Review Article

Vitamin D and Pneumonia in Children: Immunological Mechanisms, Clinical Outcomes, and Current Evidence

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ABSTRACT

Background: Vitamin D plays a notable role in regulating both innate and adaptive immunity. It supports the production of antimicrobial peptides, promotes autophagy, and helps control inflammatory signaling. These functions suggest that vitamin D may contribute to respiratory defense. However, the relationship between vitamin D levels and childhood pneumonia remains unclear and has shown inconsistent results in different studies.

Objectives: To explore the biological mechanisms of vitamin D in respiratory immunity, evaluate the association between serum 25(OH)D levels and childhood pneumonia risk/severity, assess trial results in deficient versus replete populations, and identify sources of inconsistency across studies.

Methods: This narrative review includes observational and interventional studies from several regions, such as South Asia, the Middle East, and Africa. We included studies that reported serum 25(OH)D levels, markers of pneumonia severity, and clinical outcomes in children. Special attention was given to mechanistic evidence, dose-response patterns, and differences in findings between vitamin D deficient and vitamin D adequate populations.

Results: Observational studies show that children with pneumonia have lower vitamin D levels than healthy controls. Deficiency is associated with greater susceptibility, longer hospital stays, hypoxemia, and a higher risk of complications like sepsis. A dose-response relationship has been observed, where higher 25(OH)D levels are associated with less severe disease. However, randomized controlled trials have produced mixed results. Benefits, such as reduced recurrence and modest recovery improvements, are mainly seen in vitamin D deficient populations, with little to no effect in replete groups. These inconsistencies likely stem from differences in study design and a lack of detailed clinical endpoints.

Conclusion: Observational studies associate low vitamin D with worse pneumonia outcomes in children, but randomized control trials show inconsistent results. Potential benefits (reduced recurrence, modest clinical improvement) appear mainly in deficient children, yet causality remains unproven due to heterogeneity in study design, deficiency definitions, and outcome measures. The lack of standardized pediatric vitamin D cutoffs (ranging from <12 to <20 ng/mL) limits clinical application. Rigorous prospective trials with uniform metrics are needed to establish causality and identify which deficient children benefit most.

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Introduction

Despite major advances in vaccination and antimicrobial therapy, pneumonia remains a leading cause of childhood illness and death. In the United States, the annual incidence reaches 15.7 per 10,000 children, rising to over 60 per 10,000 among those under two years of age, emphasizing its persistent clinical and public-health burden even in high-income settings [1]. Pneumonia persists due to its multifactorial etiology, involving interactions among pathogens, host immune responses, and nutritional status. In pediatric populations, deficiencies in micronutrients, such as zinc, selenium, iron, and vitamin D compromise immune function and prolong recovery. Integrating micronutrient-focused interventions into standard pneumonia care may represent a practical and cost-effective approach to reducing severity, recurrence, and post-infectious complications alongside antimicrobial and immunization efforts [2]. Among the micronutrients, zinc, selenium, iron, and vitamins A, C, E, and D work together to maintain mucosal integrity, provide antioxidant protection, and support immune function. For example, zinc deficiency can disrupt the epithelial barrier and impair the activity of neutrophils and natural killer (NK) cells [3]. In parallel, selenium supports the function of glutathione peroxidase, which is essential for maintaining redox balance [4]. Additionally, iron availability has a significant impact on both microbial virulence and the responses of host macrophages [5]. Of all the micronutrients, vitamin D stands out as the most studied and most mechanistically complex.

Vitamin D is a fat-soluble secosteroid that acts more like a hormone than a vitamin. Its two major forms, D_2 (ergocalciferol) and D_3 (cholecalciferol), are biologically inactive until hydroxylated in the liver and kidney to calcitriol, the active metabolite. It regulates calcium-phosphate balance, supports immune function, and is stored mainly in adipose and liver tissues. Evidence from various clinical contexts suggests that vitamin D deficiency is a contributing factor to immune dysregulation and an increased risk of disease. However, it is not a singular causal factor. Epidemiological and interventional studies demonstrate that sufficient vitamin D status is associated with lower incidence and severity of respiratory and gastrointestinal infections, improved immune regulation in autoimmune conditions, such as rheumatoid arthritis [6] and multiple sclerosis [7], as well as reduced inflammatory activity in disorders like inflammatory bowel disease and periodontitis [8, 9]. However, the evidence remains inconsistent, while several studies support a protective or modulatory role, others report minimal or no clinical benefit from supplementation [10]. These discrepancies likely reflect differences in baseline deficiency, population characteristics, and dosing strategies, underscoring the complexity of vitamin D's role across inflammatory and infectious diseases.

Beyond its endocrine role in calcium-phosphate regulation, vitamin D functions as a potent immunoregulatory hormone. Its active metabolite, 1,25-dihydroxyvitamin D (calcitriol), acts via the vitamin D receptor (VDR) expressed in nearly all immune cells [11]. Within innate immunity, calcitriol promotes antimicrobial peptide production—cathelicidin and β-defensin-2—enhances macrophage chemotaxis and phagocytosis, and restricts excessive inflammation through suppression of NF-κB signaling [12-14]. In adaptive immunity, it down-modulates Th1/Th17 polarization while enhancing Th2 and regulatory T-cell responses, thus fostering a balanced immune profile that supports pathogen clearance yet prevents immunopathology [15]. These mechanisms are particularly relevant in pulmonary infections, where uncontrolled inflammation often contributes more to tissue injury than to microbial persistence.

