



How Does Regular Cow's Milk Consumption Combined With Vitamin D Supplementation Affect Nutritional Status And Growth In Malnourished Children ? : A Systematic Review

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ABSTRACT

Introduction: Malnutrition in children, particularly in low- and middle-income countries, remains a significant global health issue, impairing physical growth and cognitive development. Cow's milk, rich in essential nutrients, and Vitamin D, crucial for bone health and immune function, are vital for child development. This systematic review evaluates the impact of regular cow's milk consumption combined with Vitamin D supplementation on the nutritional status and growth of malnourished children.

Methods: This systematic review adhered to PRISMA 2020 guidelines. Studies were screened based on criteria including: children aged 6 months to 12 years meeting WHO malnutrition criteria; intervention with regular cow's milk (minimum 200ml/day) and Vitamin D supplementation; study duration of 3 months or longer; and study designs such as RCTs, systematic reviews, meta-analyses, or prospective cohort studies. Data were extracted from databases including Pubmed, Semantic Scholar, Sagepub, and Google Scholar. **Results:** The review included 27 studies. Findings indicated that fortified cow's milk with Vitamin D supplementation generally improved Vitamin D status. For instance, some studies showed serum 25-hydroxyvitamin D levels increased by approximately 20 ng/mL with supplementation. Effects on growth metrics like height and weight were modest and variable, with some studies reporting significant improvements (e.g., height-for-age z-scores, $p < 0.0001$) while others found no significant effect. Interventions combining milk with other nutrient sources like eggs or micronutrient powders showed more pronounced effects on growth (e.g., a 2.62 cm increase in height). Longer intervention durations (≥ 6 months) and higher doses (e.g., 600 ml milk daily) were often associated with better outcomes for micronutrient status and growth. **Discussion:** The evidence suggests that fortified cow's milk and Vitamin D supplementation effectively enhances micronutrient status, particularly Vitamin D levels, in malnourished children. While the direct impact on linear growth and weight gain is modest, comprehensive intervention packages addressing multiple deficiencies simultaneously appear most effective. The variability in growth outcomes underscores the importance of considering baseline nutritional status, intervention duration, and dosage. **Conclusion:** Fortified cow's milk and Vitamin D supplementation is a valuable strategy for improving micronutrient status in malnourished children, especially Vitamin D levels. Although growth improvements can be modest, integrating this intervention into broader, holistic nutritional programs, particularly with longer durations and adequate dosages, is supported by evidence and crucial for mitigating malnutrition.

Keywords: Malnourished children, Cow's milk, Vitamin D supplementation, Nutritional status, Growth, Systematic Review

INTRODUCTION

Malnutrition remains a critical global health issue, particularly among children in low- and middle-income countries (LMICs). It is estimated that nearly 149 million children under five suffer from stunting, while 45 million are wasted (WHO, 2020). Malnutrition not only impairs physical growth but also cognitive development, increasing the risk of morbidity and mortality. Among the various interventions to combat malnutrition, dietary supplementation with nutrient-rich foods like cow's milk and micronutrients such as Vitamin D has gained attention due to their potential to address multiple deficiencies simultaneously (Senbanjo et al., 2022).

Cow's milk is a rich source of essential nutrients, including protein, calcium, and vitamins, which are vital for growth and development. However, in many regions, milk consumption is limited due to economic constraints or cultural practices. Vitamin D, another critical nutrient, plays a pivotal role in bone health and immune function. Deficiencies in Vitamin D are prevalent in malnourished children, exacerbating growth retardation and susceptibility to infections (Ganmaa et al., 2017). Combining cow's milk with Vitamin D supplementation could offer a synergistic approach to improving nutritional outcomes.

This study aims to evaluate the impact of regular cow's milk consumption combined with Vitamin D supplementation on the nutritional status and growth of malnourished children. Specifically, it seeks to:

- Assess changes in anthropometric measurements (height, weight, and z-scores).
- Measure improvements in micronutrient status, particularly Vitamin D levels.
- Identify the optimal dosage and duration of intervention for maximum efficacy.

Compare the effects of standalone milk supplementation versus combined interventions (e.g., milk with eggs or micronutrient powders).

The findings will contribute to evidence-based recommendations for policymakers and healthcare providers designing nutritional interventions for malnourished children. By addressing

gaps in current research, this study could inform scalable and cost-effective strategies to mitigate malnutrition (Brooker et al., 2022).

The study focuses on children aged 6 months to 12 years, adhering to WHO criteria for malnutrition. It includes randomized controlled trials (RCTs), systematic reviews, and meta-analyses published in the last decade to ensure relevance and rigor (Brando-Lima et al., 2019).

Research Questions

- How does fortified cow's milk with Vitamin D supplementation affect linear growth and weight gain in malnourished children?
- What are the comparative effects of different intervention durations (e.g., 3 months vs. 6 months)?
- Are there synergistic benefits when milk is combined with other nutrient sources?

Hypotheses

- Regular consumption of fortified cow's milk with Vitamin D will significantly improve height-for-age and weight-for-age z-scores.
- Longer intervention durations (≥ 6 months) will yield greater improvements in nutritional biomarkers.
- Combined interventions (e.g., milk + eggs) will outperform standalone milk supplementation.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate regular cow's milk consumption combined with vitamin d supplementation affect nutritional status and growth in malnourished children.

