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Vitamin D Status and Asthma Severity in School-Aged Children: A Case-Control Study

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ABS TRAC T

***Background*:** Vitamin D has been increasingly implicated in immune modulation and airway inflammation in asthma. South Asian children, despite abundant ambient sunshine, demonstrate widespread vitamin D deficiency due to cultural, dietary and environmental factors. Local evidence linking 25-hydroxyvitamin D [25(OH)D] status to asthma severity and control in Pakistani children remains limited. This study compared serum 25(OH)D concentrations between asthmatic and non-asthmatic children and assessed the relationship between vitamin D status, asthma severity and asthma control. ***Methods*:** A single-centre, prospective, hospital-based, age- and sex-matched case-control study was conducted between January 2024 and December 2025. A total of 150 children aged 5 to 15 years were enrolled: 75 cases with physician-diagnosed asthma (GINA-classified) and 75 non-asthmatic controls. Serum 25(OH)D was measured by electrochemiluminescence immunoassay. Asthma severity was classified by GINA criteria; control was assessed using the Childhood Asthma Control Test (cACT). ***Results*:** Mean serum 25(OH)D was significantly lower in cases than controls (16.4 ± 7.2 vs 24.6 ± 8.4 ng/mL; $p < 0.001$). Vitamin D deficiency (<20 ng/mL) was present in 56.0% of cases versus 28.0% of controls ($p < 0.001$). Among cases, mean 25(OH)D decreased progressively with worsening severity (mild 20.4 ± 6.8, moderate 15.2 ± 6.0, severe 11.4 ± 5.2 ng/mL; p for trend <0.001). Serum 25(OH)D correlated positively with cACT score ($r = 0.524$, $p < 0.001$) and FEV_1% predicted ($r = 0.458$, $p < 0.001$), and negatively with ICS dose ($r = –0.392$, $p = 0.001$) and exacerbations in the previous year ($r = –0.486$, $p < 0.001$). On multivariable analysis, vitamin D deficiency was independently associated with uncontrolled asthma (aOR 3.84, 95% CI 1.62–9.12; $p = 0.002$). ***Conclusion*:** Pakistani asthmatic children had significantly lower serum 25(OH)D than non-asthmatic controls, and lower vitamin D status was associated with greater asthma severity, poorer control and higher inhaled-corticosteroid requirement. These findings support routine assessment of vitamin D status in children with asthma and lend regional support to evaluating the effect of vitamin D repletion as adjunctive therapy.

Keywords: *Vitamin D, 25-hydroxyvitamin D, Asthma, Asthma severity, Children, Case-control, Pakistan.*

INTRODUCTION

Asthma is the commonest chronic respiratory disease of childhood, affecting an estimated 14% of children worldwide and accounting for substantial morbidity, school absenteeism, healthcare expenditure and impaired quality of life. The prevalence of childhood asthma has risen steadily across South Asia over the last two decades, with national surveys from Pakistan and neighbouring countries reporting current asthma symptoms in 6–13% of school-aged children [1]. Although environmental allergens, viral infections, tobacco-smoke exposure and ambient air pollution remain established triggers, attention has increasingly turned to host nutritional factors that may modulate asthma susceptibility, severity and control [1, 2].

Vitamin D, traditionally recognised for its central role in calcium homeostasis and bone mineralisation, has emerged over the last two decades as a pleiotropic immune modulator with substantial

implications for the pathogenesis and clinical course of asthma. The active metabolite, 1,25-dihydroxyvitamin D, binds the vitamin D receptor expressed on a wide range of immune cells—dendritic cells, macrophages, T-helper subsets, B cells and regulatory T cells—and modulates innate and adaptive immune responses, including the suppression of Th2 and Th17 cytokine pathways central to allergic airway inflammation [2, 3]. Vitamin D has also been shown to enhance the synthesis of antimicrobial peptides (notably cathelicidin), augment epithelial barrier function and reduce airway smooth-muscle proliferation [3].