Vitamin D is known to influence immune function, but its exact role in childhood pneumonia remains uncertain. Observational studies often report lower serum vitamin D levels in children with community-acquired pneumonia (CAP) compared with healthy peers, however the strength of this association varies by region, demographic characteristics, and study design. Intervention trials testing vitamin D supplementation during acute pneumonia have produced mixed and sometimes contradictory results. Some studies suggest modest benefits, such as slightly faster clinical improvement or reduced recurrence, while others show no significant effect on recovery. Because of these conflicts, it is still unclear to what extent vitamin D deficiency contributes to the risk or severity of pneumonia in children and whether supplements reliably improve outcomes. This uncertainty has important clinical and public-health implications. Vitamin D is inexpensive, safe, and widely accessible. If it is truly effective, it could become a simple adjunctive treatment for respiratory infections in children. However, If the deficiency is not consistently associated with severe illness, or if supplements provide only modest benefits, routine screening and treatment may be unnecessary, and this could reduce many treatment costs. By synthesizing current evidence, this narrative review seeks to clarify the true relationship between vitamin D and pediatric pneumonia and determine which children might benefit most from targeted supplementation.

Materials and Methods

Search strategy

A comprehensive literature search was conducted in PubMed, Scopus, and Google Scholar for studies published between 2000 and 2025. The search combined medical subject headings (MeSH) and free-text terms, including "vitamin D," "25-hydroxyvitamin D," "children," "pediatric," "pneumonia," "community-acquired pneumonia," "respiratory infection," "acute lower respiratory infection," "supplementation," "immunity," and "immune mechanisms."

Inclusion criteria

Studies were included if they met all the following conditions: 1) population: Children aged 0–18 years; 2) study type: Observational (cross-sectional, case–control, cohort), interventional (randomized or non-randomized trials), or mechanistic studies related to respiratory immunity; 3) outcomes: Reported serum 25(OH)D levels or vitamin D supplementation effects in relation to pneumonia; 4) setting: Community-acquired or hospital acquired pneumonia; 5) publication language: English; and 6) availability of full text with extractable data.

Exclusion criteria

Studies were excluded if they 1) were case reports, editorials, letters, conference abstracts, or narrative commentaries; 2) did not include pediatric participants; 3) did not measure vitamin D status or supplementation focused on infections other than pneumonia or acute lower respiratory infection (ALRI); 4) lacked original clinical or mechanistic data; and (5) were non-English publications.

Study selection

The initial search identified 1247 records. After removing duplicates and screening titles and abstracts, 87 articles underwent full-text review. Following application of inclusion and exclusion criteria, 41 studies were included in the final synthesis, comprising 1) 17 observational studies (cross-sectional, case–control, cohort), 2) 12 randomized or quasi-experimental trials, and 3) 12 mechanistic or immunological studies. Figure 1 illustrates the study selection process, including identification, screening, eligibility assessment, and final inclusion, along with detailed reasons for excluding records at each stage.

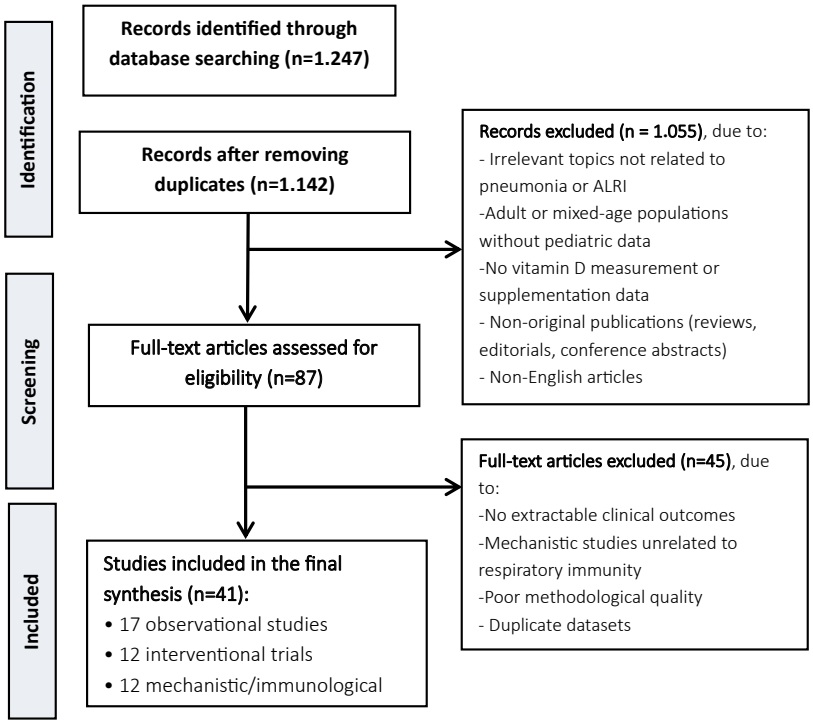

Figure 1. The study selection process, showing the number of records identified, screened, excluded with reasons, and the 41 studies included in the final synthesis

Data extraction

Key variables extracted from each study included 1) study design and country; 2) sample size and age range; 3) definitions of vitamin D deficiency/insufficiency; 4) serum 25(OH)D levels (ng/mL or nmol/L); 5) pneumonia severity markers (hypoxemia, oxygen requirement, hospitalization duration, sepsis, mortality); 6) supplementation regimen (dose, frequency, baseline status); 7) primary outcomes: Disease severity, clinical recovery, recurrence; and 8) secondary outcomes: inflammatory markers, mechanistic endpoints.

Age stratification considerations

Although studies spanning the full 0–18 years age range were included, we did not perform a formal age-stratified subgroup analysis due to inconsistent reporting of age-specific outcome data in the original studies. Most observational studies and trials reported mean or median ages for the entire cohort without providing separate outcome data for infants (0–12 months), young children (1–5 years), and older children/adolescents (6–18 years). Where age-specific data were available in individual studies, they are noted in the results. However, the absence of systematic age stratification across the literature represents a significant gap, as immune system maturity, vitamin D metabolism, and pneumonia pathophysiology differ substantially across these developmental stages.

