Systematic Review

Effectiveness of early-childhood nutrition and supplementation programs on cognitive development and stunting

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Abstract:

Background: Early childhood, particularly the first 1,000 days, is a critical period for brain development and physical growth. Malnutrition during this stage can lead to long-term impairments in cognitive function and linear growth. Despite widespread implementation of nutrition and supplementation programs, their long-term effectiveness remains inconsistent, particularly in low- and middle-income countries

Objectives: To systematically evaluate the effectiveness of early-childhood nutrition and supplementation programs on cognitive development and stunting among children aged 0–5 years

Methods A systematic search of PubMed and Google Scholar was conducted for studies published since 2011. Eligible studies included randomized controlled trials, cluster-randomized trials, quasi-experimental studies, and cohort studies involving children aged 0–5 years. Interventions included macronutrient supplementation, micronutrient supplementation, fortified foods, and integrated programs combining nutrition with stimulation or education. Primary outcomes were cognitive development and stunting; secondary outcomes included underweight, wasting, motor development, anemia, and micronutrient status. Fourteen studies were included**.**

Results: out of the 9,248 screened records, 20 studies were included according to the inclusion criteria. Dental caries (RR: 1.45-2.10) and obesity (RR: 1.20-1.35) were always related to the high levels of free sugar. There was an increase in the risk of periodontitis (OR: 1.29, 95% CI: 1.17-1.42) and T2D risk (HR: 1.44, 95% CI: 1.29-1.62) with the consumption of ultra-processed food. Mechanistic evidence supported the existence of a bidirectional relationship with periodontitis and diabetes (GRADE: Moderate-High). Defensive dietary habits (Mediterranean, DASH) proved to be beneficial in terms of results. Combined measures were to use sugar-sweetened drinks taxation, combined dietary-fluoride, and coordinated clinical screening.

Conclusions: Early-childhood interventions are most effective when nutrition is combined with psychosocial stimulation and sustained behavioral support. Isolated micronutrient supplementation has limited impact on long-term cognitive and growth outcomes. Integrated, long-term strategies are essential for achieving meaningful improvements in child development

Keywords: early childhood, nutrition, supplementation, cognitive development, stunting, linear growth, micronutrients, early childhood development, malnutrition.

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Introduction:

The most sensitive phase of cognitive development and human growth is early childhood. This phase lays a foundation for learning abilities, emotional wellbeing, motor skills and biological growth.[1] The first one thousand days in particular and five 5 years of life of an infant in general are the most critical pertaining to his neuronal development, generation of synapses, growth of hippocampus and myelination of neurons. If malnutrition occurs at this stage it has long term consequences on the cognitive development and linear growth of child.[2] Malnutrition is classified into undernutrition, over nutrition and micronutrient deficiencies. Undernutrition is further categorized as stunting, wasting and underweight.[3] Stunting is defined as height for age Z score less than -2 standard

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deviations and it is the most important indicator for labelling chronic malnutrition. It reflects long term effects of poor nutrition, prolonged infections or other stresses from environment[4]. Evidence suggests that if supplementation or nutrition interventions are introduced early in life, they can have positive impacts on child's growth and development[5]Micronutrients plays pivotal role in the synthesis of neurochemicals, transport of oxygen in body, metabolism of DNA and RNA, regulations of epigenetics and signaling of neurons.[6] Globally anemia is majorly caused by iron deficiency which affects memory, focus, processing, metabolism of serotonin and dopamine and motor development[7]. Zinc plays a key role in synthesis of neurons, regulation of appetite, immunity and growth of cells Zinc plays a key role in synthesis of neurons, regulation of appetite, immunity and growth of cells.[8] Folic acid has its role in neuronal development and RBC production.[9] For thyroid hormone synthesis iodine is required. Thyroid hormones regulate differentiation of neurons, cognition while its deficiency leads to intellectual impairment that is preventable by management of deficiency.[10] According to WHO, globally 149 million children under five years of age were found to be stunted in 2022, 45 million were wasted and 37 million were overweight or obese. The national nutrition survey of Pakistan found that 40.2% children under five years had stunting, 17.7% had wasting, 28.9% were underweight and 9.5% were overweight.[11] In Punjab the burden of stunting, wasting, underweight and overweight was found to be 36.4%, 15.3%, 23.5% and 9.9% respectively. A healthy child has an integral role in the health status of society. Keeping it in consideration, several organizations are working to reduce the burden of malnutrition. The sustainable development goal 2 targets for zero hunger by year 2030. WHO targets for 40% reduction in stunting in children under five years by 2025. World Bank emphasizes the need of addressing malnutrition as a fundamental investment of a country.[12] National programs like Benazir Nashonuma program distribute fortified foods such as wheat soya blends for lactating and pregnant women.[13] Similarly fortified foods also provided to children but literature suggests stimulation integration should be done with nutrition supplementations programs for effective results.

