.56–0.88); Park-girls 0.76 (0.64–0.89)	Park-girls 0.66 (0.53–0.82)	Maskarinec –0.50 (–0.99 to –0.01); Sun –0.21

					kg/m ²
≥12 months	Yigezu 0.25 (0.16–0.39); Paramashanti 0.14 (12–23 mo), 0.21 (>24 mo); Adnyana 0.38; Indrasari 0.09; Alajajian favourable; Khomisah NS; Andarusukma ↑; Tefera 5.45 (4.83–6.15)	Tefera: underweight 1.55; wasting 0.50	Clayton 0.33 (0.18–0.59); Dubois NS at 2 y	No estimate	No estimate

Ratios oriented as longer versus shorter breastfeeding (values <1 favour longer breastfeeding); NS, not significant; ↑, higher risk with longer breastfeeding.

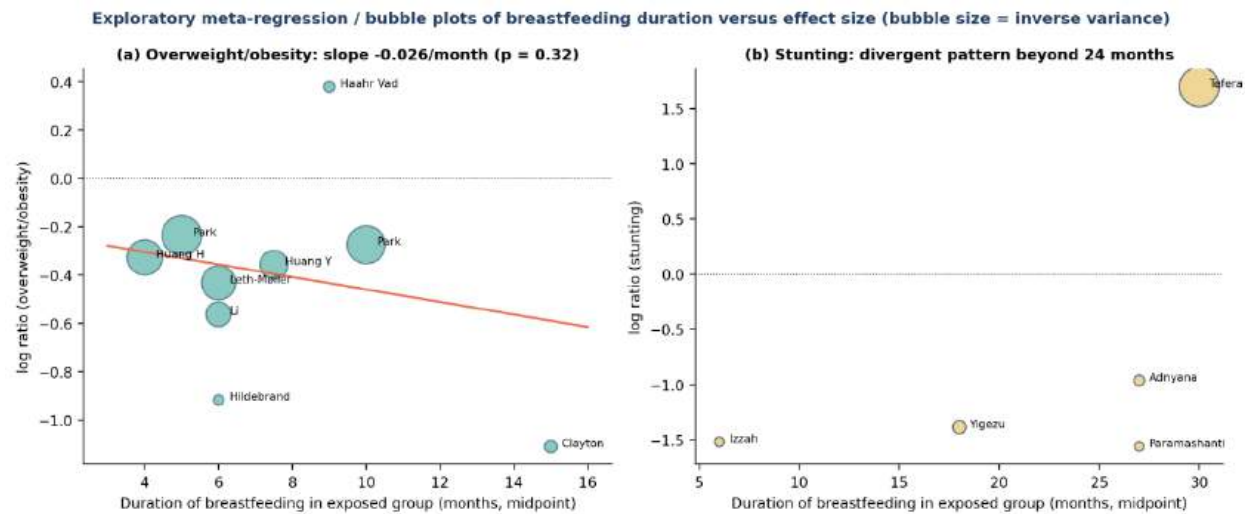


Figure 18. Exploratory meta-regression (bubble) plots of breastfeeding-duration midpoint versus log effect size for (a) overweight/obesity and (b) stunting; bubble size is proportional to inverse variance.