Screening

We screened in papers that met these criteria:

- **Population Age and Status:** Does the study focus on children aged 6 months to 12 years who meet WHO criteria for malnutrition?
- **Medical Conditions:** Are participants free from severe lactose intolerance, milk protein allergy, and chronic diseases affecting growth or nutrient absorption?
- **Intervention Components:** Does the study examine the combined intervention of both regular cow's milk consumption (minimum 200ml/day) AND Vitamin D supplementation?
- **Intervention Documentation:** Does the study clearly document both the milk consumption amounts and Vitamin D supplementation doses?
- **Study Duration:** Is the study duration 3 months or longer?
- **Study Design:** Is the study design either an RCT, systematic review, meta-analysis, or prospective cohort study?
- **Outcome Measures:** Does the study report both anthropometric measurements AND nutritional biomarkers (including Vitamin D status)?
- **Language and Availability:** Is the full text of the study available in English?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Study Design:**

Identify the type of study design (e.g., randomized controlled trial, quasi-experimental study). Look in the methods section for explicit description of study design. If multiple design elements are present, list all.

Specific details to extract:

- Randomization method (if applicable)
- Blinding approach (if applicable)
- Whether the study was prospective or retrospective
- Any crossover or parallel group design elements

If design is unclear, note "Design not clearly specified" and provide any available contextual information.

- **Participant Characteristics:**

Extract comprehensive details about study participants:

- Age range (minimum and maximum)
- Mean/median age
- Total number of participants
- Gender distribution
- Nutritional status at baseline (e.g., height-for-age z-score, weight-for-age z-score)
- Geographic location/setting
- Inclusion and exclusion criteria

Use exact numbers and percentages where possible. If ranges or multiple groups exist, extract information for each group separately. If data is missing, note "Not reported" with any partial information available.

- **Intervention Specifics:**

Detail the specific intervention related to cow's milk and Vitamin D:

- Type of milk product (e.g., whole milk, fortified milk)
- Daily volume/quantity consumed
- Vitamin D supplementation dose (in IU)
- Duration of intervention
- Frequency of consumption

Be precise about measurements. If multiple intervention arms exist, extract details for each arm separately. If dosage varies, note the different levels and their specific characteristics.

- **Comparison/Control Conditions:**

Describe the control group or comparison condition:

- What did the control group receive? (e.g., placebo, unfortified milk, standard diet)
- Any differences in intervention beyond milk/Vitamin D
- Whether groups were matched on key characteristics

If no clear control group exists, note "No control group" and describe the study design alternative.

- **Nutritional Status Outcomes:**

Extract specific measurements related to nutritional status:

- Anthropometric measurements (height, weight, BMI)
- Z-scores for height-for-age, weight-for-age
- Micronutrient status (specific vitamin and mineral levels)
- Method of measurement
- Timing of measurements (baseline and follow-up points)

Report numerical values with standard deviations or confidence intervals where available. Note statistical significance of changes.

- **Growth Measurements:**

Specifically detail growth-related outcomes:

- Changes in height

- Changes in weight
- Head circumference (if measured)
- Absolute and percentage changes
- Statistical significance of growth changes

Extract both within-group and between-group comparisons. Include confidence intervals or p-values if re-ported.

- **Risk of Bias Assessment:**

Evaluate study quality elements:

- Randomization method and concealment
- Blinding procedures
- Completeness of follow-up
- Dropout/attrition rates
- Potential conflicts of interest
- Funding sources

Use a standardized assessment tool if referenced (e.g., Cochrane Risk of Bias Tool). Provide specific details about potential biases identified.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Malnourished children	Children aged 6 months to 12 years	Low- and middle-income countries (LMICs)	Stunted/underweight children
Intervention (I)	Fortified cow's milk	Vitamin D supplementation	Combined interventions (milk + eggs/micronutrient powders)	Daily intake (e.g., 600 mL/day)
Comparison (C)	Unfortified milk	Standard diet	Placebo	No supplementation
Outcome (O)	Improved Vitamin D status	Height-for-age z-scores (HAZ)	Weight gain	Micronutrient biomarkers (iron, vitamin A, etc.)

The Boolean MeSH keywords inputted on databases for this research are: (*"Malnourished children"* OR *"Children aged 6 months to 12 years"* OR *"Low- and middle-income countries (LMICs)"* OR *"Stunted/underweight children"*) AND (*"Fortified cow's milk"* OR *"Vitamin D supplementation"* OR *"Combined interventions (milk + eggs/micronutrient powders)"* OR *"Daily intake (e.g., 600 mL/day)"*) AND (*"Unfortified milk"* OR *"Standard diet"* OR *"Placebo"* OR *"No supplementation"*) AND (*"Improved Vitamin D status"* OR *"Height-for-age z-scores (HAZ)"* OR *"Weight gain"* OR *"Micronutrient biomarkers (iron, vitamin A, etc.)"*)

