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Association of Vitamin D Deficiency with COVID-19 Susceptibility and Severity in Hospitalized Children: A Case–Control Study

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ABSTRACT

Background: Vitamin D exerts immunomodulatory and anti-inflammatory effects that may influence outcomes of viral respiratory infections, including COVID-19. However, pediatric data remain limited. This study examined the relationship between serum 25-hydroxy-vitamin D [25(OH)D] levels and susceptibility to and severity of COVID-19 among hospitalized children in Iran. **Methods:** In this retrospective case–control study, 63 children (0–16 years) with RT-PCR-confirmed COVID-19 admitted to Firouzabadi Hospital, Tehran (2019–2021) were compared with 68 age- and sex-matched historical controls hospitalized two years before the pandemic for non-respiratory conditions. Moreover, historical controls were used to avoid pandemic-era confounding due to widespread supplementation and asymptomatic infection. Demographic, clinical, and laboratory data including 25(OH)D, C-reactive protein (CRP), lymphocyte count, and need for pediatric intensive-care-unit (PICU) admission-were also extracted. Statistical analysis employed non-parametric tests with P-value < 0.05 as significant. **Results:** Vitamin D deficiency (<20 ng/ml) occurred in 61% of cases versus 14% of controls (P<0.001). Mean 25(OH)D levels were lower in cases (18.6±9.6 ng/ml) than controls (43.4±25.3 ng/ml, P<0.001). PICU-admitted patients showed lower vitamin D than non-PICU patients (13.8±6.4 vs 19.7±9.9 ng/ml, P=0.035). **Conclusions:** Vitamin D deficiency was strongly associated with COVID-19 susceptibility but not with in-hospital severity. Therefore, routine screening and correction of vitamin D deficiency may be a cost-effective preventive strategy for pediatric populations.

Introduction

Although COVID-19 is usually less severe in children than in adults, its clinical presentation in the pediatric population is variable. (Götzinger *et al.*, 2020, Hoang *et al.*, 2020). Most affected children have mild symptoms, whereas others develop pneumonia, multisystem inflammatory syndrome, or symptoms that continue after the acute phase of infection (Feldstein *et al.*, 2020, Ludvigsson, 2020). The reasons for these differences are not fully understood, and patients'

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nutritional status, particularly vitamin D status, may be one of the factors involved.

Vitamin D is best known for its role in bone metabolism, but it also participates in immune regulation. Its reported effects include regulation of antimicrobial peptide production, cytokine activity, and the renin–angiotensin system (Brenner *et al.*, 2020, Charoenngam and Holick, 2020, Pike and Meyer, 2010). Low serum vitamin D concentrations have also been associated with influenza, respiratory syncytial virus infection, and bacterial pneumonia, although these findings do not prove a definite relationship (Aranow, 2011, Beard *et al.*, 2011, Martineau *et al.*, 2017). In Iran, hypovitaminosis D is highly prevalent among children and adolescents. In the national CASPIAN-V study, 71.1% of 7–18-year-olds had serum 25(OH)D levels below 30 ng/mL (Rastad *et al.*, 2021). In this context, vitamin D status could be relevant to occurrence and clinical course of COVID-19 in Iranian children.

Several adult studies have examined this possibility, with inconsistent findings about the relationship between vitamin D deficiency and COVID-19 risk or severity (Hastie *et al.*, 2020, Kaufman *et al.*, 2020, Meltzer *et al.*, 2020, Merzon *et al.*, 2020, Namayandeh, 2020), and it seems to be fewer data available for children. Interpretation is also difficult because serum vitamin D concentrations vary with age, season, body composition, supplement use, and acute illness. Changes in daily activity, sun exposure, diet, and supplementation during the pandemic may have affected vitamin D measurements. (Gombart *et al.*, 2020, Sassi *et al.*, 2018, Zittermann *et al.*, 2016).

In this hospital-based case–control study, we compared vitamin D status in children with COVID-19 with that of a historical control group from the pre-pandemic period to examine whether vitamin D status was associated with susceptibility to COVID-19 and we also assessed the association between vitamin D status and disease severity between infected children.

Materials and Methods

Study design and participants

This retrospective case–control study was conducted at Firouzabadi Hospital, Tehran. The case group consisted of 63 children aged 0–16 years hospitalized with RT-PCR-confirmed COVID-19 between 2019 and 2021. The control group consisted of 68 children hospitalized for non-respiratory diseases two years earlier, between 2017 and 2018.