Vitamin D and Immune Regulation

Vitamin D metabolism

Vitamin D is synthesized in the skin upon UVB exposure and converted in the liver to 25-hydroxyvitamin D [25(OH)D], the circulating form used to assess status. Renal 1α-hydroxylation produces active 1,25-dihydroxyvitamin D (calcitriol), which binds the VDR expressed in immune cells [16-18]. Critically, immune cells such as monocytes and macrophages also express the enzymes needed for local calcitriol synthesis, enabling on-site immunomodulation independent of renal production [19-21].

Innate immune system enhancement

When respiratory pathogens trigger toll-like receptors (TLRs) on pulmonary macrophages, local calcitriol production increases, inducing antimicrobial peptides — particularly cathelicidin (LL-37) and β-defensin-2 — which disrupt bacterial and viral membranes [12, 24-26]. In human studies, children with lower vitamin D levels have reduced cathelicidin expression in respiratory epithelial cells, correlating with impaired pathogen clearance [24]. Vitamin D also enhances macrophage phagocytosis and chemotaxis [27].

A major anti-inflammatory function relevant to pneumonia is the suppression of NF-κB signaling. Excessive NF-κB activation drives potentially harmful levels of tumor necrosis factor (TNF)-α, interleukin (IL)-1β, and IL-6, which can cause pulmonary tissue injury. Calcitriol limits this response by increasing IκBα (an NF-κB inhibitor) and modulating anti-inflammatory microRNAs, such as miR-146a [28-33]. This dual action—promoting pathogen killing while restraining excessive inflammation—is particularly important in pediatric pneumonia, where immunopathology often contributes more to respiratory failure than the infection itself.

Adaptive immunity modulation

Vitamin D shapes adaptive responses by promoting a shift away from Th1/Th17 (pro-inflammatory) toward Th2 and regulatory T-cell (Treg) responses [34-38]. In the context of pneumonia, this balance may help resolve inflammation after pathogen clearance and reduce the risk of post-infectious airway hyperreactivity. However, maximum evidence for adaptive immune effects comes from autoimmune disease models (e.g. multiple sclerosis, inflammatory bowel disease); direct evidence in children with pneumonia is limited [39-41].

Autophagy regulation

Vitamin D also regulates cellular cleanup and defense through autophagy. Through the calcitriol-VDR pathway, it activates genes like Beclin-1 and Atg5 and increases the antimicrobial protein LL-37, helping autophagosomes form and destroy pathogens [42, 43]. In macrophages, this action speeds up bacterial clearance, improves antigen presentation, and reduces cell stress [44]. Vitamin D also enhances autophagy and lowers inflammation by blocking mTOR and activating AMPK [45].

Summary of clinical relevance

The mechanisms above suggest that vitamin D deficiency could plausibly increase pneumonia susceptibility and severity by 1) reducing antimicrobial peptide production in the airways, 2) impairing macrophage function, and 3) permitting unchecked NF-κB-mediated pulmonary inflammation. However, as discussed in Section 4, human trials have not consistently confirmed these mechanistic predictions, highlighting a gap between in vitro biology and clinical outcomes (Figure 2).