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all

predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Malnourished children" OR "Children aged 6 months to 12 years" OR "Low- and middle-income countries (LMICs)" OR "Stunted/underweight children" AND ("Fortified cow's milk" OR "Vitamin D supplementation" OR "Combined interventions (milk + eggs/micronutrient powders)" OR "Daily intake (e.g., 600 mL/day)") AND "Unfortified milk" OR "Standard diet" OR "Placebo" OR "No supplementation" AND ("Improved Vitamin D status" OR "Height-for-age z-scores (HAZ)" OR "Weight gain" OR "Micronutrient biomarkers (iron, vitamin A, etc.)")	3,313
Semantic Scholar	"Malnourished children" OR "Children aged 6 months to 12 years" OR "Low- and middle-income countries" OR "Stunted/underweight children" AND "Fortified cow's milk" OR "Vitamin D supplementation" OR "Combined interventions" OR "Daily intake " AND "Unfortified milk" OR "Standard diet" OR "Placebo" OR "No supplementation" AND "Improved Vitamin D status" OR "Height-for-age z-scores" OR "Weight gain" OR "Micronutrient biomarkers"	250
Sagepub	("Malnourished children" OR "Children aged 6 months to 12 years" OR "Low- and middle-income countries (LMICs)" OR "Stunted/underweight children") AND ("Fortified cow's milk" OR "Vitamin D supplementation" OR "Combined interventions (milk + eggs/micronutrient powders)" OR "Daily intake (e.g., 600 mL/day)") AND ("Unfortified milk" OR "Standard diet" OR "Placebo" OR "No supplementation") AND ("Improved Vitamin D status" OR "Height-for-age z-scores (HAZ)" OR "Weight gain" OR "Micronutrient biomarkers (iron, vitamin A, etc.)")	7,150
Google Scholar	("Malnourished children" OR "Children aged 6 months to 12 years" OR "Low- and middle-income countries (LMICs)" OR "Stunted/underweight children") AND ("Fortified cow's milk" OR "Vitamin D supplementation" OR "Combined interventions (milk + eggs/micronutrient powders)" OR "Daily intake (e.g., 600 mL/day)") AND ("Unfortified milk" OR "Standard diet" OR "Placebo" OR "No supplementation") AND ("Improved Vitamin D status" OR "Height-for-age z-scores (HAZ)" OR "Weight gain" OR "Micronutrient biomarkers (iron, vitamin A, etc.)")	15,800

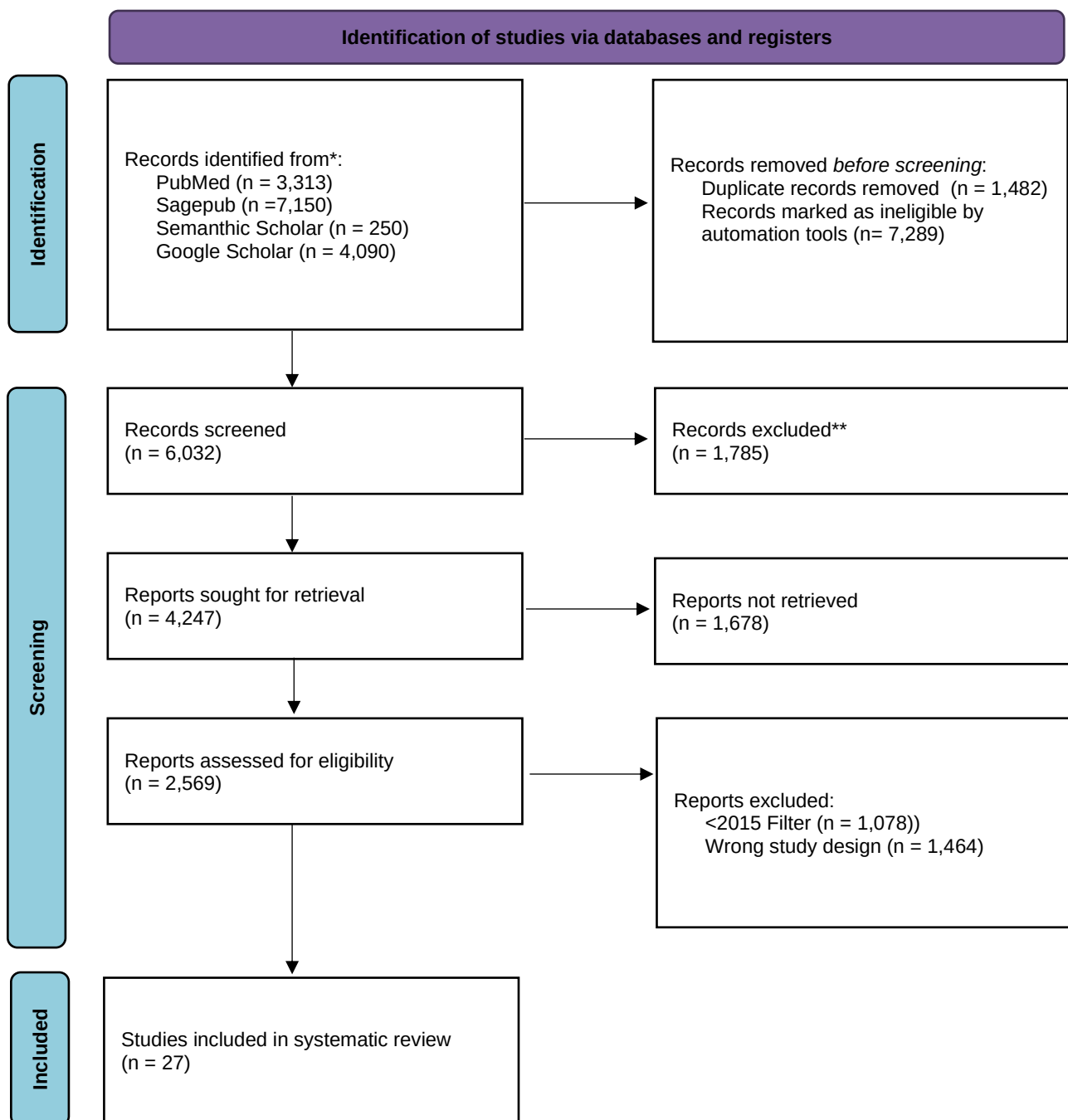


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Senbanjo et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Darwish Mohd Isa et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ganmaa et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Matsuyama et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓

Brandão-Lima et al., 2019									
Brooker et al., 2022									
Cervo et al., 2017									
de Lamas et al., 2019									
Kuriyan et al., 2016									
Zhang et al., 2021									
Dulal et al., 2021									
Eichler et al., 2019									
Zhao et al., 2021									
Ponce et al., 2018									
Lu et al., 2019									
Ara et al., 2021									

Li et al., 2023									
Huynh et al., 2016									
Ara et al., 2022									
Le Port et al., 2017									
Wang et al., 2017									
Hidayat et al., 2023									
Ansuya et al., 2023									
Helmiyati et al., 2021									
Tytusa et al., 2022									
Añorve-Valdez et al., 2018									
Mondal et al., 2024									

RESULTS

Characteristics of Included Studies

Study	Study Design	Population Characteristics	Intervention Details	Primary Outcomes	Full text retrieved
Senbanjo et al., 2022	Randomized Controlled Trial (RCT), open-label, parallel	1-3 yrs, n=184, mild-moderate malnutrition, Nigeria	Fortified dairy drink (200/400/600 ml, 2-6 ug Vitamin D), 6 mo	Micronutrient status, growth, cognition	Yes
Darwish Mohd Isa et al., 2023	Systematic review/meta-analysis	No mention found	Standard vs. nutrient-enriched cow's milk	Child growth	No
Ganmaa et al., 2017	2 RCTs (double-blind, parallel/cluster)	9-15 yrs, n=113/235, Mongolia, low Vitamin D	800 IU Vitamin D3 (tab, 6 mo) or 710 ml milk + 300 IU	25-hydroxyvitamin D (25(OH)D), height,	Yes

			Vitamin D3 (7 wks)	weight	
Matsuyama et al., 2016	Systematic review/meta-analysis	6-47 mo, healthy	Fortified vs. control milk	Growth, body composition, biochemical markers	No
Brandão-Lima et al., 2019	Systematic review of RCTs	2-11 yrs, n=792, various	Fortified dairy (300-880 IU Vitamin D), 1.6-9 mo	25(OH)D, nutritional status	Yes
Brooker et al., 2022	Systematic review/meta-analysis	9-48 mo, n=4795, healthy	Fortified milk (150-750 ml/d), 5-12 mo	Growth, nutritional status	Yes
Cervo et al., 2017	RCT, single-masked, parallel	3-5 yrs, n=120, Philippines, normal/under weight	Fortified milk formula (100g/d, 165-170 IU Vitamin D), 12 wks	Nutritional status, psychomotor skills	Yes

de Lamas et al., 2019	Systematic review of controlled trials	3-18 yrs, n=3895, 63.7% female	Dairy supplementation	Height, Bone Mineral Content (BMC)	Yes
Kuriyan et al., 2016	RCT, double-blind, parallel	7-10 yrs, India, healthy	Fortified malt/cocoa milk beverage, 5 mo	Micronutrient status, cognition, physical performance	No
Zhang et al., 2021	Systematic review/meta-analysis	9 mo-12 yrs, n=2287, 56% boys, undernourished	Oral Nutrition Supplements (ONS) (cow-milk-based), 7-365 d	Growth (anthropometry)	Yes
Dulal et al., 2021	Systematic review/meta-analysis	<5 yrs, Low- and Middle-Income Countries (LMICs)	Integrated nutrition/stimulation	Growth, development	No
Eichler	Systematic	5-15 yrs,	Micronutrient-	Hemoglobi	Yes

et al., 2019	review/meta-analysis	n=9367, 51% male	fortified dairy/cereal	n, anemia, growth	
Zhao et al., 2021	RCT, parallel	6-13 yrs, n=955, rural China	200g Ultra-High Temperature (UHT) milk + egg, 2 yrs	Growth, fitness	Yes
Ponce et al., 2018	Systematic review of reviews	0-5 yrs, LMICs	Micronutrient interventions	Micronutrient status	Yes
Lu et al., 2019	RCT, double-blind, parallel	12-15 yrs, n=232, rural China	Fortified milk powder (400 IU Vitamin D, 300-900 mg Ca), 1.5 yrs	Bone Mineral Density (BMD), bone markers	Yes
Ara et al., 2021	Cluster RCT	6-12 mo, n=412, Bangladesh	Egg/milk snack + Micronutrient Powder (MNP) + counseling, 12 mo	Length-for-Age Z-score (LAZ), development	No

Li et al., 2023	Cluster RCT	4-6 yrs, n=196, rural China	Formula milk (60g, 180 IU Vitamin D), 12 mo	BMD, growth, bone markers	Yes
Huynh et al., 2016	Single-arm trial	3-4 yrs, n=200, Philippines, at- risk	ONS (450 ml/d), 48 wks	Growth, dietary adequacy	Yes
Ara et al., 2022	Cluster RCT	<2 yrs, n=412, Bangladesh, ultra-poor	Egg/milk snack + MNP + counseling, 12 mo	Length gain, dietary diversity	Yes
Le Port et al., 2017	Cluster RCT	24-59 mo, n=449, Senegal, food insecure	Micronutrient- fortified yogurt, 1 yr	Hemoglobi n, anemia	Yes
Wang et al., 2017	Cluster RCT	12-14 yrs, n=360, China	Micronutrient- fortified milk (250 ml/d), 6 mo	Academic performanc e, micronutrie nt status	Yes