This systematic review is needed because existing evidence shows inconsistent long-term reduction in stunting and limited translation of biochemical improvements into sustained cognitive and linear-growth gains when early-childhood nutrition interventions are delivered alone or for short durations, while psychosocial stimulation shows stronger sustained cognitive benefit highlighting a gap on how early, integrated, and community-delivered interventions truly influence durable child development outcomes.

Methodology:

Search Strategy:

Literature search was conducted on PubMed and Google Scholar using combinations of the keywords: early childhood, nutrition, supplementation, macronutrients, micronutrients, cognitive development, neurodevelopment, stunting, and linear growth. To refine the search Boolean operators (AND/OR/NOT) were used.

Inclusion and Exclusion Criteria:

We included all the studies published since year 2011 in English language, availability of free full text, studies on Humans. the included study designs were Randomized controlled trials (RCTs), Quasi-experimental studies, Cohort studies. The studies done on pregnant women and those focused on clinical treatment of malnutrition in hospitals were excluded. The studies included in the final review had following characteristics: population was children from birth to 5 years in lower middle income countries, intervention was early childhood nutrition or supplementation (iron, zinc, vitamin A, multiple micronutrients, fortified foods, lipid-based nutrient supplements) programs, primary outcome was cognitive development and linear growth. Cognitive development was reported as IQ level, Developmental scores (Bayley, Denver, Griffiths, etc.), Language development, School readiness / executive function. Height-for-age Z score (HAZ), Prevalence of stunting (< -2 SD) or linear growth were used to report stunting. Secondary Outcomes included: Underweight, Wasting, Motor development, Behavioral changes, Anemia, Micronutrient deficiencies (iron, zinc, vitamin A).

Interventions were categorized into four categories: Macronutrient interventions (Complementary feeding, Protein-energy supplementation), Micronutrient supplementation (Iron, Zinc, Vitamin A, Multiple micronutrient powders), Fortification interventions (Fortified cereals, milk, blended foods), Integrated programs (Nutrition and stimulation, Nutrition and health education).

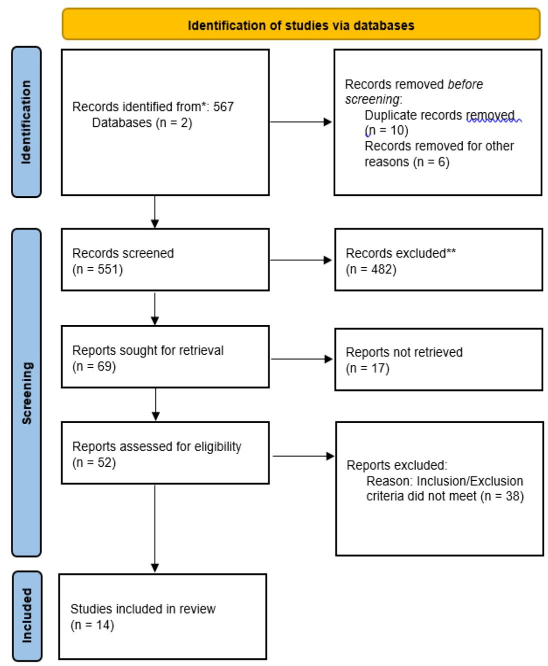

Figure 1: Prisma Flow Diagram

Data Extraction:

Study characteristics comprised of first author name, year of publication, country, study design, sample size, and age of the enrolled children. Intervention details included the type of supplementation or nutrition intervention, the dose administered, duration of the intervention, and the method of delivery of intervention including home based or school based. Outcome variables were cognitive scores, height-for-age z-scores and prevalence of stunting.