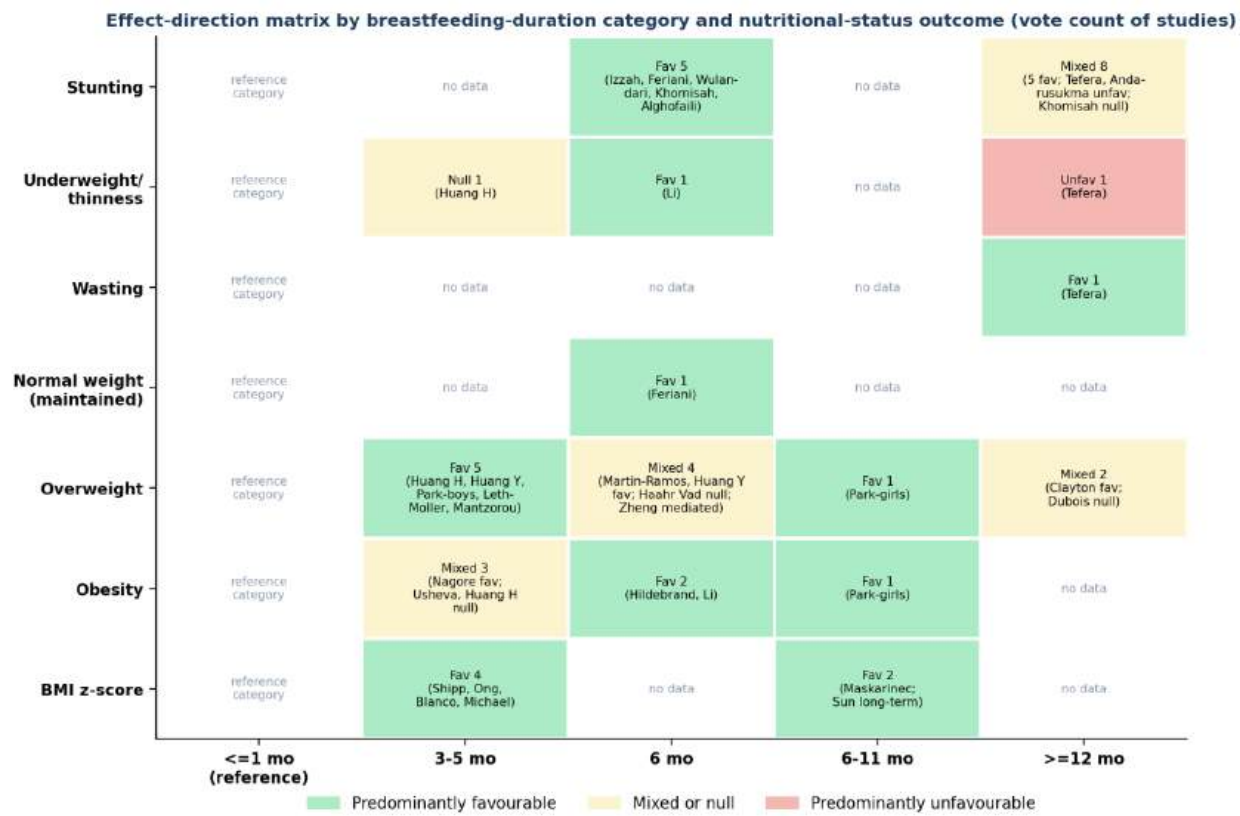


Figure 19. Effect-direction matrix summarising the number and direction of study findings by breastfeeding-duration category and nutritional-status outcome.

Randomised evidence

No new RCT randomising breastfeeding duration itself was identified, which is expected for ethical reasons. The only randomised source was a 2026 secondary analysis of PROBIT, the single large-scale cluster-randomised trial promoting prolonged exclusive breastfeeding. Assignment to the promotion intervention increased weight-for-age in infancy, with effects persisting through adolescence; mediation analysis attributed most of the early weight gain to a more calorie-dense diet (more breast milk and less water, juice and other liquids) rather than to reduced illness. The authors emphasised that effects of promotion depend on the local alternatives to breast milk. A 2023 meta-analysis of 32 randomised trials of exclusive-breastfeeding promotion likewise found improved exclusive breastfeeding rates but no effect on child growth up to seven years.^{31,67}

Certainty of evidence

Certainty was low for the association of longer breastfeeding with lower overweight/obesity, obesity and BMI z-score (observational evidence without serious downgrading; direction consistent across 9 of 10 estimates, robust sensitivity analyses), and very low for stunting, underweight/wasting and child-level DBM because of serious risk of bias, very serious inconsistency and imprecision.²⁵

Table 17. GRADE summary of findings: breastfeeding duration and nutritional status at 2–6 years.