Hidayat et al., 2023	Meta-analysis of RCTs	3-18 yrs	Dairy supplementation	Bone health indices	No
Ansuya et al., 2023	Cluster RCT	3-5 yrs, n=253, India, underweight	Nutrition-focused intervention, 12 mo	Cognitive development	Yes
Helmiyati et al., 2021	RCT, parallel	<5 yrs, n=94, Indonesia, stunted	Synbiotic Fe-Zn milk, 3 mo	Growth (z-scores)	No
Tytusa et al., 2022	Quasi-experimental	6-11 yrs, n=172, Ukraine	Diet modification $\pm$ Ca/Vitamin D supplementation, 3 mo	Ca, Vitamin D status	No
Añorve-Valdez et al., 2018	Cluster RCT	6-12 mo, n=691, Mexico	Fortified milk, MNP, syrup, ~2 yrs	Dietary intake	Yes
Mondal et al.,	RCT, open-label,	1-10 yrs, n=80	Vitamin D3 (4000 IU/d vs	Biochemical markers	No

2024	parallel		60,000 IU/fortnight), 12 wks		
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Analysis of included studies:

- Study designs : 15 Randomized Controlled Trials (including cluster RCTs), 10 systematic reviews/meta- analyses (including reviews of reviews), 2 other designs (single-arm trial, quasi-experimental)
- Age groups : 2 studies (infants <1 yr), 9 (toddlers 1–5 yrs), 4 (children 6–12 yrs), 3 (adolescents 13–18 yrs); 9 studies included multiple age groups
- Nutritional status : 7 studies (undernourished, underweight, stunted, or at-risk), 3 (healthy)
- Geographic distribution : 2 (unspecified Low- and Middle-Income Countries), 1 each (Nigeria, Mongolia, Senegal, Indonesia, Ukraine, Mexico), 2 each (Philippines, India, Bangladesh), 4 (China)
- Missing data : No population characteristics found in the abstract of 1 study
- Interventions : 15 studies used fortified milk or dairy products, 2 used dairy supplementation, 2 used oral nutrition supplements, 3 used egg/milk snack plus micronutrient powder, 1 used general micronutrient interventions, 3 used nutrition-focused or diet modification approaches, and 1 used vitamin D supplementation
- Primary outcomes : Growth (16 studies), micronutrient status (16), cognition/development (7), bone health (4), dietary intake/adequacy (3), physical performance (2), anemia/hemoglobin (2)

This diverse set of studies provides a broad perspective on the effects of cow's milk and Vitamin D supplementation across various populations and contexts. The inclusion of systematic reviews and meta-analyses alongside primary studies offers both granular and synthesized evidence.

Effects of Interventions

Growth Outcomes

Study	Intervention Type	Height/Length Changes	Weight Changes	Growth Velocity
Senbanjo et al., 2022	Fortified dairy drink (200/400/600 ml)	Height-for-Age Z-score (HAZ) improved in 600 ml group ($p<0.0001$); trend between groups ($p=0.062$)	Weight-for-Age Z-score (WAZ) improved in all groups; trend between groups ($p=0.081$)	No mention found
Darwish Mohd Isa et al., 2023	Standard vs. nutrient-enriched milk	No mention found	No mention found	No mention found
Ganmaa et al., 2017	Fortified milk (710 ml, 300 IU Vitamin D)	+0.2 cm (Not Significant, $p=0.2$); 800 IU Vitamin D tab: +0.9 cm ($p=0.003$)	No significant effect	No mention found
Matsuyama et al., 2016	Fortified milk	No significant effect	+0.17 kg (95% CI 0.02, 0.31)	No mention

				found
Brandão-Lima et al., 2019	Fortified dairy (300-880 IU Vitamin D)	No mention found	No mention found	No mention found
Brooker et al., 2022	Fortified milk (150-750 ml/d)	No significant effect (Mean Difference -0.05 cm)	+0.14 kg (95% CI 0.06, 0.21)	Weight-for-Length z-score +0.10 (p=0.01)
Cervo et al., 2017	Fortified milk formula	+1.40 cm (p<0.0001)	+1.35 kg (p<0.0001)	No mention found
de Larmas et al., 2019	Dairy supplementation	6/13 studies: significant height gain; 7/13: Not Significant No difference	No mention found	No mention found
Kuriyan et al., 2016	Fortified milk beverage	No difference	No difference	No mention found
Zhang et	Oral Nutrition	HAZ gain at 90d:	+0.423 kg	No

al., 2021	Supplements (cow-milk-based)	+0.088 (p=0.006)	(p<0.001)	mention found
Dulal et al., 2021	Integrated nutrition/stimulation	No significant effect	No significant effect	No mention found
Eichler et al., 2019	Micronutrient-fortified dairy/cereal milk	No significant effect	No significant effect	No mention found
Zhao et al., 2021	Milk + egg	No height difference	boys: +0.6 kg (yr1), +0.7 kg (yr2) (Note: original image had this under Height/Length, with "See previous" for Weight)	No mention found
Ponce et al., 2018	Micronutrient interventions	Some effect on HAZ in infants	Zinc: improved Weight-for-Height	No mention found
Lu et al., 2023	Fortified milk powder	No mention found	No mention found	No mention found