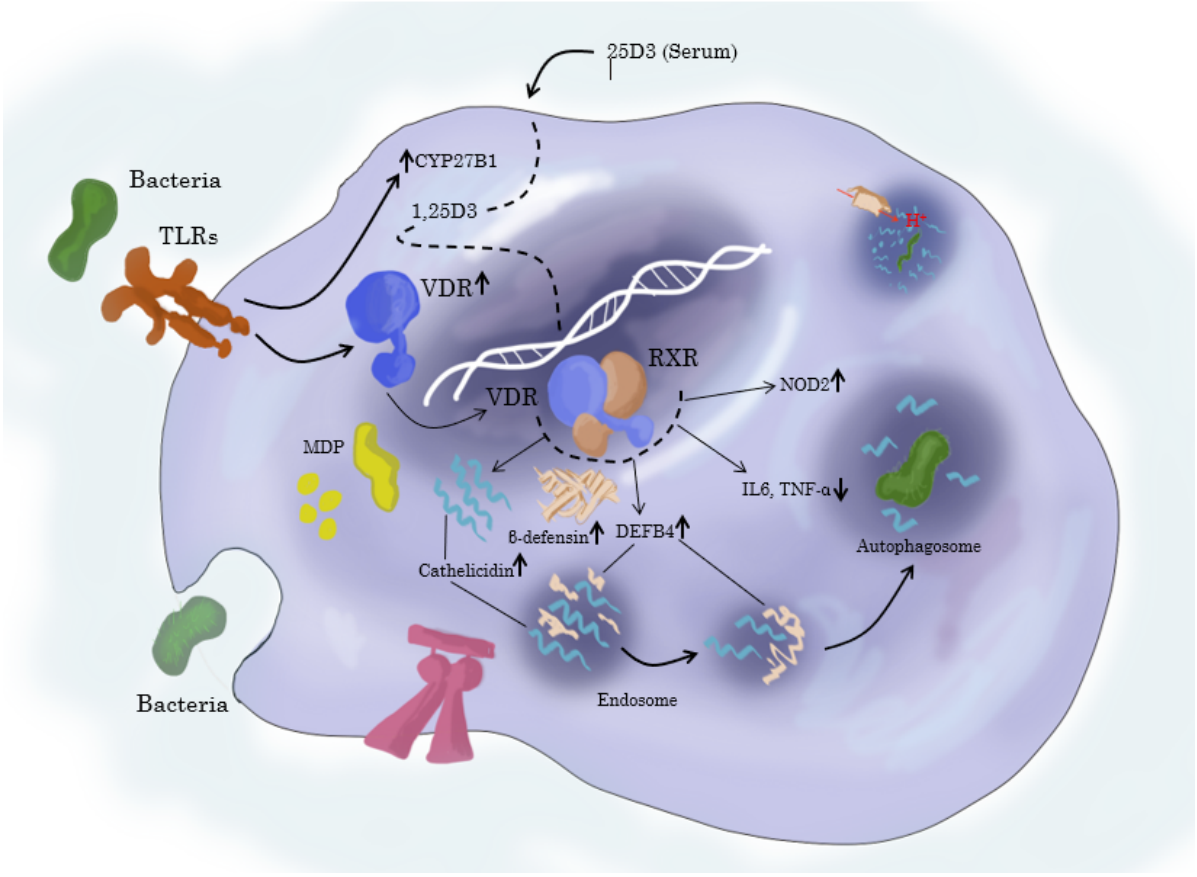

Figure 2. Mechanistic overview of vitamin d-driven innate immunity

Note: Bacterial recognition through TLRs triggers monocytes and macrophages to convert 25(OH)D to active 1, 25$(OH)_2$D, which binds the VDR-retinoid X receptor (VDR–RXR) complex and induces antimicrobial pathways. This activation increases cathelicidin (LL-37) and β-defensin 2, enhances autophagy and NOD2 signaling, and suppresses proinflammatory cytokines, such as IL-6 and TNF-α. Together, these actions strengthen bacterial clearance while limiting excessive inflammation. This figure was designed and implemented with Sketchbook software, version 6.2.4 on iOS by the first author of the article.

Clinical Evidence on Vitamin D and Pediatric Pneumonia

Vitamin D status in children with pneumonia

Clinical observations suggest that vitamin D deficiency may influence both the risk and severity of pneumonia in children. In hospitalized patients, lower serum vitamin D levels are associated with longer illness, more complications, and in some cases, increased mortality. This relationship may indicate that vitamin D serves as a marker of disease severity rather than merely reflecting nutritional status, underscoring the need to assess its impact across different populations. Early evidence for this association comes primarily from observational studies. In China, Li et al. [46] observed that children hospitalized with pulmonary infections had markedly lower serum 25(OH)D concentrations than healthy controls. Also, this deficiency correlated with disease severity after adjusting for confounding factors. The deficiency was most marked in children with sepsis, who had the highest severity scores and complication rates. By identifying a 25(OH)D threshold of 18.15 ng/mL that predicted sepsis, the study demonstrated that insufficient vitamin D aligns with both higher pneumonia risk and more severe outcomes, including longer hospitalization and organ failure. Similar associations appeared in Nigeria, where Oduwole et al. [47] showed that pneumonia cases with serum 25(OH)D below 70 nmol/L (28 ng/mL) were more likely to develop hypocalcemia, anemia, and complications, such as empyema or even death. In Indonesia, Oktaria et al. [48] found that over four-fifths of pediatric pneumonia patients were vitamin D deficient and that deficiency nearly tripled the odds of severe disease. They examined vitamin D levels in 133 Indonesian children hospitalized with pneumonia. Over 80% were vitamin D deficient, and deficiency was strongly associated with increased disease severity (odds ratio [OR]: 2.84; 95%

CI, 1.11%, 7.25%). Deficient children exhibited greater respiratory distress and longer hospitalization. The study identified a high prevalence of vitamin D deficiency and established a significant association between low vitamin D status and increased pneumonia severity. These findings suggest that assessment of vitamin D status may serve as a valuable adjunct to clinical evaluation in pediatric respiratory illness, particularly when accounting for variables that may modulate disease severity. These geographically distinct studies share a common message that vitamin D deficiency is associated with poorer outcomes and longer recovery, indicating biological vulnerability, not a simple marker of malnutrition.

To expand on this view, further studies have examined the interactions between multiple micronutrients. Alsharkawy and Rezk [49] in Egypt demonstrated that deficiencies of vitamin D, zinc, and iron often coexist and jointly predict greater pneumonia severity and longer hospitalization. This perspective places vitamin D within a broader nutritional system, showing it is not acting alone but contributing to overall resilience. A similar perspective emerges from Dinlen et al. [50], who traced the chain of deficiency back to the perinatal period. In their Turkish cohort, neonates with ALRIs had significantly lower vitamin D levels than controls, a pattern that is also observed in their mothers. Maternal vitamin D insufficiency may influence an infant's immune system and increase vulnerability even before environmental exposure begins. In a Turkish case–control study of 60 term newborns, infants with acute lower respiratory tract infection (ALRTI) and their mothers had much lower 25(OH)D levels than healthy controls. Deficiency (≤15 ng/mL) was strongly linked to a higher risk of ALRTI (OR: 5.3; 95% CI, 1.3%, 21.1%). Maternal and neonatal levels were closely correlated, and lower vitamin D levels predicted longer oxygen therapy, showing how a mother's deficiency can shape her infant's early immune responses.

The idea that vitamin D deficiency directly causes respiratory illness is complicated by studies that do not show a simple cause-and-effect pattern. Large trials in South Asia, for instance, have not found a clear preventive benefit. In Bangladesh, Roth et al. [51] followed over a thousand infants and found no meaningful link between baseline vitamin D levels and later ALRI, despite widespread deficiency. Another study in Bangladeshi infants aged 1–18 months reported lower 25(OH)D levels in children with ALRI and showed that each 10 nmol/L (4 ng/mL) increase was associated with a 47% drop in ALRI risk, even after adjusting for confounders. This suggests that vitamin D deficiency may still play an independent role in early childhood susceptibility.

Research emerging from recent viral outbreaks adds useful clarity to the picture. Alpcan et al. [52] found that Turkish children with COVID-19 had much lower vitamin D levels than healthy controls and showed higher inflammatory markers, suggesting that low vitamin D may increase the risk of infection or lead to a stronger inflammatory response. In a related finding, Golan-Tripto et al. [53] found that infants with acute bronchiolitis had much lower 25(OH)D levels than controls (median 11.2 ng/mL vs 20 ng/mL), with deficiency present in 73% of cases compared with 51% of controls. These infants also needed longer oxygen therapy, suggesting that low vitamin D may influence airway inflammation. Although bronchiolitis is not pneumonia, the pattern mirrors findings from bacterial infections, where deficiency seems to amplify how strongly the illness presents.