Outcome	Studies (estimates); design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Relative effect (95% CI)	Certainty
Overweight/obesity	9 (10); cohort, cross-sectional	Not serious	Not serious (I ² 61%; 9/10 same direction)	Not serious	Not serious	Undetected	0.71 (0.63–0.80)	⊕⊕○○ LOW
Obesity	2 (2); cohort, cross-sectional	Not serious	Not serious (I ² 0%)	Not serious	Serious (few events)	Not assessable	0.55 (0.43–0.71)	⊕⊕○○ LOW
BMI z-score	5 (7); cohort, cross-sectional	Not serious	Not serious (7/7 negative)	Not serious	Not serious	Not assessable	–0.02 to –0.50 SD (not pooled)	⊕⊕○○ LOW

Stunting	5 (5); case-control, cross-sectional	Serious	Very serious (I ² 98%)	Not serious	Serious	Suspected	0.49 (0.08–3.17); excl. DHS 0.27 (0.19–0.38)	⊕○○○ VERY LOW
Underweight/wasting/thinness	3; cohort, survey	Serious	Serious	Not serious	Serious	Not assessable	Not pooled (mixed direction)	⊕○○○ VERY LOW
Child-level DBM	1; hospital cross-sectional	Serious	Not assessable	Serious	Very serious	Not assessable	Non-EBF aOR 5.46 (2.13–14.00)	⊕○○○ VERY LOW

DISCUSSION

Principal findings

This systematic review of 41 primary studies published between 2021 and 2026 found that longer breastfeeding was associated with a more favourable nutritional status among children aged 2–6 years, but that the strength and certainty of this association differed markedly between over-nutrition and under-nutrition. For overweight and obesity, the pooled estimate indicated about 29% lower odds with longer or any breastfeeding (0.71, 0.63–0.80), a stronger association for exclusive breastfeeding and for obesity, and a consistent reduction in BMI z-score. For stunting, exclusive breastfeeding to six months and continued breastfeeding into the second year were associated with

lower odds (0.27, 0.19–0.38), whereas national surveys in Ethiopia and Indonesia associated breastfeeding beyond 24 months with more stunting and underweight. Hypotheses H1 and H2 were therefore supported with low and very low certainty, respectively, and H3 was partially supported: the relationship with over-nutrition appeared monotonic, while the relationship with stunting was context-dependent beyond 24 months.^{22,45,51,57–59}

Comparison with previous systematic reviews and meta-analyses

Our pooled estimate for overweight/obesity (0.71) is strikingly close to the WHO-commissioned update by Horta et al. (0.73 across 159 studies) and lies between their overall estimate and the estimate restricted to studies at lower risk of residual confounding (0.85). Our review extends that evidence in two directions: it restricts inclusion to contemporary cohorts (2021–2026), many of which prospectively recorded feeding, and it shows that the association is apparent across duration categories rather than only for ever-versus-never contrasts, addressing the gap noted by the Dietary Guidelines Advisory Committee, which rated evidence on duration among ever-breastfed children as insufficient. The trajectory-based review by Zheng et al. reached a concordant conclusion, with 12 of 15 cohorts linking longer duration to lower BMI trajectories and between-group differences increasing with age.^{10–12}

For under-nutrition, our protective estimate after excluding the third-year DHS contrast (0.27) is stronger than the stunting estimates of Mardani et al. (0.73) and Azizah et al. (0.62), probably because our included studies contrasted well-defined exclusive or ≥ 12 -month exposures rather than ever breastfeeding, and because several were small case-control or cross-sectional studies prone to overestimation. The paradoxical association with prolonged breastfeeding reproduces the pattern described in the 2025 Indonesian systematic literature review by Widyantari et al., in which breastfeeding beyond 12 months in poor households was associated with increased stunting attributed to low dietary diversity, and is compatible with the Ethiopian meta-analyses in which breastfeeding duration and non-exclusive breastfeeding were determinants of stunting and wasting. Randomised trials of breastfeeding promotion, as summarised by Dib et al., did not demonstrate effects on growth, although PROBIT data show a durable effect on weight-for-age when breast milk displaces less energy-dense liquids.^{13–16,31,67,68}

Table 18. Comparison of the present findings with recent systematic reviews and meta-analyses (not included in the evidence tables).