Sr No.	First author, year and	Study design	Country	Age range enrolled	Total study population	Intervention	Intervention dose and formulation	Intervention duration and frequency	delivery method	Control Control dose	Outcome
1.	Rao et al., 2017 [14]	Systematic review + Meta-analysis (multilevel meta-regression)	30 developing countries (pooled evidence; Hong Kong institution as base)	<8 years (participants across included trials were below 8 years)	43,696 children from 62 studies (106 interventions, 586 effect sizes)	ECD programs: Comprehensive, child stimulation/education, parent support, income supplementation, nutrition/health	Not applicable (meta-analysis of programs; no single clinical dose)	Varied (studies published 1992–2012; program durations ranged 3–30+ months depending on trial)	Mostly home-, community-, or center-based infrastructure	Comparison groups varied (concurrent or pre-post depending on trial)	Most effective: Comprehensive (g=1.05); Child-focused education/stimulation (g=0.64); Parent-focused (g=0.44); Income supplementation (g=0.23); Nutrition/health (g=0.11).

											Overall benefit strongest for school readiness (g=1.13, p<0.0001). No durable cognition/schooling effect from nutrition alone in most follow-ups.
2.	Marisol Warthon-Medina, Year: 2015 [15]	Randomized controlled trial	Peru	6 to 17 months	902 infants	Multiple micronutrient supplementation,	12.5 mg iron, 10 mg zinc gluconate, 160 µg folic acid, 30 mg vitamin C, and 300 µg vitamin A	6 months daily supplementation,	Community Health workers visited homes	Iron supplementation, Control dose: 12.5 mg iron	no significant difference in cognitive or behavioral outcomes between the two groups. Although some gender-related differences

											were observed, these were not statistically significant after correction, indicating no added cognitive benefit of MMN over iron supplementation.
3.	Ansuya, 2023[16]	Randomized controlled trial	India	3 to 5 years	253 participants	Nutrition-focused intervention	Mothers were asked to prepare nutritious food daily (or at least four times per week)	12 months	Home-based, with mothers maintaining a diary and receiving follow-up support	Standard care without the nutrition intervention	Significant improvement in cognitive development scores in the intervention group compared to the control

											group ($p < 0.001$).
4.	Harahap, D. A. et al., 2025 (2025)[17]	Quasi-experimental design using a longitudinal cohort method	Indonesia	6 months – 6 years	128 children Intervention group: 65 Control group: 63	Integrated nutritional intervention package, consisting of: Micronutrient supplementation Dietary diversification Maternal nutrition education	Vitamin A: 100,000–200,000 IU Iron: 12.5 mg/day Zinc: 5–10 mg/day Folic acid: 150 mcg/day Mother Education	Total duration: 18 months Frequency: Vitamin A: Biannual Iron, Zinc, Folic acid: Daily Dietary diversification education: Monthly Maternal nutrition education sessions: Monthly	Community-based delivery	Control group received standard community care / routine health services	$p = 0.047$ (significant) Conclusion: Significant reduction in stunting prevalence in intervention group.
5.	Attanasio	Cluster rand	Colombia	12 – 24 mont	96 clusters/com	Psychosocial stimula	Psychosocial stimulat	18 months,	Home-based deliver	None	Stimulation improv

	et al., 2014 [18]	omized controlled trial, 2×2 factorial design		hs at enrollment	munities	tion via weekly home visits delivered through national CCT welfare infrastructure ± micronutrient supplementation	ion: weekly home visits; Micronutrients: daily oral supplementation (formulation not dose-specified, no placebo used)	weekly visits (stimulation arm), daily supplementation (micronutrient arm)	y by local trained women using CCT program infrastructure; Bayley-III testing by blinded assessors		ed: Cognition +0.260 SD (P=0.002), Receptive language +0.218 SD (P=0.032). No benefit from micronutrients alone or combined. No effect on height, weight, Hb from supplementation. No significant interaction effects.
6.	Elisaria et al., 2021 [19]	Quasi-experimental evaluati	Tanzania mainland	All children <5 years residing; feeding	3467 children baseline + 4145 childre	Integrated package: Health & nutrition	No single supplement dose tested; education	3 years program; education sessions	Village health days + peer support groups	Matched paired districts, neutral	No statistically significant reduction in stuntin

		on design (Difference-in-Difference analysis)		data collected for <24 months	n endline	education + promotion of ANC service use + home gardening + village health days	curriculum package "Mkoba wa Siku 1000" used; stunting screened twice a year; cooking demos quarterly	quarterly, screening bi-annual	led by CHWs; home/community education	visits, routine services only	g (DID: 0.8%, p=0.704) but significant improvements in intermediate outcomes: Iron-folic acid uptake +5.2% (p=0.003), facility delivery +6.5% (p=0.006), pre-lacteal feeding −5.9% (p=0.001), BF within 1 hr +7.8% (p=0.006), EBF <6 months +20.3 %