Taken together, these studies show that vitamin D's role in pediatric pneumonia is more nuanced than a simple protective effect. It does not act as a universal shield, but rather as a biological modulator whose impact depends on context, timing, and the degree of deficiency. Across different regions, low 25(OH)D levels consistently track with poorer outcomes such as longer recovery, hypocalcemia, anemia, and higher inflammation. However, supplementation trials make it clear that correcting deficiency does not automatically prevent illness or speed recovery. This issue suggests that vitamin D works alongside other micronutrients and immune factors instead of functioning on its own. Its importance lies in maintaining immune readiness, supporting macrophage activity, shaping cytokine responses, and preventing excessive inflammation. In settings where children face both poor nutrition and low sunlight exposure, keeping vitamin D levels sufficient may lower recurrence and reduce complications, providing a low-cost addition to current pneumonia control efforts. In contrast, in populations where children already have adequate levels, supplementation seems to offer limited benefit, highlighting the need for more targeted public health approaches. Overall, the evidence positions vitamin D not as a cure or a vaccine-like tool, but as a physiological support that helps maintain immune balance and respiratory resilience in early childhood. Table 1 provides a summary of the observational studies evaluating the association between serum 25(OH)D concentration and the clinical severity, progression, and outcomes of pneumonia in children.

Table 1. Summary of observational studies examining vitamin d status and clinical outcomes in pediatric pneumonia

Study Type	Study Sample	Mean Age	Vitamin D Status	Study Result	Ref.
Case–control study	84 children (42 with severe pneumonia, 42 with pneumonia)	11.5 months	Mean: 23.8±10.9 ng/mL	Multivariate analysis identified vitamin D insufficiency (odds ratio [OR]: 4.71) and cigarette smoke exposure (OR: 5.19) as independent predictors of severe pneumonia. Low vitamin D increased severity risk nearly fivefold, even after adjusting for nutritional and immunization factors, highlighting its role in pediatric respiratory defense.	[64]
Case–control study	31 CAP patient's vs 36 healthy controls	Median age ~12 months in patients, ~10.5 months in controls	Patients: 37.3±20.6 nmol/L vs controls: 82.5±30.7 nmol/L	Children with CAP had much lower vitamin D levels than controls, and deficiency was linked to greater severity. Zinc deficiency also correlated with CAP, while iron showed no association. These findings suggest that adequate vitamin D and zinc support innate immunity and may lower pneumonia risk in early childhood.	[49]
Observational case–control study	1582 children (797 with CAP and 785 healthy controls)	3.2 years (range 3 days–14 y)	Mean 25(OH)D: insufficient (25.32 ng/mL); CAP group: 19.04 ng/mL; controls: 31.71 ng/mL (P<0.001); sepsis subgroup: 15.96 ng/mL (lowest)	Low 25(OH)D levels were strongly associated with CAP and sepsis severity. Children with lower levels more often required ventilation or developed organ dysfunction, and an 18.15 ng/mL cut-off predicted sepsis. The authors suggested vitamin D deficiency may serve as a severity marker in pediatric CAP.	[46]
Prospective case–control study	60 term newborns (30 with ALRTI and 30 healthy controls) and their mothers.	Study group: 12.2±4.6 days; control group: 10.3±5.2 days.	Deficiency cutoff: ≤15 ng/mL; Neonatal 25(OH)D: 9.5 ng/mL (ALRTI) vs 15.5 ng/mL (controls); maternal 25(OH)D: 11.6 ng/mL (study group) vs 17.3 ng/mL (controls), (P=0.0001)	Newborns with ALRTI and their mothers had much lower 25(OH)D levels than controls. Neonatal deficiency (≤15 ng/mL) sharply increased ALRTI risk (OR: 5.3). Maternal and neonatal levels were strongly correlated, and lower neonatal vitamin D predicted longer oxygen therapy. The authors suggested that correcting maternal deficiency may help protect newborn respiratory health.	[50]
Hospital-based cross-sectional study	Sample: 133 children hospitalized with WHO-defined pneumonia; Vitamin D data available: 127 children	12 months	Mean 67±24 nmol/L; 19% (25/127) were deficient (<50 nmol/L). Of those, 36% had very low levels (<30 nmol/L).	In Indonesian children with pneumonia, vitamin D deficiency was frequent but not related to severity or hospital outcomes. Young age, low birth weight, and poor nutrition were the main predictors of severe disease and hypoxemia. The authors suggested that vitamin D may not independently affect severity and recommended larger studies to clarify its role.	[48]
Cross-sectional observational study	103 children with confirmed COVID-19 infection and 140 healthy controls	Children aged 1 month–18 years (mean age≈9 years)	Mean 25(OH)D: 21.5 ng/mL (COVID-19) vs 28.0 ng/mL (controls), P<0.001; Deficiency <20 ng/mL: 41% (cases) vs 19% (controls)	Lower vitamin D levels were associated with higher inflammatory markers and greater disease severity in children with COVID-19. The authors suggested that vitamin D insufficiency may contribute to immune dysregulation and increase susceptibility to respiratory viral infections.	[52]
Matched case–control study	50 children (25 hospitalized with acute lower respiratory infection [ALRI] and 25 healthy controls)	4.2 months	Mean 25(OH)D levels were lower in ALRI cases than controls (29.1 vs 39.1 nmol/L, P=0.015). Each 10 nmol/L increase in 25(OH)D was linked to a 47% reduction in ALRI risk (OR: 0.53; 95% CI, 0.30%, 0.96%).	Lower vitamin D levels were strongly associated with increased ALRI risk in Bangladeshi infants, and the association remained significant after adjusting for socioeconomic and nutritional factors (adjusted OR: 0.23; 95% CI, 0.06%, 0.81%). The authors concluded that vitamin D deficiency may raise susceptibility to respiratory infections in early childhood, suggesting potential benefit for supplementation in low-resource settings.	[51]
Case–control	24 children with pneumonia vs 10 controls (total=34)	Mean 20 months (cases) vs 21 months (controls)	Mean 20 months (cases) vs 21 months (controls)	In Nigerian children with pneumonia, vitamin D insufficiency was common and linked to serious complications, while severe deficiency was associated with empyema and death. The authors suggested improving vitamin D status to help reduce severe pneumonia risk.	[47]