Multiple observational studies have linked low serum 25-hydroxyvitamin D [25(OH)D] concentrations with increased asthma prevalence, greater severity, poorer pulmonary function and higher exacerbation frequency in children. The landmark Costa Rica Childhood Asthma Study reported that lower serum 25(OH)D was associated with increased odds of severe asthma exacerbations, higher total IgE and greater airway responsiveness [4]. Brehm and colleagues, in the Childhood Asthma Management Program (CAMP) cohort, found that vitamin D insufficiency at baseline predicted increased risk of hospitalisations and emergency department visits over 4 years of follow-up, independent of asthma severity at baseline [5]. Litonjua's review summarises a growing body of evidence linking vitamin D status to maternal–fetal asthma programming, child-onset asthma and disease course [6].

In contrast, results from randomized controlled trials of vitamin D supplementation in established asthma have been heterogeneous. The VIDA trial in adults found no significant benefit of high-dose vitamin D_3 on the rate of treatment failure or asthma exacerbations [7]. However, Cochrane meta-analyses, pooling several paediatric and adult trials, have reported a modest but statistically significant reduction in the rate of asthma exacerbations requiring systemic corticosteroids with vitamin D supplementation, with the benefit most evident in individuals with baseline 25(OH)D below 25 nmol/L [8]. These conflicting data underline the importance of carefully characterising vitamin D status in regional populations with high rates of deficiency before designing trial-based interventions.

South Asian children, despite abundant ambient sunshine, demonstrate paradoxically high rates of vitamin D deficiency, with prevalence estimates frequently exceeding 70% in Pakistani, Indian and Bangladeshi paediatric cohorts. Contributing factors include cumulative sun avoidance because of cultural dress, modesty norms, urban indoor lifestyles, darker skin pigmentation reducing cutaneous synthesis efficiency, limited fortification of staple foods and limited dietary intake of vitamin D-rich foods [9]. The intersection of widespread vitamin D deficiency with a rising childhood asthma prevalence makes South Asia a population of particular interest for examining the vitamin D–asthma relationship.

Although data from individual Pakistani and broader South Asian centres have begun to emerge, the available evidence remains heterogeneous in design, sample size, assay methodology and asthma classification, leaving substantial uncertainty about the strength and consistency of the relationship in this setting. Furthermore, prior work has not consistently examined the relationship between vitamin D status and validated measures of asthma control such as the Childhood Asthma Control Test, nor has it consistently integrated pulmonary function data alongside cross-sectional vitamin D measurement [10]. Local, regionally relevant evidence is therefore needed to inform routine clinical practice and to underpin future interventional trials.

Accordingly, the present hospital-based, age- and sex-matched case-control study was designed to compare serum 25(OH)D concentrations between asthmatic and non-asthmatic Pakistani school-aged children and to evaluate the relationship between vitamin D status and asthma severity (by GINA criteria), asthma control (by cACT score), pulmonary function (FEV_1% predicted) and exacerbation history.

Aims and Objectives

The principal aim of the study was to determine the relationship between vitamin D status, as reflected by serum 25-hydroxyvitamin D concentration, and asthma severity and control in Pakistani school-aged children.

Specific objectives were to compare mean serum 25(OH)D concentrations between asthmatic cases and age- and sex-matched non-asthmatic controls; to determine the prevalence of vitamin D deficiency and insufficiency in cases and controls using standard cut-offs (deficient <20 ng/mL, insufficient 20–29 ng/mL, sufficient ≥30 ng/mL); to examine the relationship between 25(OH)D and asthma severity stratified by GINA classification; to evaluate the correlation between 25(OH)D and Childhood Asthma Control Test score, FEV_1% predicted, inhaled corticosteroid dose and exacerbation frequency in the preceding 12 months; and to identify factors independently associated with uncontrolled asthma in a multivariable logistic regression model.

Materials and Methods

Study design and setting

A single-centre, prospective, hospital-based, age- and sex-matched case-control study was conducted in the Department of Paediatrics of Allama Iqbal Medical College & Jinnah Hospital, Lahore, Pakistan, Pakistan, between January 2024 and December 2025. The protocol was approved by the Institutional Ethics Committee in accordance with the Declaration of Helsinki, and written informed consent from a parent or

legal guardian and age-appropriate assent from the child were obtained prior to enrolment. The study was conducted and reported in accordance with the STROBE guidelines for observational studies.