											(p=0.001)
7.	Sofi et al., 2022 [20]	Cluster Randomized Controlled Trial (cRCT), 2×2 factorial	Pakistan	Mothers enrolled during pregnancy; infants received intervention from birth to 24 months, cognition/growth assessed at 24 months	2,030 pregnant women (1,017 intervention; 1,013 control); 1,745 total live births; 1,352 children analyzed at 24 months	WSB+ for pregnant & lactating women + medium-quantity LNS for children 6–23 months + quarterly nutrition education	WSB+: 5 kg/month (165 g/day) wheat-soya blend, fortified; given during pregnancy + 6 months lactation. LNS-MQ: medium-quantity lipid-based paste (roasted chickpeas + veg oils + skimmed milk + sugar + vitamins/minerals)	WSB+: monthly supply for pregnancy + 6 months lactation (≈ 18 months exposure window) LNS-MQ: daily from 6–23 months Education: quarterly cooking + feeding sessions + bi-annual stunting	Delivered via Lady Health Workers (LHWs) through home visits + community health facility distribution points; outcome testing by blinded assessors	Routine maternal-child health & hygiene services via primary health facilities	Stunting reduced at 24 months: absolute difference −10.2% (95% CI −18.2 to −2.3), p=0.017 Underweight reduced at 24 months: −13.7%, p=0.001 Improved LAZ, WAZ, WLZ at 24 months: LAZ +0.3 SD, WAZ +0.3 SD, WLZ

								screening			+0.2 SD Wasting not significantly reduced at 24 months: p=0.057 Significant improvement in Minimum Dietary Diversity (MDD, p=0.018) and Minimum Acceptable Diet (MAD, p=0.004) at 24 months
8.	Ashraf et al., 2024 [21]	Mixed-methods, quasi-experimen	Pakistan	6 – 59 months (primary outcome assessed	Baseline: 3,397 children (1,832 intervention, 1,565	Pregnant & lactating women (first 6 months postpartum): Wheat	WSB+: 5 kg/month (165 g/day), fortified wheat-	3 years (2014 –2017 implementation period)	Delivered through Lady Health Workers (LHWs) via home	Routine public-sector health care servi	Overall stunting (6–59 mo): DID = −5.1 pp, p = 0.079

		tal impact evaluation, analyzed using Difference-in-Difference (DID) with kernel Propensity Score Matching		for all children under 5); subgroup effects analyzed for 6–23 months and 24–59 months	control) Endline: 3,277 children (1,650 intervention, 1,627 control)	Soy Blend Plus (WSB+) - Children 6–23 months: Lipid-based nutrient supplement (LNS) – branded Wawamum - Children 24–59 months: Multiple Micronutrient Powder (MNP) - Underpinned by quarterly Behavior Change Communication	soya blend LNS (Wawamum): lipid-based paste from roasted chickpeas, vegetable oils, skimmed milk, sugar, vitamins/minerals MNP: 1 g powder sachets (multi-micronutrient)	Maternal WSB+: monthly supply throughout pregnancy + first 6 months lactation LNS-MQ: daily from 6–23 months MNP: alternate day for 24–59 months BCC: quarterly; stunting screening twice a year	visits + community/village health days + facility-linked distribution; survey staff trained/standardized; outcome assessors blinded to allocation	ces, no nutritional supplementation or BCC-based supplementation package	→ not statistically significant Stunting (24–59 mo): DID = −13.0 pp, p = 0.001 → significant reduction Underweight (24–59 mo): DID = −9.4%, p = 0.014 → significant reduction Wasting (overall): DID = −2.1 pp, p = 0.298 → no significant reduction