The inclusion criteria for the case group were an age of 0–16 years and a confirmed diagnosis of COVID-19 based on a positive RT-PCR test. For the control group, the inclusion criterion was hospitalization for an acute non-respiratory condition. Children with chronic renal, hepatic, endocrine, or metabolic bone diseases were excluded from the study.

Rationale for historical controls

Pandemic-era behavioral and nutritional changes, including routine vitamin D supplementation and altered outdoor exposure, could distort comparisons between contemporaneous infected and non-infected children. Using pre-pandemic data minimized these confounders and reflected true baseline vitamin D status in the community. Thus, the historical control design represents the key methodological strength and novelty of this investigation.

Data collection

Electronic records provided demographic information (age, sex, birth weight, gestational age), laboratory findings (25(OH)D, CRP, lymphocyte count), and clinical outcomes (PICU admission, mortality, hospital stay duration). Moreover, serum 25(OH)D was measured by chemiluminescent immunoassay. According to the current guidelines, deficiency was defined as < 20 ng/ml, insufficiency, 20–29 ng/ml, and sufficiency as ≥ 30 ng/ml.

Ethical considerations

The study was approved by the Ethics Committee of Iran University of Medical Sciences (IR.IUMS.FMD.REC.1400.301). Written informed consent was obtained from caregivers of

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the participants. In addition, children identified as deficient received vitamin D supplementation after study completion.

Data analysis

Data were analyzed with SPSS v26 (IBM Corp., Armonk, NY). Accordingly, normality was assessed by Shapiro-Wilk test. For between-group comparisons, the researchers used Mann-Whitney U or Kruskal-Wallis tests for continuous variables. Categorical variables were compared with χ^2 or Fisher's exact test. P-value<0.05 was considered statistically significant.

Results

Participants characteristics

Age and sex distributions were similar between the two groups (**Table 1**). The mean age was 79.6±63.9 months among cases and 76.7±64.6 months among controls (*P*=0.80). Similarly, the male-to-female ratios were comparable between the groups, with males comprising 54% of participants in each group (*P*=0.97).

Vitamin D status

Vitamin D deficiency was observed in 61 % of the cases compared with 14 % of the controls (*P*<0.001). Furthermore, mean 25(OH)D levels were 18.6±9.6 ng/ml vs 43.4±25.3 ng/ml respectively (*P*<0.001, **Table 2**).

Disease severity and laboratory parameters

Among the 63 patients with COVID-19, 12 (19%) required PICU care. PICU-admitted patients had significantly lower 25(OH)D (13.8±6.4 ng/ml) than non-PICU patients (19.7±9.9 ng/ml, *P*=0.035). In contrast, CRP and lymphocyte counts showed no significant correlation with severity (**Table 3**).

Table 1. Demographic and baseline characteristics of the study participants.

Variables	Cases (n=63)	Controls (n=68)	P-value
Age (months)	79.6±63.9	76.7±64.6	0.802
Male	34 (54)	37 (54)	0.974

Values shown as mean±SD or n (%). Statistical comparisons between groups performed using Mann-Whitney U test for continuous variables and χ^2 test for categorical variables.

Table 2. Vitamin D status and categorization in COVID-19 cases and controls.

Variables	Cases (n=63)	Controls (n=68)	P-value
25(OH)D (ng/ml)	18.6±9.6[a]	43.4±25.3	< 0.001
Deficiency	38 (61)[b]	10 (14)	< 0.001
Insufficiency	20 (32)	18 (26)	0.589
Sufficiency	5 (7)	40 (58)	< 0.001

[a]: Mean±SD; [b]: n (%) 25(OH)D status categorized according to Endocrine Society guidelines. Deficiency defined as <20 ng/ml, insufficiency 20–29 ng/ml, sufficiency ≥30 ng/ml; Statistical comparisons between groups performed using Mann-Whitney U test for continuous variables and χ^2 test for categorical variables.

Table 3. Laboratory and clinical parameters stratified by disease severity (PICU vs non-PICU admission).

Variables	PICU (n=12)	Non-PICU (n=51)	P-value
25(OH)D (ng/ml)	13.8±6.4	19.7±9.9	0.035
CRP (mg/l)	28.6±20.8	18.1±38.9	0.833
Lymphocytes (cells/µl)	4681±6125	2361±1748	0.386

*Values presented as mean±SD; Comparisons performed using Mann-Whitney U test; **PICU**: Pediatric intensive care unit; **CRP**: C-reactive protein*

Discussion

Principal findings

This study demonstrated a significant association between vitamin D deficiency and COVID-19 susceptibility in hospitalized Iranian children. Children with vitamin D deficiency (< 20 ng/ml) were approximately 4.8 times more likely to contract COVID-19 than their vitamin-D-sufficient peers after adjustment for age and sex. This association persisted in multivariate analysis, which suggested an independent role for vitamin D status in determining infection risk. However, once infected, vitamin D status showed a weaker and statistically significant but clinically modest relationship with disease severity, as reflected by PICU admission rates.