Review	Scope	Key pooled result	Concordance with present review
Horta et al. 2022 ¹⁰	159 studies; BF and later OW/OB (mostly 1–9 y)	OR 0.73 (0.71–0.76); 0.85 in low-bias studies	Concordant (0.71); present review adds duration categories
Dewey et al. 2021 ¹¹	42 articles, high-HDI countries; sibling and RCT emphasis	Moderate evidence ever vs never; insufficient for duration	Present review provides duration-specific estimates, low certainty
Zheng et al. 2023 ¹²	3 RCT + 24 cohorts; BMI trajectories	12/15 cohorts: longer duration → lower trajectories	Concordant (7/7 BMIZ estimates negative)
Mardani et al. 2022 ¹³	33 studies, developing countries; undernutrition	Stunting OR 0.73 (0.55–0.95)	Direction concordant; larger effect for EBF/≥12 mo
Azizah et al. 2022 ⁶⁸	8 studies; BF and stunting	aOR 0.62 (0.41–0.94)	Concordant
Widyantari et al. 2025 ¹⁶	12 articles 2020–2025; 1000 days and stunting	EBF protective; BF >12 mo in poor households ↑ stunting	Concordant with DHS/IFLS paradox
Kassaw et al. 2024 ¹⁵	Wasting in Ethiopian <2 y	No EBF OR 5.30 for wasting	Concordant (EBF favourable)
Dib et al. 2023 ⁶⁷	32 RCTs of EBF promotion	EBF rates ↑ (OR 3.15); no effect on growth	Partly discordant; explains reliance on observational data

Talukder et al. 2026 ²	30 studies; household DBM in South/Southeast Asia	Breastfeeding protective against household DBM	Concordant with child- level DBM finding
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The paradox of prolonged breastfeeding and stunting

Three observations argue that the positive association between breastfeeding beyond 24 months and stunting is not causal. First, the association was observed in cross-sectional national surveys (EDHS, IFLS) in which current or recalled breastfeeding status is measured at the same time as height, so that mothers of small, frequently ill children may continue breastfeeding precisely because the child is perceived as vulnerable (reverse causation). Second, in the same EDHS data, breastfeeding in the second and third years was associated with *less* wasting, the acute form of undernutrition most directly responsive to energy intake, which is difficult to reconcile with a harmful effect of human milk. Third, in settings where analyses accounted for household economic status and birth length, or followed children longitudinally, continued breastfeeding to 12–24 months was protective against stunting and positively associated with linear growth.^{22,59,62,65}

Complementary-feeding adequacy is the most plausible effect modifier. After six months, breast milk alone cannot meet requirements for energy, iron, zinc and protein; children who continue to breastfeed but receive monotonous, carbohydrate-based complementary foods are at risk of faltering. Korean children breastfed beyond 12 months had lower protein, calcium and iron intake per calorie and lower weight gain, Vietnamese survey data showed that continued breastfeeding reduced underweight while minimum dietary diversity was the key determinant of stunting, and in the Guatemalan cohort food insecurity and small portion sizes were negatively associated with linear growth. The policy message is therefore not to shorten breastfeeding, but to ensure that continued breastfeeding is accompanied by diverse, nutrient-dense complementary foods.^{16,65,69,70}

Duration–response and critical windows

Across studies, protective associations with over-nutrition were already present with 3–5 months of breastfeeding: exclusive breastfeeding for more than four months in Danish routine data neutralised the excess overweight risk associated with accelerated infant growth; full breastfeeding

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for 3–5 months lowered early-childhood overweight among large-for-gestational-age infants in Hangzhou; and three months of any or exclusive breastfeeding lowered BMI z-score across maternal BMI strata in ECHO. Associations were at least as large at 6–11 and ≥ 12 months, and the exploratory meta-regression suggested roughly 2.5% lower odds per additional month, consistent with the graded dose–response in the WIC data (3–5% lower obesity risk per month of full breastfeeding).^{42,44,45,51}