						(BCC) on IYCF + hygiene promotion					Intervention conclusion stated in paper: short-term nutrient uptake alone is insufficient for durable stunting reduction; sustained maternal + child supplementation underpinned by effective BCC is required
9.	Kvestad etl, 20	Randomized Controlled	Norway	4–6 years	314 eligible invited, 232 enrolled &	Fatty fish meals replacing usual diet (salmo	No supplement sachet or pharmaceutical formula	52 school/kindergarten days; fish meals	Center-based delivery in kindergartens	Meat-based kindergarten lunches	Nonverbal index improved significantly in fish

	18[22]	Trial			randomized	n, mackerel, herring; DHA-rich marine fish) in kindergarten lunch program	tion; intervention was whole-food fatty fish meals served as kindergarten lunches; biochemical mediators measured: RBC EPA/DHA/arachidonic acid, s-25(OH)D, s-ferritin, Urinary Iodine (UIC), hair mercury (THHg)	repeatedly served during intervention period		(active comparator), matched for age and socioeconomic background Control dose Whole-food meat meals, no placebo supplement dose	group (d=0.55, p=0.002) Simultaneous / conceptual thinking sub-test improved (d=0.48, p=0.008) Mental processing index showed small positive trend (d=0.36, p=0.072 – borderline) No significant effect on most other cognitive sub-tests

											No significant effect on Hb, height, weight, MUAC, triceps skinfold Cognitive gains were domain-specific, small, and compliance-dependent; no effect on linear growth over short exposure
10	Rauh-Pfeiffer et al., 2014 [23]	Double-blind Randomized Controlled	Germany	4– 6 years (pre-school children attending kinde	1,002 children screened for low folate status → 250 lowest-	Daily B-vitamin + folic acid supplementation (with calciu	Sachet powder containing: • 220 µg folic acid • 1.1 mg	3 months (90 days), 1 sachet daily, mixed into breakf	Home-based delivery (parents mixed sachet into meals)	Matched flavorless calcium-only sachet (130 mg	Folate status improved: median blood folate ↑ ≈ 50% vs control

		Trial		rgartens in Munich region)	ranking children recruited & randomized; 115 intervention + 122 control completed primary outcome assessments	m base) for children with suboptimal folate status	Vitamin B2 (riboflavin) • 0.73 mg Vitamin B6 (pyridoxine) • 1.2 µg Vitamin B12 (cobalamin) • 130 mg calcium lactate pentahydrate (base)	ast/meal at home; compliance monitored via diaries, phone calls, letters, and small incentives	; cognitive testing conducted in kindergarten setting by trained psychology students; outcome assessors blinded to allocation	calcium lactate); no B vitamins or folic acid	, $p < 0.0001$ Homocysteine reduced: −1.1 µmol/L vs baseline, significant vs control ($p < 0.0001$) Urinary folate marker (ap-ABG) higher vs control, $p < 0.0001$ No significant improvement in cognitive performance (verbal IQ, short-term memory, process

											ing speed, K-ABC subscales all non-significant; no gender-specific effects)
11.	Saleem et al., 2014[24]	Cluster Randomized Controlled Trial (cRCT)	Pakistan	Infants 10 – 20 weeks at baseline	194 infants analyzed (110 intervention clusters, 84 control clusters); 212 recruited initially	Maternal education on complementary feeding (CF) + breastfeeding promotion + hygiene messages	No pharmaceutical supplement dose tested; education modules only; 10 key WHO/UNICEF-based CF messages delivered verbally, pictorially, and by demonstration	30 weeks total; 4 visits (baseline + 3 follow-ups), each 10 weeks apart; education sessions at first 3 visits, 15–20 min each	Home-visiting delivery by trained community health workers/LHW program infrastructure; anthropometry and counselling done by separate teams to minimize bias	Routine national BF advice via public-sector health services; attention-control neutral visits, no CF education package	Weight gain higher vs control: +350 g (p=0.001) Length gain higher vs control: +0.66 cm (p=0.001) MUAC higher vs control: +0.46 cm (p=0.002) Underweight reduced by