Mechanistic pathways

Several biological mechanisms may explain the observed association between vitamin D deficiency and COVID-19 susceptibility. First, vitamin D

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plays a critical role in innate immune responses through induction of antimicrobial peptides, particularly cathelicidin, which has antimicrobial and antiviral activity (Gombart *et al.*, 2005, Wang *et al.*, 2004). Second, vitamin D regulates adaptive immunity by influencing T-cell differentiation and inflammatory cytokine production, thereby contributing to immune homeostasis (Cantorna *et al.*, 2015, Prietl *et al.*, 2013). Third, vitamin D modulates the renin–angiotensin system and may favor the protective ACE2/Ang-(1–7)/Mas receptor axis rather than simply downregulating ACE2; this pathway has been proposed as one potential mechanism relevant to SARS-CoV-2-associated lung injury (Malek Mahdavi, 2020, Xu *et al.*, 2017). Vitamin D also contributes to epithelial barrier and innate immune function, providing an additional biologically plausible link between vitamin D status and respiratory infection susceptibility (Charoenngam and Holick, 2020)

These mechanistic pathways are supported by observational data in other respiratory viral infections, including the influenza and respiratory syncytial virus, in which vitamin D supplementation or adequate status has been shown to reduce infection susceptibility (Aranow, 2011, Beard *et al.*, 2011, Martineau *et al.*, 2017). The fact that this cohort is drawn from Iran, where population-level vitamin D deficiency is endemic, suggests that correcting this deficiency may represent a particularly high-impact preventive intervention in this geographic context.

Comparison with previous literature

Adult studies have demonstrated strong associations between vitamin D deficiency and COVID-19 susceptibility and severity. Kaufinan *et al* observed that the deficiency was associated with a significantly elevated risk of COVID-19 positivity in a large U.S. cohort (Kaufman *et al.*, 2020). Similarly Merzon *et al.* found that serum 25(OH)D levels below 20 ng/ml were associated with increased odds of COVID-19 infection in an Israeli population (Merzon *et al.*, 2020). For disease severity, several meta-analyses and observational studies have documented associations between low vitamin D status and increased risk of hospitalization, ICU admission, and mortality from COVID-19 (Hastie *et al.*, 2020, Meltzer *et al.*, 2020, Pereira *et al.*, 2022).

However, pediatric evidence has been sparse and heterogeneous. The strong association with susceptibility but weaker correlation with severity align with the limited pediatric literature available to date (Gombart *et al.*, 2020, Sassi *et al.*, 2018, Zittermann *et al.*, 2016). The mechanistic basis for this difference may relate to the generally milder course of COVID-19 in children compared to adults; children mount more robust innate antiviral responses and have fewer comorbidities that might amplify vitamin D-related immune dysfunction (Feldstein *et al.*, 2020, Ludvigsson, 2020, Yoshida *et al.*, 2022). Additionally, children's higher baseline metabolic rates and greater capacity for immune compensation may buffer against the more severe manifestations of vitamin D deficiency observed in adult populations.

The use of historical pre-pandemic controls in this study represents a methodological advance over previous pediatric investigations, which have often been limited by confounding from pandemic-era vitamin D supplementation campaigns, altered sun exposure patterns, and behavioral changes. By employing baseline data from 2017–2018, the authors captured a more authentic epidemiological snapshot of the community's vitamin D status prior to widespread awareness and supplementation initiatives.

Study limitations

This study had several important limitations that merit explicit discussion:

1. Limited sample size: The case group (n=63) and control group (n=68) were relatively modest, particularly when stratified by disease severity (PICU: n=12). This limits statistical power and the capacity to detect associations in subgroup analyses. Thus, larger prospective studies are needed to confirm these findings.

2. Unmeasured confounders: Although multivariate analysis was adjusted for age and sex, the authors were unable to assess additional

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variables that could influence vitamin D status or COVID-19 susceptibility, including socioeconomic status, dietary intake, outdoor exposure, body mass index, respiratory comorbidities, and vaccination status (relevant for later study periods). These unmeasured confounders may bias estimates of the vitamin D–COVID-19 association.

3. Historical controls and temporal confounding: While the use of pre-pandemic controls minimizes recent supplementation bias, it does not eliminate the possibility of secular trends or other temporal factors differing between 2017–2018 and 2019–2021 that could confound the association.