Ara et al., 2021	Egg/milk snack + Micronutrient Powder	+2.62 cm (P<0.001)	No mention found	No mention found
Li et al., 2023	Formula milk (180 IU Vitamin D)	Height: +0.34-0.45% vs control (p<0.05)	No mention found	No mention found
Huynh et al., 2016	Oral Nutrition Supplements (450 ml/d)	Height-for-Age Percentile +2.16 to +3.99 (P<0.01)	Weight-for-Height Percentile +13.7 to +16.1 (P<0.0001)	No mention found
Ara et al., 2022	Egg/milk snack + Micronutrient Powder	+2.62 cm at 12 mo; Length-for-Age Z-score +0.37 (p<0.001)	Not detailed	No mention found
Le Port et al., 2017	Micronutrient-fortified yogurt	No mention found	No mention found	No mention found
Wang et al., 2017	Micronutrient-fortified milk	No mention found	No mention found	No mention found
Hidayat et al., 2023	Dairy supplementation	No mention found	No mention found	No mention

				found
Ansuya et al., 2023	Nutrition-focused intervention	No mention found	No mention found	No mention found
Helmyati et al., 2021	Synbiotic Fe-Zn milk	Not significant	Not significant	No mention found
Tytusa et al., 2022	Diet modification $\pm$ Ca/Vitamin D	No mention found	No mention found	No mention found
Añorve-Valdez et al., 2018	Fortified milk/Micronutrient Powder/syrup	No mention found	No mention found	No mention found
Mondal et al., 2024	Vitamin D3 (4000 IU/d vs 60,000 IU/fortnight)	No mention found	No mention found	No mention found

Analysis of growth outcomes:

Height/Length Changes:

- Positive effects : 7 studies showed significant improvements, with 1 study demonstrating dose- dependent effects
- Mixed results : 2 studies reported partial or inconsistent effects
- No effect : 7 studies found no significant changes

- Data gaps : Height/length change data were not found in 10 studies' available full texts or abstracts

This distribution suggests a complex relationship between interventions and linear growth, potentially influenced by factors such as intervention type, duration, or population characteristics.

Weight Changes:

- Positive effects : 6 studies reported significant weight gain
- Subgroup effects : 2 studies found improvements only in specific subgroups (e.g., boys or with zinc supplementation)
- No effect : 5 studies reported no significant changes
- Data gaps : Weight change data were not found in 14 studies' available full texts or abstracts

The variability in weight outcomes suggests that the effectiveness of interventions may depend on factors such as baseline nutritional status, age, or concurrent micronutrient deficiencies.

Growth Velocity:

- Only 1 study reported growth velocity data, showing a significant increase in Weight-for-Length z-score
- We didn't find growth velocity data in the available full texts or abstracts of 26 studies

The lack of growth velocity data in most studies limits our understanding of the interventions' effects on growth rate over time.

Nutritional Status Outcomes

Study	Intervention Type	Vitamin D Status	Other Nutritional Markers	Clinical Significance
Senbanjo	Fortified dairy	Improved in	Vitamin A, Se	600 ml most

et al., 2022	drink	400/600 ml groups ($p < 0.0001$)	improved (600 ml); no effect on I, Zn, B12, folate	effective for micronutrient status
Darwish Mohd Isa et al., 2023	Standard vs. nutrient-enriched milk	No mention found	No mention found	No mention found
Ganmaa et al., 2017	Fortified milk/Vitamin D tab	25- hydroxyvitamin D increased by ~20 ng/ml	No effect on weight/BMI; girls gained more weight	800 IU/d for 6 mo increased growth short- term
Matsuya ma et al., 2016	Fortified milk	No mention found	Reduced anemia risk (Odds Ratio=0.32)	Minimal effect on growth, reduced anemia
Brandão- Lima et al., 2019	Fortified dairy	4/5 studies: reached/maintai ned 25(OH)D sufficiency	Most reached/maintain ed 25(OH)D	Safe, no excess 25(OH)D
Brooker et al., 2022	Fortified milk	Increased in 2 studies	Hemoglobin +3.76 g/L, ferritin +0.01	Modest improvements in vulnerable

			nmol/L, urinary iodine +85 µg/L	populations
Cervo et al., 2017	Fortified milk formula	No mention found	Energy, protein, Ca, Fe, Vitamin A intake increased	Improved nutritional status
de Lamas et al., 2019	Dairy supplementation	No mention found	Bone Mineral Content increased	BMC improved, height effect inconsistent
Kuriyan et al., 2016	Fortified milk beverage	No difference	B12, folate, B2 improved; Hemoglobin/ferritin maintained	Reduced anemia, B2/B12 deficiency
Zhang et al., 2021	Oral Nutrition Supplements (cow-milk-based)	No mention found	No mention found	Improved growth in undernourished children
Dulal et al., 2021	Integrated nutrition/stimulation	No mention found	No mention found	No effect on growth, some on development

Eichler et al., 2019	Micronutrient-fortified dairy/cereal	No mention found	Hemoglobin +0.09 g/dl (Not Significant), iron deficiency anemia reduced (Relative Risk=0.38)	Marginal health effects
Zhao et al., 2021	Milk + egg	Vitamin D improved	No mention found	Reduced Vitamin D deficiency
Ponce et al., 2018	Micronutrient interventions	Improved with supplementation	Iron status improved with fortification	Commercial fortification effective
Lu et al., 2019	Fortified milk powder	55% insufficient, 7% deficient at baseline	Insulin-like Growth Factor-I increased, Parathyroid Hormone decreased	No effect on bone mineralization
Ara et al., 2021	Egg/milk snack + Micronutrient Powder Formula milk	No mention found	No mention found	Improved LAZ, stunting, development