											6% in intervention vs 9% increase in control (trend) Stunting lower in intervention at end: 74% vs 84% in control, but DID across visits not significant overall No significant reduction in wasting between groups at end (ORadj 1.42; 95% CI 0.56–3.58) Education

											alone improves linear growth short-term but may not be enough for population-level stunting or wasting reduction without food/MN supplementation
12	Yousafzai et al., 2016 [25]	Longitudinal follow-up of a cluster-randomised 2×2 factorial effe	Pakistan	Originally enrolled at ⩽2.5 months of age → follow-up assessments done within 1 mont	1,489 mother – infant dyads originally enrolled → 1,302 re-enrolled at age 4	3 arms in original trial continued into follow-up: 1. Responsive stimulation 2. Enhanced	Nutrition arm: • Sprinkles multiple micronutrient powder, 1 sachet mixed into food daily (child	Original trial exposure window: birth → 24 months Follow-up observation period: 2 years	Delivered by paid community health workers (Lady Health Workers – LHWs) via home visits + comm	Routine health & nutrition services from LHW programme (hygiene, BF advice,	IQ: very small, not significant Executive function: improved, moderate effect ($d \approx$ 0.3,

		ctiveness trial		h of the child's 4th birthday		nutrition 3. Combined responsive stimulation + enhanced nutrition	6–24 months in original trial phase) • Enhanced curriculum included responsive feeding, ANC promotion, home gardening, village health days, and BCC on IYCF/hygiene Stimulation arm: play & communication coaching (Care for Child Development adaptation)	post-intervention, no new supplement started Sessions previously delivered: monthly home visits + group sessions (during original 2-year trial phase)	unity group sessions; cognitive/motor assessors were masked/blinded to allocation	immunisation, basic nutrition education); no enhanced curriculum, no MN powders, no stimulation coaching	$p<0.0001$) Pre-academic skills: best when stimulation + nutrition ($d\approx 0.5$), smaller with stimulation only ($d\approx 0.2$) Social skills: small benefit, better in combined arm Growth/Hb: no lasting improvement School enrollment: no effect

13.	Fenn et al., 2016/2017 [26]	4-arm parallel longitudinal cluster-randomized controlled trial (cRCT)	Pakistan	Children 6–48 months in eligible households; outcomes assessed at 6 months and 1 year	2,496 households with 3,584 children (6–48 mo) at baseline; 1,302 children assessed at age 4 in reliability subsample; main analysis unit = cluster effect sizes	Unconditional Cash Transfers (UCTs): • Standard Cash (SC) = 1,500 PKR/month (~US$ 14) • Double Cash (DC) = 3,000 PKR/month (~US$ 28) • Fresh Food Voucher (FFV) = 1,500 PKR value/ month	1,500 PKR or 3,000 PKR monthly cash (no clinical supplement formulation); voucher redeemable for fruits, vegetables, milk, meat in nominated shops	1,500 PKR or 3,000 PKR monthly cash (no clinical supplement formulation); voucher redeemable for fruits, vegetables, milk, meat in nominated shops	Distributed through Action Against Hunger/WINS infrastructure, delivered to enrolled households by community programme channels (LHW/ CHW linked)	Control Group (CG) = routine access to WINS programme services, no cash or voucher allocation	Child wasting odds significantly lower in DC arm at 6 months: OR = 0.52 (95% CI 0.29–0.92), p = 0.02 Mean WHZ improved in FFV and DC arms at 6 months: FFV +0.16 z (95% CI 0.05–0.26), p = 0.004 DC +0.11 z (95% CI 0.00–0.21),

											p = 0.05 No sustained effect on wasting at 1 year (significant differences only at 6 months, not at 1 year) No significant effect on HAZ, WAZ, Hb, height, weight, MUAC, skinfolds in longer follow-up points
14	Trenouth et al., 20	Longitudinal cluster Random	Pakistan	Children 6–48 months living in benef	2,496 households; 3,584 children at baseline	Three cash-based interventions (CBIs):	DC: USD $28/month unconditional cash	6 months, transfers provided	Implemented by Action Against Hunger via	Routine services only through under	Wasting: Reduced only in DC arm at 6 months

	18[27]	ized Controlled Trial (cRCT) with economic evaluation		iciary households	across four arms (DC, SC, FFV, Control)	1. Double Cash (DC) 2. Standard Cash (SC) 3. Fresh Food Vouchers (FFV) All arms received identical monthly BCC sessions (breastfeeding, complementary feeding, hygiene)	• SC: USD $14/month unconditional cash • FFV: USD $14/month voucher redeemable for fresh foods (milk, meat, fruits, vegetables)	monthly	community distribution points; cash via bank/payment agents; vouchers via contracted food vendors; BCC delivered monthly	lying EU-WINS programme (no cash or voucher transfer)	(−4.17%; 35 cases averted) SC and FFV did not reduce wasting Stunting: Reduced in all three arms at 12 months (DC −15.7%, SC −15.3%, FFV −18.1%)