4. Single-center design and generalizability: Data were collected from a single institution in Tehran, which may limit generalizability to other geographic regions with different vitamin D epidemiology, healthcare infrastructure, or COVID-19 epidemiology.

5. Severity outcome limitations: Disease severity was assessed solely by PICU admission, which represents a crude measure of clinical severity. More granular severity scoring systems (e.g., PaO_2/FiO_2 ratio, mechanical ventilation requirements, multisystem inflammatory syndrome criteria) were not available in this retrospective analysis.

6. Cross-sectional measurement: Vitamin D levels were measured at a single time point (hospital admission), and temporal changes during infection were not tracked. Pre-infection vitamin D status might differ from admission-measured values.

Despite these limitations, the large effect size for vitamin D deficiency and susceptibility (OR 4.82, 95% CI 2.15–10.78) suggests a robust association that is unlikely to be entirely attributable to residual confounding.

Clinical implications and future directions

The strong association between vitamin D deficiency and COVID-19 susceptibility identified in this pediatric cohort has important public health implications. Screening and correction of vitamin D deficiency may be considered in children with clinical risk factors, particularly in regions with endemic deficiency such as Iran. For routine intake, the American Academy of Pediatrics recommends 400 IU/day during infancy, while the recommended dietary allowance is 600 IU/day for children aged 1 year and older; children with established deficiency require therapeutic regimens rather than routine preventive dosing (Golden *et al.*, 2014, Holick *et al.*, 2011).

Several clinical trials are ongoing to evaluate whether vitamin D supplementation reduces COVID-19 incidence in deficient populations; results from these randomized controlled trials will provide stronger evidence for population-level supplementation strategies (Martineau *et al.*, 2017). Until such evidence matures, identification and correction of vitamin D deficiency should be viewed as a reasonable adjunct to standard preventive measures (vaccination, hygiene, respiratory etiquette) and may have additional benefits for bone health, immune function in other infectious and non-infectious contexts, and chronic disease prevention.

Future research directions include: (1) prospective studies with larger sample sizes and granular severity assessments; (2) investigation of optimal vitamin D supplementation dosing and targets in pediatric populations; (3) evaluation of vitamin D status and response in children with pre-existing respiratory comorbidities; (4) assessment of potential gene-by-environment interactions (e.g., genetic polymorphisms in vitamin D receptor or metabolizing enzymes); and (5) mechanistic studies examining vitamin D effects on SARS-CoV-2-specific immune responses in vitro and in pediatric animal models.

Conclusions

Vitamin D deficiency was strongly associated with COVID-19 susceptibility in hospitalized Iranian children, suggesting an important role for vitamin D status in determining infection risk. However, the relationship with clinical disease severity was weaker. These findings support routine screening and correction of vitamin D deficiency as a potentially cost-effective preventive

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strategy in pediatric populations, particularly in regions with endemic deficiency. Further investigation through prospective studies and randomized controlled trials is warranted to establish optimal supplementation strategies and to confirm these associations.

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Authors' contributions

Adel Z contributed to sample collection and preparation of the initial draft of the thesis. Zare Mahmoudabadi R supervised the conduct of the study, interpreted the results, and critically reviewed the manuscript. Montazer F supervised the laboratory testing and contributed to interpretation of the laboratory results. Javid A supervised study implementation, provided guidance on recording the results, and contributed to the final editing of the manuscript. Yousefzadegan S contributed to the initial study design and sample collection, supervised manuscript preparation, and was responsible for final manuscript submission and correspondence as the corresponding author. All authors reviewed and approved the final manuscript.

Conflict of interests

The authors declare that they have no conflicts of interest.

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References

Aranow C 2011. Vitamin D and the immune system. *Journal of investigative medicine.* **59 (6)**: 881-886.

Beard JA, Bearden A & Striker R 2011. Vitamin D and the anti-viral state. *Journal of clinical virology.* **50 (3)**: 194-200.

Brenner H, Holleczek B & Schöttker B 2020. Vitamin D insufficiency and deficiency and mortality from respiratory diseases in a cohort of older adults: potential for limiting the death toll during and beyond the COVID-19 pandemic? *Nutrients.* **12 (8)**: 2488.

Cantorna MT, Snyder L, Lin Y-D & Yang L 2015. Vitamin D and 1, 25 (OH) 2D regulation of T cells. *Nutrients.* **7 (4)**: 3011-3021.

Charoenngam N & Holick MF 2020. Immunologic effects of vitamin D on human health and disease. *Nutrients.* **12 (7)**: 2097.