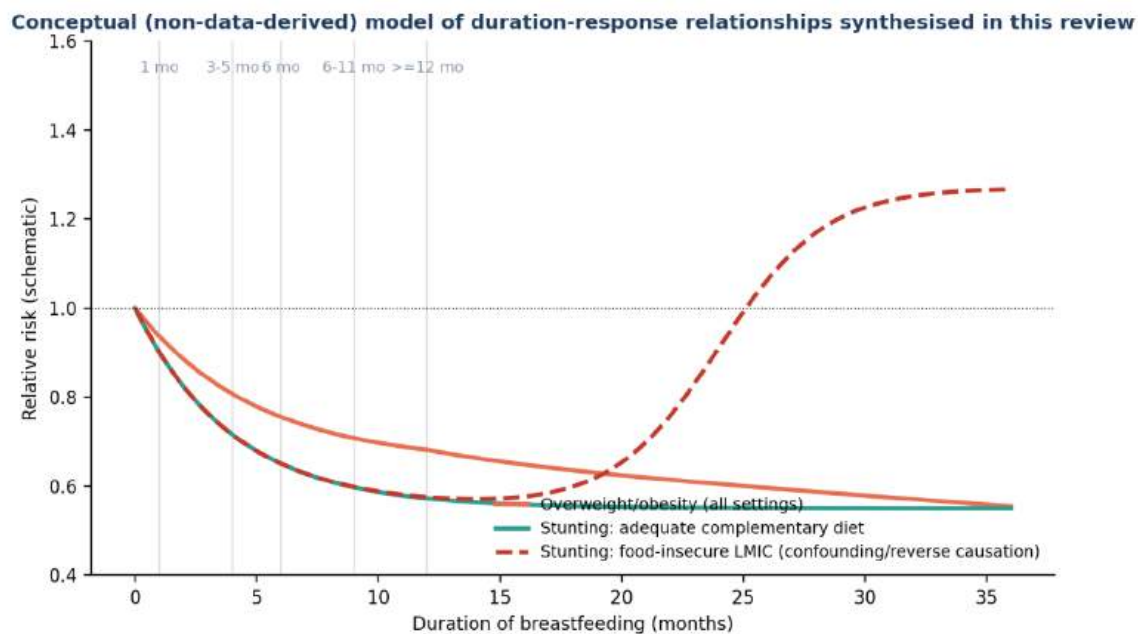


Figure 20. Conceptual model (schematic, not fitted to data) of the duration–response relationships synthesised in this review: a monotonic decline in overweight/obesity risk and a protective association for stunting when complementary diets are adequate, contrasted with an apparent rise in stunting beyond 24 months in food-insecure settings driven by confounding and reverse causation.

Sex-specific findings merit attention. In the US ECLS-B cohort, breastfeeding for eight months or longer reduced transitions into overweight and obesity among girls in a dose–response manner, whereas among boys the benefit was observed for 3–7 months but breastfeeding did not facilitate exit from elevated body mass. School-age data from the ABCD study showed the opposite pattern (benefit confined to boys), suggesting that sex differences may be age-dependent and should be examined in future pooled cohorts.^{50,71}

Biological mechanisms

The early protein hypothesis is supported by randomised evidence: infants fed lower-protein formula had lower BMI trajectories to 11 years and a BMI at adiposity rebound similar to breastfed infants, whereas higher protein intake increased overweight at 11 years. Breast milk, with its lower protein content, is expected to lower circulating IGF-1 and insulin and thereby limit adipogenesis; the mediation of breastfeeding effects by rapid infant weight gain observed in the Australian/New Zealand pooled cohorts, the Spanish cohort and the Danish data is consistent with this pathway.^{1,20,41,51,53}

Bioactive milk components provide additional pathways. HMO composition has been associated with height and weight over the first five years, and higher HMO diversity and sialylated HMOs were inversely associated with early adiposity rebound in the Tohoku Medical Megabank cohort. HMOs act as prebiotics that favour *Bifidobacterium*-dominant microbiota and short-chain fatty acid production, while milk leptin and adiponectin may programme appetite regulation. Anti-infective factors reduce diarrhoeal and respiratory morbidity, which in LMIC contributes to protection against stunting and wasting, although the PROBIT mediation analysis attributed early weight gain mainly to greater caloric intake rather than reduced illness.^{17–19,31,72,73}