Results:

We performed a systematic review and included 14 studies for the final data extraction. These studies focused on early childhood nutrition interventions. Asia, Africa, America and Europe were the regions where the studies were conducted. The number of Randomized Controlled Trials was 10 which also included 4 Cluster-RCTs and Quasi experimental studies were 3. These studies were conducted since 2011. For the evidence before 2011 we included a systematic review with meta-analysis that pooled data from 1992 to 2012.

Study Characteristics:

Lower and low-middle income countries had the highest number of studies. The largest number was taken from Pakistan (6 in number). Other countries were Colombia, Indonesia, Peru, Jamaica, Tanzania, India and Norway. The age groups enrolled in these studies varied but all the studies had age groups falling between 0-5 years. Some studies focused on first 1000 days of life of infant. Sample size ranged from 128 to 3584.

Intervention Types:

Interventions fell into four major categories:

1. Macronutrient supplementation: Wheat Soy Blend Plus (WSB+) or Protein-Energy fortified foods (3 studies)
2. Micronutrient supplementation: Iron, zinc gluconate, folic acid, vitamin C, vitamin A, Multiple Micronutrient Powders (MNP) or Sprinkles (5 studies)
3. Fortification / Blended fortified foods: Fortified cereals, milk, high-protein liquid blends (3 studies)
4. Integrated ECD + Nutrition programs: Responsive stimulation, caregiver coaching, and nutrition education delivered through community health systems or welfare infrastructure (3 studies)

Among the included studies, two studies tested cash-based support rather than food supplements. Standard Cash ($14/month) and Double Cash ($28/month), while one arm used food vouchers redeemable for fresh foods. (Fenn et al., Trenouth et al.)

Cognitive and Developmental Outcomes

Psychosocial stimulation manifested the strongest cognitive benefit which improved executive function ($p<0.0001$), school readiness ($p<0.0001$), reading comprehension ($p<0.01$), verbal IQ ($p=0.02$), and perceptual-motor development ($p<0.01$). Integrated stimulation along with nutrition arms produced higher pre-academic and pro-social outcomes, but did not outperform stimulation alone in adolescent follow-ups. Micronutrient supplementation alone (MMN, iron, zinc) did not produce added cognitive benefit over control in 3 RCTs, even though biochemical markers such as folate (+50%), homocysteine reduction, ferritin and iodine status improved significantly.

Anthropometric & Hematologic Outcomes:

Durable reduction in stunting was inconsistent when intervention duration was short (<6 months). Significant reduction in stunting was observed only when supplementation exposure was longer and sustained: Pakistan 1000-days trial: −10.2% stunting, $p=0.017$. Pakistan DID evaluation (older subgroup 24–59 mo): −13 pp stunting, $p=0.001$. Peru iron/zinc/Vit A/C MMN trial: no stunting or Hb improvement. Most micronutrient-only RCTs showed no lasting effect on HAZ, WAZ, Hb, or wasting at 1-year or later follow-ups. Wasting risk was reduced only in the Double Cash arm in one cRCT at 6 months (35 cases averted; $OR=0.52$, $p=0.02$), but this effect did not sustain at 1 year. No long-term improvements were observed for Hb, weight, height, MUAC, skinfold thickness, or wasting in trials without continuous supplementation.

Overall Evidence Pattern:

Community and system-linked delivery platforms (LHWs, CHWs, welfare shops, kindergartens) were feasible and scalable**.** Cognitive improvements were robust for stimulation-based and comprehensive integrated programs. Supplementation based on only nutrition or only micronutrients positively impacted biochemical markers but hardly translated into sustained cognitive or linear-growth gains. No dose exists for control arms in non-supplemented comparisons**.** Long-term undernutrition reduction requires sustained maternal + child supplementation supported by strong behavior-change components**.**

Discussion

This systematic review synthesized evidence from 14 studies evaluating the effectiveness of early-childhood nutritional supplementation and Early Child Development (ECD) interventions on child cognition and linear growth. The findings demonstrate a clear and consistent pattern: psychosocial or responsive stimulation interventions produced the strongest and most sustained improvements in cognitive outcomes, whereas nutrition-only or micronutrient-only supplementation showed limited long-term impact on cognition and inconsistent sustainability for anthropometric recovery.