Sample size estimation

The sample size was calculated to detect a between-group difference of 4 ng/mL in mean serum 25(OH)D with a common standard deviation of 8 ng/mL, a two-sided α of 0.05 and statistical power of 80%. The minimum required size was 64 children per group. To compensate for an anticipated 15% rate of unusable samples or incomplete data, the final target was 75 children per group, for a total sample of 150 participants.

Eligibility criteria

Cases were children aged 5 to 15 years with physician-diagnosed asthma, classified and managed according to the Global Initiative for Asthma (GINA) 2023 framework, and attending the paediatric outpatient or asthma clinic during the study period. Controls were age- (within ±1 year) and sex-matched children attending paediatric outpatient services for non-respiratory, non-allergic and non-chronic complaints, with no personal history of asthma, recurrent wheeze, eczema, allergic rhinitis or food allergy.

Exclusion criteria common to both groups included: receipt of vitamin D supplementation, multivitamin preparations or calcium supplementation within the preceding 3 months; chronic conditions known to affect vitamin D metabolism (chronic kidney disease, chronic liver disease, malabsorption syndromes including coeliac disease and cystic fibrosis, hyperparathyroidism); use of medications affecting vitamin D metabolism (anticonvulsants, glucocorticoids beyond inhaled therapy, antifungals, antiretrovirals); acute infection within the preceding 4 weeks; significant comorbid cardiac, renal or hepatic disease; and inability to provide assent or consent. Children with severe acute asthma exacerbation requiring inpatient care at the time of recruitment were assessed after clinical stabilisation.

Clinical assessment

All participants underwent a structured clinical evaluation including detailed history (asthma onset, duration, exacerbations in the preceding 12 months, hospitalisations, emergency-department visits, current medications), examination, and anthropometric measurement (height, weight, BMI z-score). Sun-exposure history (estimated hours of direct sunlight exposure per week), dietary intake of vitamin D-rich foods (frequency-based questionnaire), and socio-demographic variables (urban/rural residence, parental education, household income category) were recorded.

Asthma classification and control assessment

Asthma severity was classified according to GINA 2023 criteria as intermittent, mild persistent, moderate persistent or severe persistent on the basis of symptom frequency, nocturnal symptoms, activity limitation, reliever use and pulmonary function. Asthma control was assessed using the validated Childhood Asthma Control Test (cACT) for children 4–11 years and the Asthma Control Test (ACT) for those ≥12 years, with cut-offs of ≥20 indicating well-controlled, 16–19 partly controlled and ≤15 uncontrolled asthma. Spirometry was performed by a trained respiratory technician in children aged 6 years and above using a calibrated spirometer per ATS/ERS criteria; FEV_1, FVC, FEV_1/FVC and FEV_1% predicted were recorded.

Laboratory measurement

A 3-mL venous blood sample was drawn into a serum separator tube, centrifuged within 30 minutes, and serum stored at –80 °C until batch analysis. Serum 25(OH)D was measured by electrochemiluminescence immunoassay (Roche Cobas e411) with manufacturer-validated calibration; intra- and inter-assay coefficients of variation were <5% and <8%, respectively. Standard cut-offs were used: deficient <20 ng/mL, insufficient 20–29 ng/mL, sufficient ≥30 ng/mL. Serum calcium, phosphorus and alkaline phosphatase were also measured to characterise mineral status.

Statistical analysis

Data were analysed using SPSS version 27.0. Continuous variables were summarised as mean ± SD when normally distributed and median (IQR) otherwise. Categorical variables were presented as frequencies and percentages. Between-group comparisons used the independent samples t-test or Mann–Whitney U test for continuous variables and the chi-square or Fisher exact test for categorical variables. One-way ANOVA with post-hoc Bonferroni testing compared 25(OH)D across GINA severity strata. Pearson correlation was used for normally distributed variables and Spearman for non-normal data. Multivariable logistic regression identified independent predictors of uncontrolled asthma. A two-sided p-value below 0.05 was considered statistically significant.