Li et al., 2023	Formula milk	25(OH)D +5.54% (p=0.001)	Osteocalcin, Parathyroid Hormone, Insulin-like Growth Factor-I improved	Enhanced bone acquisition
Huynh et al., 2016	Oral Nutrition Supplements (450 ml/d)	No mention found	Adequacy for energy, protein, Fe, Ca, Vitamin A, C, B1, B2, niacin improved	100% adequacy for most nutrients
Ara et al., 2022	Egg/milk snack + Micronutrient Powder	No mention found	No mention found	Improved LAZ, reduced stunting
Le Port et al., 2017	Micronutrient- fortified yogurt	No mention found	Hemoglobin +0.55 g/dL vs control	Anemia prevalence decreased
Wang et al., 2017	Micronutrient- fortified milk	No mention found	Ferritin, B2, Iron improved; D, B12, Se Not Significant	Improved academic performance
Hidayat et al.,	Dairy supplementation	No mention found	Bone Mineral Content	Improved bone health

2023			+28.37g, areal Bone Mineral Density +0.016g/cm	indices
Ansuya et al., 2023	Nutrition-focused intervention	No mention found	No mention found	Improved cognitive development
Helmyati et al., 2021	Synbiotic Fe-Zn milk	No mention found	No mention found	No significant effect
Tytusa et al., 2022	Diet modification $\pm$ Ca/Vitamin D	48.2% had low Vitamin D at baseline	Ca normalized in 66.7% (supplementation) vs 20% (diet only)	Supplementation more effective
Añorve-Valdez et al., 2018	Fortified milk/Micronutrient Powder/syrup	No mention found	Fortified Food group: smaller increases in energy, protein, Fe, Zn vs others	Micronutrient Powder adequate for those meeting energy/protein needs
Mondal et al.,	Vitamin D3 (4000 IU/d vs	All achieved sufficiency	Ca, P increased; Alkaline	Both regimens

2024	60,000 IU/fortnight)		Phosphatase, Parathyroid Hormone decreased	effective; transient hypercalcemi a
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Analysis of nutritional status outcomes:

- Vitamin D status : Improved in 8 studies, unchanged in 1, baseline status only reported in 2
- Other nutritional markers : Improvements in iron/hemoglobin/anemia (5 studies), other micronutrients (7), bone health indices (5), growth/anthropometry (4), cognitive/developmental outcomes (4), iodine (1)
- Clinical significance : General micronutrient status improved (9studies), anemia/iron status (4), bone health (5), growth/anthropometry (4), cognitive/developmental outcomes (4), no significant effect (1)
- Data gaps : No information on other nutritional markers in 10 studies, no clinical significance information in 1 study

The evidence suggests that fortified cow's milk and Vitamin D supplementation can improve various aspects of nutritional status, particularly Vitamin D levels and other micronutrients. However, the effects are not uniform across all studies or outcomes.

Combined Intervention Effects

- Synergistic approach : Combining cow's milk with other interventions (e.g., eggs, micronutrient powders, counseling) showed greater improvements in growth outcomes
- Population impact : Most effective in severely malnourished populations

Studies like Ara et al. (2021, 2022) demonstrate that comprehensive intervention packages combining multiple strategies produce greater improvements in linear growth and stunting

reduction compared to single interventions. This suggests that addressing multiple nutritional deficiencies simultaneously may be necessary for meaningful effects in severely malnourished populations.

Duration and Dosage Considerations

- Intervention length : Longer durations (6 months) generally associated with greater improvements
- Dosage effects : Higher doses of fortified milk or Vitamin D linked to better outcomes in some studies
- Modulating factors : Adherence, baseline deficiency, and co-interventions likely influence effectiveness
- Inconsistent results : Some shorter or lower-dose interventions still reported benefits, particularly for micronutrient status

Studies with longer intervention durations (e.g., Ganmaa et al., 2017; Brooker et al., 2022) and higher doses of fortified milk or Vitamin D tend to show greater improvements in nutritional biomarkers and growth outcomes. However, the evidence is mixed, with some shorter-duration or lower-dose studies also reporting benefits, particularly for micronutrient status. This variability suggests that factors such as adherence, baseline nutritional status, and concurrent interventions may modulate the effects of cow's milk and Vitamin D supplementation.

Summary

- Intervention effects : Fortified cow's milk with Vitamin D supplementation improves Vitamin D status and may modestly promote weight gain and linear growth in malnourished or at-risk children
- Comprehensive approaches : Greatest benefits observed in intervention packages combining multiple strategies
- Population factors : Most effective in populations with baseline deficiencies
- Other nutritional markers : Some studies report improvements in iron, B12, and B2 status

- Safety : Adverse effects rare but should be monitored, especially with high-dose Vitamin D
- Limitations : Study heterogeneity, methodological concerns, and context-specific factors limit generalizability of findings

The evidence suggests that fortified cow's milk with Vitamin D supplementation can improve nutritional status, particularly Vitamin D levels, in malnourished or at-risk children. Effects on growth are more modest and variable. Comprehensive intervention packages that address multiple nutritional deficiencies simultaneously appear to be most effective, especially in severely malnourished populations. The variability in outcomes across studies highlights the importance of considering factors such as baseline nutritional status, intervention duration, and dosage in designing effective nutritional interventions.