Cognitive Outcomes:

Across multiple trials, responsive or psychosocial stimulation significantly improved executive function, school readiness, reading comprehension, verbal IQ, and perceptual-motor performance, with moderate to large effect sizes in community-based integrated arms ($d \approx 0.3–0.5$; $p<0.01$). These findings are aligned with global ECD evidence showing that brain development, synaptogenesis, and neurocognitive wiring are more sensitive to enriched interaction, responsive feeding, and caregiver play coaching than to nutrient intake alone at preschool age. The Oyen et al. FINS-KIDS trial further supports that whole-food DHA-rich diet replacement (fatty fish) produced only small, domain-specific cognitive gains and no anthropometric benefit, emphasizing that dietary interventions at 4–6 years may enhance selected biochemical mediators but do not drive linear growth recovery in short exposure windows.

Nutrition-Only Supplementation:

Multiple RCTs administering MMN sachets, zinc gluconate, iron, folic acid, and B-vitamin powders resulted in significant biochemical improvement (folate ↑≈50%, ferritin ↑, homocysteine ↓, UIC ↑; all $p<0.0001$), but did not translate into significant cognitive or behavioral benefit over control. This suggests that micronutrient repletion improves physiological reserves but may not be sufficient to influence higher-order cognition unless paired with stimulation, responsive caregiving, or longer exposure during infancy. This finding is particularly relevant for SRs focused on cognition, and is consistent with trials where micronutrients alone had no impact on Bayley-III cognition, Hb, HAZ, WAZ, or wasting at 12 months or later follow-ups.

Stunting Requires Sustained & Continuous Supplementation:

While early-life supplementation with fortified WSB+ and LNS-MQ during the first 1000 days significantly reduced stunting and underweight in Pakistan (−10.2% and −13.7%, respectively; $p \leq 0.017$), shorter interventions (<6 months) or supplement-without-stimulation models showed non-significant or non-sustained effects on HAZ and Hb. Woldehanna et al. cohort evidence also reinforces that early stunting predicts long-term cognitive disadvantage independent of SES and maternal education, indicating that linear-growth impairment has durable neurodevelopmental consequences, and catch-up requires early, sustained, multi-component support. The lack of stunting reduction in some integrated education-only arms (e.g., Saleem et al., Tanzania Mkoba wa Siku 1000; $p \geq 0.704$) suggests that nutrition education and hygiene-linked BCC can significantly improve feeding practices (EBF +20%, IFA uptake +5%, pre-lacteal feeding −5.9%; all $p<0.01$) but may not reduce stunting prevalence without parallel macronutrient or micronutrient supplementation.

Role of Maternal & Home Cognitive Environment:

Two studies highlighted that supplementation effects were moderated by maternal verbal IQ and home caregiving capacity, where growth or cognition gains were observed only when maternal PPVT or verbal IQ was higher. In addition, caregiving environment improved moderately across all stimulation-based arms ($d \approx 0.3$), even when anthropometry remained unchanged, showing that home cognitive enrichment can improve developmental pathways even before physical catch-up is measurable. Importantly, maternal depression scores did not improve, which may reflect the limited mental-health responsiveness of short-term nutrition interventions and the need for targeted psychosocial or clinical support for maternal affective outcomes.

Conclusion:

The evidence supports that psychosocial stimulation and enriched caregiving environments are the most powerful determinants of sustained cognitive development, while nutrition supplementation must be early, sustained, and integrated with behavioral support to influence stunting and physical growth outcomes. These findings emphasize that future early-childhood public health programs in LMICs should prioritize stimulation-driven integrated models rather than isolated micronutrient supplementation or short-term nutrition education alone.

Limitations:

Many trials lacked exact supplement dose reporting, placebo matching, or long-term biochemical mediation models. Effect durability beyond 24 months for nutrition-only arms was limited. Maternal mental-health outcomes were under-reported.

Heterogeneity across intervention types, countries, and compliance levels limits direct effect pooling. Several studies evaluated stunting as exposure, not intervention, which may reduce comparability in intervention-dose columns.

Conflict of Interest:

The authors declare no conflict of interest.

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