RESULTS

Baseline demographic and clinical characteristics

Of 162 children screened, 150 fulfilled the eligibility criteria and were enrolled (75 cases and 75 controls), with 12 excluded (5 receiving vitamin D supplementation, 4 with chronic comorbidity and 3 declining participation). The mean age of the cohort was 9.6 ± 2.8 years, with 86 boys (57.3%) and 64 girls (42.7%). Cases and controls were comparable in age, sex, BMI z-score, urban/rural residence, parental education and household income (Table 1). Among the 75 asthmatic cases, GINA classification was mild persistent in 32 (42.7%), moderate persistent in 28 (37.3%) and severe persistent in 15 (20.0%).

Table 1: Baseline demographic and clinical

characteristics

Variable	Cases (n=75)	Controls (n=75)	p-value
Age (years), mean ± SD	9.7 ± 2.8	9.5 ± 2.7	0.654
Male, n (%)	44 (58.7)	42 (56.0)	0.737
BMI z-score, mean ± SD	–0.42 ± 1.06	–0.36 ± 0.98	0.720
Urban residence, n (%)	48 (64.0)	46 (61.3)	0.736
Maternal education ≥ secondary, n (%)	42 (56.0)	44 (58.7)	0.737
Household income (PKR 50,000+/mo), n (%)	32 (42.7)	34 (45.3)	0.741
Sun exposure ≥30 min/day, n (%)	28 (37.3)	36 (48.0)	0.187
Family history of atopy, n (%)	44 (58.7)	14 (18.7)	<0.001
Tobacco-smoke exposure at home, n (%)	26 (34.7)	20 (26.7)	0.286
Asthma duration (years), mean ± SD	4.2 ± 2.6	—	—

Serum 25-hydroxyvitamin D and vitamin D status

Mean serum 25(OH)D was significantly lower in asthmatic cases than in non-asthmatic controls (16.4 ± 7.2 vs 24.6 ± 8.4 ng/mL; mean difference –8.2 ng/mL, 95% CI –10.7 to –5.7; $p < 0.001$). Vitamin D deficiency (<20 ng/mL) was present in 42 cases (56.0%) versus 21 controls (28.0%) ($p < 0.001$). Serum calcium, phosphorus and alkaline phosphatase were within the reference range in both groups and did not differ significantly (Table 2).

Table 2: Serum 25(OH)D and vitamin D status categories in cases and controls

Parameter	Cases (n=75)	Controls (n=75)	p-value
Serum 25(OH)D (ng/mL), mean ± SD	16.4 ± 7.2	24.6 ± 8.4	<0.001
Serum 25(OH)D, median (IQR)	15.6 (11.4–21.2)	23.8 (19.0–30.4)	<0.001
Deficient (<20 ng/mL), n (%)	42 (56.0)	21 (28.0)	<0.001
Insufficient (20–29 ng/mL), n (%)	24 (32.0)	30 (40.0)	0.305
Sufficient (≥30 ng/mL), n (%)	9 (12.0)	24 (32.0)	0.003
Serum calcium (mg/dL), mean ± SD	9.4 ± 0.6	9.5 ± 0.5	0.273
Serum phosphorus (mg/dL), mean ± SD	4.6 ± 0.7	4.7 ± 0.6	0.350
Alkaline phosphatase (U/L), mean ± SD	186 ± 54	180 ± 48	0.473

Vitamin D status by asthma severity

Among the 75 asthmatic cases, mean serum 25(OH)D decreased progressively with worsening GINA-classified severity: 20.4 ± 6.8 ng/mL in mild persistent (n = 32), 15.2 ± 6.0 ng/mL in moderate persistent (n = 28) and 11.4 ± 5.2 ng/mL in severe persistent (n = 15) asthma (one-way ANOVA $p < 0.001$; p for trend < 0.001). The proportion of children with vitamin D deficiency rose stepwise with severity (37.5% mild, 64.3% moderate, 80.0% severe; p for trend < 0.001) (Table 3).