One major obstacle to synthesizing evidence across studies is the lack of a standardized cutoff for vitamin D deficiency in pediatric populations. Definitions vary widely: some studies use ≤15 ng/mL (37.5 nmol/L) [50], others <20 ng/mL (50 nmol/L) [52], and still others <12 ng/mL (30 nmol/L) [58] or <30 nmol/L [48]. This variation has direct consequences for observed associations. For example, studies adopting a stricter <12 ng/mL threshold tend to show stronger correlations with severe outcomes (e.g. sepsis, prolonged ventilation) because only profoundly deficient children are classified as "deficient." Conversely, studies using a more liberal <20 ng/mL cutoff may dilute effect sizes by including children with moderate insufficiency in the deficient group. Furthermore, none of these cutoffs have been rigorously validated for respiratory outcomes in children; most are extrapolated from bone health standards in adults. This lack of pediatric-specific, outcome-based thresholds severely limits cross-study comparability and hinders the translation of research findings into clinical practice. Until consensus is reached on age-appropriate, pneumonia-relevant 25(OH)D cutoffs, the true relationship between vitamin D status and pediatric pneumonia will remain difficult to quantify.

Vitamin D supplement therapy and prevention of pneumonia.

Recent clinical research has examined the potential role of vitamin D in preventing respiratory infections in young children. Although multiple studies have investigated this association, the evidence does not currently support a clear conclusion about the preventive efficacy of supplemental vitamin D.

Evidence suggests that children with low vitamin D levels are more vulnerable to respiratory infections, and supplementation in deficient individuals can reduce the risk of recurrence. In a hospital-based case-control study, Leis et al. [54] found that children with lower weight-adjusted vitamin D intake had a substantially higher risk of ALRI. Intake below 80 IU/kg/d was associated with nearly a 5-fold increase in ALRI odds, indicating a possible protective threshold during winter months. Findings from low-income regions have reinforced this association. Jadhav et al. [55] conducted a randomized trial in 310 Indian children aged 1–5 years and found that a single 120000 IU dose of cholecalciferol accelerated recovery from acute respiratory infection and reduced recurrence over 6 months (32% to 7.7%). These findings suggest that restoring vitamin D stores, even with a single high dose, may offer prolonged immunological benefit in children who are likely deficient. In India, Singh et al. [56] conducted a trial assessing vitamin D supplementation's effect on recurrent pneumonia in children. Ninety-one children received either 300000 IU of vitamin D every 3 months or a placebo for 1 year. The intervention group had a lower vitamin D deficiency rate (32.6%) compared to the control group (55.6%). The vitamin D group experienced a slight reduction in respiratory infections and hospital admissions, but these differences were not statistically significant, and no adverse effects were reported. The authors concluded that while quarterly vitamin D supplementation showed a modest preventive trend, it did not significantly decrease the recurrence of the condition.

In contrast, Manaseki-Holland et al. [57] conducted a randomized trial in Kabul with 453 children hospitalized for pneumonia. A single 100000 IU vitamin D_3 dose did not shorten recovery (4.7 vs 5.0 days; P=0.17) but significantly reduced 90-day recurrence (45% vs 58%; relative risk [RR]: 0.78; P=0.01) and prolonged time to recurrence, with no reported adverse effects. Also in India, Gupta et al. [58] ran a double-blind, placebo-controlled trial involving 324 children with severe pneumonia, giving either a single 100,000 IU dose of vitamin D_3 or placebo. Vitamin D supplementation shortened the time to clinical improvement slightly (30 vs 31 hours; P=0.005) but had no meaningful impact on recurrence, hospitalization duration, fever clearance, or immune markers. Although supplementation increased serum vitamin D levels, the authors concluded that it provided minimal clinical or immunologic benefit and does not support routine use in pneumonia management. Recent evidence from Romania supports the relationship found by Tanase et al. [59], who discovered that children who received regular vitamin D supplementation (more than 800 IU per week) and maintained serum 25(OH)D levels above 30 ng/mL experienced significantly fewer respiratory infections compared to their non-supplemented peers. This association remained significant even after adjusting for age and nutritional factors, highlighting the role of vitamin D as a modifiable factor in pediatric respiratory health.

Rajshekhar et al. [60] studied the effects of vitamin D supplementation on recovery from severe pneumonia in 96 Indian children aged 2 months to 5 years. Participants received either 1000 IU (under 1 year) or 2000 IU (over 1 year) of vitamin D daily, or a placebo, alongside standard treatment. The average ages were 1.94 and 2.08 years. The results revealed no significant differences in recovery time, symptom resolution, or hospitalization duration between the groups. Thus, the authors concluded that short-term, low-dose vitamin D supplementation