Effect modification by maternal and perinatal factors

Several contemporary cohorts suggested that breastfeeding benefits may be greatest in children at high baseline risk. Protective associations were larger among infants exposed to gestational diabetes (aOR 0.58 for >6 months) and among large-for-gestational-age infants; each month of full breastfeeding produced greater obesity-risk reductions after high gestational weight gain; and breastfeeding lowered BMI z-score in children of mothers with overweight or obesity, a group in which breastfeeding duration is typically shorter. Maternal pre-pregnancy BMI also modified the association at 24 months in Spain. These findings argue for targeted lactation support for mothers with obesity or gestational diabetes.^{37,41,42,44,45,49}

Socioeconomic context modified associations in both directions. The inverse association of breastfeeding with BMI was stronger in low-income US households, whereas in European and Swedish cohorts the association was attenuated after adjustment for socio-demographic factors,

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illustrating the potential for positive confounding by socioeconomic status in high-income settings and negative confounding in LMIC, where the poorest mothers breastfeed longest.^{22,28,46,52}

Persistence into school age

Although this review focused on 2–6 years, the title question concerns long-term associations, and evidence excluded from the main synthesis because outcomes were measured only at school age is informative. In 10,753 Chinese children aged 6–16 years, breastfeeding for more than 12 months was associated with lower BMI in boys; in Brazilian schoolchildren the protective association was confined to 7–10 years; in the ABCD study, breastfeeding beyond six months was associated with healthier BMI trajectories and lower unhealthy weight risk at 11–12 years in boys and with lower adiposity in children from deprived neighbourhoods. Conversely, a Portuguese cohort found no association at ten years, the Japanese IBACHIL cohort found attenuation after three years, and a Chinese national survey associated prolonged breastfeeding with higher metabolic-syndrome risk in adolescents born small for gestational age. The balance suggests that associations established in the preschool window partly persist into school age, but with attenuation and effect modification.^{34,52,71,74–78}

Table 19. Evidence on persistence of associations into school age and adolescence (studies outside the 2–6-year eligibility window or with long follow-up).

Study	Population / age	Principal finding	Interpretation
Liu F et al. 2022 ⁷⁴	10,753; 6–16 y; China	BMI β –0.44 for BF >12 mo in boys	Persistent benefit, male-specific
Wagner et al. 2021 ⁷⁵	Schoolchildren 7–14 y; Brazil	OW/OB OR 0.54 at 7–10 y; null at 11–14 y	Attenuation with age
Esaian et al. 2026 ⁷¹	4,161; 9–12 y; USA (ABCD)	BF >6 mo: RR 0.52 unhealthy weight in boys	Persistent, male-specific
Rajagopalan et al. 2024 ⁷⁶	7,511; 9–10 y; USA (ABCD)	Lower BMIz, waist and WHtR with longer BF	Stronger in deprived neighbourhoods
Roldão et al.	0–10 y; Portugal	No relation with OW/OB	Null long-term

2024 ⁷⁷		at 10 y	
Sata et al. 2021 ³⁴	3–22 y; Japan	Benefit at 3 y, not at 6–22 y	Attenuation
Haahr Vad et al. 2025 ⁵²	4–16 y; Sweden	No association with BMI trajectory	Null
Yuan et al. 2024 ⁷⁸	10,275; 7–18 y; China	Prolonged BF ↑ MetS, esp. SGA	Possible harm in SGA subgroup

Relevance to Indonesia and other double-burden settings

Eight of the 41 included studies were Indonesian, reflecting the national priority on stunting reduction. These studies consistently associated exclusive breastfeeding with less stunting, but the national IFLS-5 survey reproduced the prolonged-breastfeeding paradox, and analyses of the 2022 Indonesian Nutritional Status Survey found maternal education, antenatal care and low birth weight to be stronger determinants of stunting than early breastfeeding practices among children aged 6–23 months. Exclusive breastfeeding was associated with lower odds of household-level DBM in the 2024 survey, and breastfeeding was protective against household DBM across South and Southeast Asia. Programmes should therefore integrate breastfeeding support with maternal nutrition, prevention of low birth weight, complementary-feeding counselling and WASH interventions.^{2,24,30,57,59,62,79,80}