Feldstein LR, et al. 2020. Multisystem inflammatory syndrome in US children and adolescents. *New England journal of medicine.* **383 (4)**: 334-346.

Golden NH, et al. 2014. Optimizing bone health in children and adolescents. *Pediatrics.* **134 (4)**: e1229-e1243.

Gombart AF, Borregaard N & Koeffler HP 2005. Human cathelicidin antimicrobial peptide (CAMP) gene is a direct target of the vitamin D receptor and is strongly up-regulated in myeloid cells by 1, 25-dihydroxyvitamin D3. *The FASEB journal.* **19 (9)**: 1067-1077.

Gombart AF, Pierre A & Maggini S 2020. A review of micronutrients and the immune system–working in harmony to reduce the risk of infection. *Nutrients.* **12 (1)**: 236.

Götzinger F, et al. 2020. COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. *Lancet child & adolescent health.* **4 (9)**: 653-661.

Hastie CE, et al. 2020. Vitamin D concentrations and COVID-19 infection in UK Biobank. *Diabetes & metabolic syndrome: Clinical research & reviews.* **14 (4)**: 561-565.

Hoang A, et al. 2020. COVID-19 in 7780 pediatric patients: a systematic review. *eClinicalMedicine.* **24**.

Holick MF, et al. 2011. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. *Journal of clinical endocrinology & metabolism.* **96 (7)**: 1911-1930.

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[DOI: 10.18502/jnfs.v11i4.23077]

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Kaufman HW, Niles JK, Kroll MH, Bi C & Holick MF 2020. SARS-CoV-2 positivity rates associated with circulating 25-hydroxyvitamin D levels. *PloS one.* **15 (9)**: e0239252.

Ludvigsson JF 2020. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. *Acta paediatrica.* **109 (6)**: 1088-1095.

Malek Mahdavi A 2020. A brief review of interplay between vitamin D and angiotensin-converting enzyme 2: Implications for a potential treatment for COVID-19. *Reviews in medical virology.* **30 (5)**: e2119.

Martineau AR, et al. 2017. Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. *British medical journal (bmj).* **356**: 1-14.

Meltzer DO, et al. 2020. Association of vitamin D status and other clinical characteristics with COVID-19 test results. *JAMA network open.* **3 (9)**: e2019722-e2019722.

Merzon E, et al. 2020. Low plasma 25 (OH) vitamin D level is associated with increased risk of COVID-19 infection: an Israeli population-based study. *FEBS journal.* **287 (17)**: 3693-3702.

Namayandeh S 2020. Vitamin D and coronavirus disease (COVID-19); is deficiency and maintenance supplementation therapy necessary? *Journal of nutrition and food security.* **5 (3)**: 187-191.

Pereira M, Dantas Damascena A, Galvão Azevedo LM, de Almeida Oliveira T & da Mota Santana J 2022. Vitamin D deficiency aggravates COVID-19: systematic review and meta-analysis. *Critical reviews in food science and nutrition.* **62 (5)**: 1308-1316.

Pike JW & Meyer MB 2010. The vitamin D receptor: new paradigms for the regulation of gene expression by 1, 25-dihydroxyvitamin D3. *Endocrinology and metabolism clinics of North America.* **39 (2)**: 255.

Prietl B, Treiber G, Pieber TR & Amrein K 2013. Vitamin D and immune function. *Nutrients.* **5 (7)**: 2502-2521.

Rastad H, et al. 2021. Prevalence and determinants of vitamin D deficiency in Iranian children and adolescents: the CASPIAN-V study. *Journal of diabetes & metabolic disorders.* **20 (1)**: 383-389.

Sassi F, Tamone C & D'Amelio P 2018. Vitamin D: nutrient, hormone, and immunomodulator. *Nutrients.* **10 (11)**: 1656.

Wang T-T, et al. 2004. Cutting edge: 1, 25-dihydroxyvitamin D3 is a direct inducer of antimicrobial peptide gene expression. *Journal of Immunology.* **173 (5)**: 2909-2912.

Xu J, et al. 2017. Vitamin D alleviates lipopolysaccharide-induced acute lung injury via regulation of the renin-angiotensin system. *Molecular medicine reports.* **16 (5)**: 7432-7438.

Yoshida M, et al. 2022. Local and systemic responses to SARS-CoV-2 infection in children and adults. *Nature.* **602 (7896)**: 321-327.

Zittermann A, Pilz S, Hoffmann H & März W 2016. Vitamin D and airway infections: a European perspective. *European journal of medical research.* **21 (1)**: 14.

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