offers no measurable benefits in treating severe pediatric pneumonia. Aglipay et al. [61] ran a multicenter, double-blind RCT in Toronto testing whether 2000 IU/d vitamin D prevents winter viral URTIs versus the recommended 400 IU/day in 703 healthy children aged 1–5 years. Parents collected nasal swabs for laboratory confirmation. Despite raising mean 25(OH)D to 48.7 ng/mL vs 36.8 ng/mL, high-dose vitamin D did not reduce total laboratory-confirmed URTIs (incidence rate ratios [IRR]: 0.97; 95% CI, 0.80%, 1.16%), nor hasten time to first infection; parent-reported illnesses were similar. A secondary finding suggested fewer influenza infections with high dose, but absolute differences were small. The authors concluded routine high-dose vitamin D for URTI prevention is not supported. The evidence suggests that vitamin D may only help prevent respiratory infections in children under specific conditions. How well it works depends on factors such as whether children are already low in vitamin D, how the vitamin is given, and the group's risk level. Studies conducted in regions where vitamin D deficiency is prevalent among otherwise healthy children, such as India and Afghanistan [62, 63], indicate that vitamin D plays a role in preventing recurrent infections, though it does not necessarily confer protection against the initial infection. In countries where most children receive sufficient vitamin D, such as Canada, additional vitamin D doesn't appear to offer significant benefits, except possibly in preventing the flu. How vitamin D is administered also matters: taking it daily or weekly helps maintain steady levels and supports the immune system, while taking large amounts at once can cause fluctuations that do not provide as effective protection. Furthermore, because studies employ different methods to measure results, it is challenging to compare them directly. Some studies examine recurrent or doctor-diagnosed infections, which can be influenced by nutrition, while others count only pneumonia seen on X-rays, a more specific but complex condition.

Overall, although vitamin D supplementation does not reliably prevent a child's first episode of pneumonia, correcting a deficiency can reduce recurrent infections and lower the risk of some viral illnesses. The strongest benefits appear in children who are truly vitamin D-deficient. From a public health perspective, targeting undernourished or high-risk groups is more effective than universal high-dose supplementation. Providing regular, moderate doses to deficient children helps reduce respiratory recurrence, whereas extra supplementation offers little added value for those with adequate levels. In summary, vitamin D supports immune function and decreases respiratory infection risk in vulnerable children, but it should be considered a complementary measure rather than a substitute for vaccines. Table 2 summarized the interventional trials assessing the effect of vitamin D supplementation on clinical outcomes in children with pneumonia.

Future directions

Future research on vitamin D and childhood infections needs to focus on finer clinical details to reach reliable conclusions. Most existing studies only measure broad outcomes like infection rates or hospitalization, which cannot show how vitamin D affects the course of illness. Future studies should follow children over time and track specific indicators of recovery, such as how quickly fever resolves, how long oxygen is needed, changes in inflammatory markers like C-reactive protein and IL-6, and whether infections recur. Randomized trials should also use doses that reliably correct deficiency and recheck vitamin D levels during treatment. Including immune markers such as cathelicidin or cytokine profiles can help explain why vitamin D works in some children but not others. Only by collecting these detailed clinical and biological measures can future research determine the true benefit of vitamin D and identify which children are most likely to respond.

Conclusion

This review shows that vitamin D is important for childhood pneumonia, but its effects depend on the situation. In areas where many children do not get enough vitamin D, such as South Asia, the Middle East, and parts of Africa, children hospitalized with pneumonia often have lower vitamin D levels than healthy children. In these areas, not getting enough vitamin D makes children more likely to get sicker, stay in the hospital longer, and be at higher risk of low oxygen levels and serious infections. On the other hand, in richer countries where most children have enough vitamin D, giving extra vitamin D does not seem to help much. So, vitamin D should be seen as a risk factor that can be changed, and it matters most in places where children do not get enough vitamin D, do not have enough to eat, and do not get much sunlight, rather than as a treatment that helps everyone. Furthermore, because most studies pooled children across a wide age range (0–18 years) without age-stratified outcome reporting, it remains unclear whether the observed associations between vitamin D deficiency and pneumonia severity apply equally to infants, young children, and adolescents — whose immune systems differ substantially in maturity and function.

Table 2. Interventional studies evaluating vitamin D supplementation for the prevention or treatment of pneumonia in children