Clinical and public-health implications

For clinicians, the evidence supports counselling that each additional month of breastfeeding, and particularly exclusive breastfeeding for about six months, is associated with lower risk of preschool overweight and obesity, with benefits already apparent after 3–5 months; mothers who cannot sustain exclusive breastfeeding should be encouraged to continue partial breastfeeding. Growth monitoring should flag rapid weight gain in infancy, which appears to be the main mediating pathway. For children breastfed beyond 12–24 months in food-insecure households, clinicians should assess dietary diversity, meal frequency and protein- and iron-rich foods rather than recommend weaning. At policy level, the evidence reinforces full implementation of the

International Code of Marketing of Breast-milk Substitutes, paid maternity leave and workplace lactation support, which address the structural barriers identified by the 2023 *Lancet* Series (Table 22).^{4,5,7,41,51}

Strengths

Strengths include the contemporary five-year evidence window, the integrated treatment of the full nutritional-status spectrum, explicit harmonisation of exposure categories, orientation of all effect measures, comprehensive sensitivity analyses (leave-one-out, cumulative, trim-and-fill, alternative strata, fixed-effect), dual appraisal frameworks (ROBINS-E-adapted and NOS), GRADE rating and verification that every included record is retrievable online through Consensus with a DOI.^{21,23}

Implications for research

Future studies should (i) record feeding prospectively with standard WHO infant and young child feeding indicators and report estimates for harmonised duration categories (≤ 1 , 3–5, 6, 6–11, 12–23, ≥ 24 months); (ii) use causal designs such as sibling comparisons, instrumental variables, target-trial emulation and follow-up of breastfeeding-promotion trials; (iii) jointly model stunting and overweight to capture the double burden at child level; (iv) measure complementary-feeding adequacy and food insecurity as effect modifiers; (v) examine sex, maternal BMI, gestational diabetes and birth size as modifiers; and (vi) extend follow-up from the preschool period into school age with body-composition measures.^{12,31,81}

CONCLUSION AND RECOMMENDATIONS

Conclusion

In children aged 2–6 years, longer breastfeeding — particularly exclusive breastfeeding — is associated with approximately 30% lower odds of overweight/obesity and with lower BMI z-score, with benefits evident from 3–5 months and extending beyond 12 months (low-certainty evidence). Exclusive breastfeeding to six months and continued breastfeeding into the second year are associated with lower stunting, whereas higher stunting and underweight with breastfeeding beyond 24 months in food-insecure settings most likely reflects reverse causation and inadequate complementary feeding (very low-certainty evidence). Breastfeeding thus behaves as a double-duty

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action whose benefit against under-nutrition depends on the adequacy of the complementary diet.^{10,22,51,65}

Recommendations

Table 20. Recommendations for clinical practice, public-health policy and research.

Domain	Recommendation	Supporting evidence
Clinical practice	Promote exclusive breastfeeding for 6 months and continued breastfeeding with appropriate complementary feeding; emphasise that even 3–5 months confers benefit	Pooled OR 0.71; EBF 0.61; 3–5-month estimates favourable
Clinical practice	Provide intensified lactation support for mothers with obesity, gestational diabetes or LGA infants	Huang Y 2024; Shipp 2024; Matias 2023
Clinical practice	Monitor infant weight velocity; address rapid weight gain	Mediation in Zheng 2023, Leth-Møller 2025, Nagore 2025
Clinical practice	For children breastfed >12–24 months with growth faltering, assess and improve dietary diversity rather than advise weaning	Tefera 2025; Andarusukma 2025; Alajajian 2026
Public health	Integrate breastfeeding promotion in stunting- and obesity-prevention programmes (double-duty actions), with WASH and maternal nutrition	Paramashanti 2026; Balapou 2026; Talukder 2026
Policy	Enforce the International Code of Marketing of Breast-milk Substitutes; extend paid maternity leave and workplace lactation facilities	Rollins 2023; Baker 2023; Horwood 2024

Research	Prospective cohorts with harmonised duration categories, joint modelling of stunting and overweight, causal designs, follow-up into school age	GRADE low/very low certainty
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