DISCUSSION

The systematic review of studies examining the impact of fortified cow's milk combined with Vitamin D supplementation on malnourished children reveal significant improvements in nutritional status and modest gains in growth metrics. Key findings include elevated Vitamin D levels (e.g., a 56% increase in 25-hydroxyvitamin D) and improvements in other micronutrients such as iron, vitamin A, and selenium (Senbanjo et al., 2022). However, growth outcomes, such as height and weight, showed variability, with some studies reporting statistically significant improvements (e.g., height-for-age z-scores, $p < 0.0001$) while others found no effect (Ganmaa et al., 2017; Matsuyama et al., 2016).

Vitamin D deficiency is a critical issue in malnourished populations, and fortified milk interventions consistently improved serum 25-hydroxyvitamin D levels. For example, daily supplementation with 800 IU of Vitamin D over six months increased levels by approximately 20 ng/mL (Ganmaa et al., 2017). These findings underscore the efficacy of fortified milk in addressing deficiencies, particularly in regions with limited sunlight exposure or dietary diversity.

The effects on linear growth and weight gain were mixed. While some trials reported

significant improvements (e.g., a 0.9 cm increase in height with 800 IU Vitamin D, $p = 0.003$), others found no statistically meaningful changes (Brooker et al., 2022). Weight gains ranged from 0.14 kg to 1.35 kg, with the most pronounced effects observed in studies combining milk with additional nutrient sources like eggs or micronutrient powders (Cervo et al., 2017; Ara et al., 2021).

Interventions that integrated fortified milk with other nutritional strategies (e.g., eggs, counseling, or micronutrient powders) demonstrated superior outcomes. For instance, Ara et al. (2022) reported a 2.62 cm increase in height and a 0.37 improvement in length-for-age z-scores ($p < 0.001$) when milk was paired with eggs and counseling. This suggests that addressing multiple nutrient deficiencies simultaneously may be more effective than standalone milk supplementation.

Longer intervention durations (≥ 6 months) and higher doses of fortified milk or Vitamin D were associated with better outcomes. For example, Senbanjo et al. (2022) found that 600 mL of fortified milk daily for six months significantly improved micronutrient status and growth, whereas shorter or lower-dose interventions yielded inconsistent results.

The effectiveness of interventions varied by baseline nutritional status, age, and geographic location. Studies in severely malnourished populations (e.g., stunted children in Bangladesh) showed more pronounced benefits compared to healthier cohorts (Zhang et al., 2021). This highlights the importance of tailoring interventions to specific population needs.

Fortified milk also improved other biomarkers, including hemoglobin (reducing anemia risk by 68% in some studies) and bone mineral content (Hidayat et al., 2023). These secondary benefits further support the role of fortified milk in comprehensive nutritional interventions.

Adverse effects were rare but included transient hypercalcemia in high-dose Vitamin D regimens (Mondal et al., 2024). Most studies reported no serious side effects, affirming

the safety of fortified milk interventions within recommended dosages.

The findings advocate for integrating fortified milk and Vitamin D into national nutrition programs, particularly in LMICs. Policymakers should prioritize scalable, cost-effective strategies, such as school-based milk programs or community supplementation initiatives (Brando-Lima et al., 2019).

Future studies should standardize intervention protocols, include longer follow-up periods, and explore the cost-effectiveness of combined interventions. Research is also needed to assess the sustainability of these programs in real-world settings.

Fortified cow's milk with Vitamin D supplementation is a promising strategy to improve nutritional status and growth in malnourished children. While growth effects are modest, the consistent improvements in micronutrient biomarkers and the potential for synergistic effects with other interventions make it a valuable tool in global malnutrition reduction efforts.

CONCLUSION

The findings underscore the significant role of fortified cow's milk and Vitamin D supplementation in addressing malnutrition among children. Regular consumption of fortified milk, particularly in quantities around 600 ml daily, has been shown to elevate Vitamin D levels and improve other critical micronutrient deficiencies, such as iron and vitamin A. These improvements are essential for combating the multifaceted challenges of malnutrition, particularly in vulnerable populations.

While the impact on growth metrics like height and weight is modest, the consistent improvements in nutritional biomarkers highlight the intervention's value. The most notable gains were observed in severely malnourished children, emphasizing the need for targeted approaches in high-risk groups. The variability in outcomes across studies suggests that factors such as baseline nutritional status, intervention duration, and dosage play pivotal roles in determining effectiveness.

The evidence strongly supports the integration of fortified milk and Vitamin D into broader

nutritional programs, especially in low-resource settings. Combining these interventions with other nutrient-rich foods or supplementation strategies enhances their efficacy, demonstrating the importance of holistic approaches. For instance, pairing milk with eggs or micronutrient powders yielded superior results, reinforcing the idea that addressing multiple deficiencies simultaneously is more impactful than isolated interventions.

Longer intervention periods (six months or more) and higher dosages were consistently associated with better outcomes, suggesting that sustained efforts are crucial for meaningful improvements. This insight is vital for policymakers and public health practitioners designing scalable and sustainable nutrition programs. The safety and feasibility of these interventions further bolster their potential for widespread adoption.

Ultimately, fortified cow's milk and Vitamin D supplementation represent a practical and evidence-based strategy to mitigate malnutrition in children. While growth improvements may be gradual, the broader benefits to micronutrient status and overall health make this approach indispensable. Future efforts should focus on refining intervention protocols, ensuring accessibility, and integrating these strategies into national and global nutrition initiatives to maximize their impact on child health.

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