Study Type	Study Sample	Mean Age	Vitamin D Exposure	Study Result	Ref.
Case–control observational study	197 children (<5 y)—105 with ALRI (55 bronchiolitis, 50 pneumonia) and 92 controls	ALRI: 13.4±13.8 months; control: 13.8±15.2 months	Mean intake 48 IU/kg/d (ALRI group) vs 60 IU/kg/d (controls)	Low vitamin D intake, particularly below 80 IU/kg/d, was independently associated with increased susceptibility to acute lower respiratory infection in young children, suggesting higher weight-adjusted vitamin D intake may be protective.	[55]
Randomized, double-blind, placebo-controlled trial	453 children aged 1–36 months (224 received vitamin D3; 229 placebo)	13.2±9.1 months	Intervention: single oral dose 100000 IU vitamin D_3 in olive oil; Control: placebo (olive oil only); Both groups received standard antibiotics	Recovery time was similar between groups (4.7 vs 5 d), but pneumonia recurrence at 90 days was lower with vitamin D (45% vs 58%). The authors concluded that high-dose vitamin D_3 safely reduced recurrence in deficient children.	[57]
Prospective randomized controlled study	310 children aged 1–5 years with diagnosed ARTI	35±16.8 months (group A) and 36.3±15.5 months (group B)	Allocation: vitamin D_3 or placebo; Intervention: single oral dose 120000 IU vitamin D_3+standard treatment; control: Placebo+standard treatment	Vitamin D supplementation greatly improved outcomes: 40% recovered by day 4 compared with 5.6% on placebo (OR: 6.97, P<0.0001). Acute respiratory infections were also less frequent (7.7% vs 32.4%, P<0.001). No toxicity occurred, supporting vitamin D's safety and benefit in young children.	[55]
Randomized, double-blind, placebo-controlled trial	324 children aged 6 months–5 years with WHO-defined severe pneumonia	Median 12 months (IQR 7–19.8)	Baseline deficiency (<12 ng/mL): 39%; Intervention: Single 100,000 IU cholecalciferol dose at enrollment; Follow-up duration: 6 months	Vitamin D supplementation did not meaningfully shorten pneumonia resolution (30 h vs 31 h) or reduce 6-month recurrence (25% vs 22.8%). No differences were seen in hospitalization length, fever clearance, or immune markers. Although deficiency was corrected, supplementation provided no therapeutic or preventive benefit.	[58]
Cross-sectional Study	194 children & adolescents	1 – 18 y (mean≈ 9.6±5.1 y)	Deficient <20 ng/mL; insufficient 20–30 ng/mL; sufficient >30 ng/mL (endocrine society criteria)	Children receiving >800 IU/wk vitamin D had far fewer respiratory infections than those <400 IU/week (16.7% vs 60%, P<0.001). Levels >30 ng/mL were similarly protective (16.7% vs 61.4%, P<0.001). Multivariate analysis confirmed a strong independent preventive effect (OR: 0.23–0.28), especially in children under 6 ys.	[59]
Randomized, double-blind, placebo-controlled trial	96 children (2 months–5 years) hospitalized with severe pneumonia	1.94±1.46 y (vitamin D group) vs 2.08±1.92 years (placebo)	Intervention: Daily vitamin D tablets (1000 IU <1 y; 2000 IU >1 y) + standard antibiotics; Duration: daily dosing during hospitalization	No significant difference in resolution of severe pneumonia, symptom recovery, or hospitalization time between vitamin D and placebo. Authors concluded no therapeutic benefit from short-term supplementation when added to antibiotics.	[60]
Randomized controlled trial	91 analyzed children (<5 y) with recurrent pneumonia (46 intervention, 45 control)	Majority 1–5 y	Baseline deficiency (<20 ng/mL): 33% (intervention) vs 56% (control); intervention: oral cholecalciferol 300,000 IU every 3 months for 1 y (in milk); control: Placebo (sugar powder)	Quarterly high-dose vitamin D produced only mild, non-significant reductions in URTI/LRTI episodes, hospitalizations, and pneumonia severity. Mean LRTI episodes were similar (1.42 vs 1.72). Overall, the effect was minimal and not statistically meaningful, indicating no significant preventive benefit.	

A critical caveat must be stated at the outset. Nearly all evidence linking low vitamin D levels to pneumonia severity comes from observational studies, which cannot distinguish whether deficiency causes worse outcomes or simply serves as a marker of poorer overall health, malnutrition, or reduced sunlight exposure. Randomized controlled trials—the gold standard for establishing causality—have produced mixed results, and even among positive trials, the clinical benefits have been modest. Therefore, while the association is consistent, a causal role for vitamin D in modifying pneumonia severity remains unproven.

In studies where children were given vitamin D, the results are clearer when looking at specific signs of improvement, such as how quickly serious pneumonia symptoms resolve, when fever returns to normal, improved oxygen levels, slower breathing, and shorter hospital stays. In some studies, vitamin D helped prevent pneumonia from coming back, but it did not often help children get better faster, and even when it did, the improvements in things like fever or oxygen needs were small. This shows that vitamin D is better at preventing future cases of pneumonia than at helping children recover quickly.

How vitamin D is given also affects the results. Review studies show that giving very large single doses (100000–300,000 IU) raises vitamin D levels quickly but may not keep the immune system strong for long. Giving smaller amounts every day or every week (1000–2000 IU per day, or more than 800 IU per week) keeps vitamin D levels steadier and is more clearly linked to fewer repeat infections and stronger lungs. Studies that kept vitamin D levels above 30 ng/mL, instead of just giving one big dose, saw the most reliable drops in breathing infections. So, giving vitamin D regularly seems better than giving it all at once, especially for young children and those at higher risk.

Social and economic issues also add to health risks. In many poorer areas, not getting enough vitamin D often happens along with poverty, mothers not getting enough to eat, babies being born small, not getting much sun because of clothing or staying indoors, and air pollution at home. All these things make children more likely to get pneumonia. In these places, giving vitamin D is not just about addressing a vitamin deficiency, but also a cheap way to help protect children's health when it is hard to get medical care. In richer countries, where children usually have better nutrition and living conditions, giving vitamin D to everyone does not help much and may not be worth the cost.

Together, these findings support a targeted clinical strategy. Screening is most useful for infants, malnourished children, those living in areas with limited sunlight, and populations in low-resource regions where deficiency is common. Supplement children who are truly deficient, because they experience the greatest improvement in recurrence and long-term respiratory health. For vitamin D-replete children, additional supplementation offers minimal benefit and should not replace standard pneumonia prevention measures such as vaccination, nutrition, and timely care. Ultimately, vitamin D is best used as a supportive, affordable adjunct—not a standalone treatment—for improving respiratory resilience in vulnerable pediatric populations.

Study limitations

This narrative review is limited by substantial heterogeneity across studies, including differences in design, vitamin D cut-offs (<12 to <20 ng/mL), dosing regimens, and pneumonia definitions, which prevented formal meta-analysis. Many trials did not measure follow-up 25(OH)D levels, making it unclear whether clinical effects reflected true correction of deficiency. Key confounders (nutrition, maternal status, sunlight exposure, socioeconomic factors) were inconsistently controlled. A critical gap is the absence of pediatric-specific, outcome-validated vitamin D cutoffs. Additionally, pooling children across 0–18 years without age stratification is problematic because immune system maturity, vitamin D metabolism, and pneumonia pathophysiology differ substantially between infants and adolescents; yet few primary studies reported age-subgroup outcomes. This lack of age-stratified evidence weakens the specificity of our conclusions. Standardized prospective studies with narrow age cohorts or granular subgroup analyses are needed.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

Conceptualization and supervision: Zahra Sahraei; Investigation and data collection: Shahed Ahmadi; Methodology, data analysis, and writing: All authors.

Conflict of interest

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