Table 3: Serum 25(OH)D and vitamin D deficiency prevalence by GINA-classified asthma severity (n = 75)

Severity (GINA)	n	Mean 25(OH)D (ng/mL)	Deficient n (%)
Mild persistent	32	20.4 ± 6.8	12 (37.5)
Moderate persistent	28	15.2 ± 6.0	18 (64.3)
Severe persistent	15	11.4 ± 5.2	12 (80.0)
p-value (one-way ANOVA / χ^2 trend)	—	<0.001	<0.001

Vitamin D status and asthma control

Children with uncontrolled asthma (cACT/ACT ≤15) had the lowest mean serum 25(OH)D (12.6 ± 5.4 ng/mL), followed by partly controlled (16.8 ± 6.4 ng/mL) and well-controlled (21.4 ± 7.0 ng/mL) asthma ($p < 0.001$). The proportion of children with vitamin D deficiency was 76.7% in uncontrolled, 53.6% in partly controlled and 29.4% in well-controlled asthma ($p < 0.001$) (Table 4).

Table 4: Serum 25(OH)D by level of asthma control (n = 75 cases)

Asthma control (cACT/ACT)	n	Mean 25(OH)D (ng/mL)	Deficient n (%)
Well-controlled (≥20)	17	21.4 ± 7.0	5 (29.4)
Partly controlled (16–19)	28	16.8 ± 6.4	15 (53.6)
Uncontrolled (≤15)	30	12.6 ± 5.4	23 (76.7)
p-value (ANOVA / χ^2)	—	<0.001	<0.001

Correlations with clinical and pharmacological variables

Among asthmatic cases, serum 25(OH)D showed a moderate positive correlation with cACT/ACT score ($r = 0.524$, $p < 0.001$) and with FEV_1% predicted ($r = 0.458$, $p < 0.001$), and moderate

inverse correlations with inhaled corticosteroid dose (r = –0.392, p = 0.001) and the number of exacerbations in the preceding 12 months (r = –0.486, p < 0.001) (Table 5).

Table 5: Pearson correlations of serum 25(OH)D with clinical and pharmacological variables among cases (n = 75)

Variable	r	p-value
cACT / ACT score	0.524	<0.001
FEV_1% predicted	0.458	<0.001
FEV_1/FVC ratio	0.346	0.002
Inhaled corticosteroid dose (BDP equivalent)	–0.392	0.001
Number of exacerbations in last 12 months	–0.486	<0.001
Hospitalisations in last 12 months	–0.354	0.002
Emergency department visits in last 12 months	–0.418	<0.001

Predictors of uncontrolled asthma

Variables with univariable p-value below 0.20 were entered into a multivariable logistic regression model with uncontrolled asthma (cACT/ACT ≤15) as the dependent variable. Vitamin D deficiency (<20 ng/mL) was independently associated with uncontrolled asthma (adjusted OR 3.84, 95% CI 1.62–9.12; p = 0.002), as were severe-persistent severity (aOR 4.62, 95% CI 1.74–12.28; p = 0.002), tobacco-smoke exposure at home (aOR 2.86, 95% CI 1.18–6.92; p = 0.020), and family history of atopy (aOR 2.42, 95% CI 1.02–5.74; p = 0.045) (Table 6).

Table 6: Multivariable logistic regression for predictors of uncontrolled asthma (cACT/ACT ≤15)

Variable	Adjusted OR (95% CI)	p-value
Vitamin D deficiency (<20 ng/mL)	3.84 (1.62–9.12)	0.002
Severe persistent severity (GINA)	4.62 (1.74–12.28)	0.002
Tobacco-smoke exposure at home	2.86 (1.18–6.92)	0.020
Family history of atopy	2.42 (1.02–5.74)	0.045
BMI z-score <–1	1.84 (0.74–4.58)	0.190
Sun exposure <30 min/day	1.92 (0.82–4.50)	0.132
Urban residence	1.46 (0.62–3.42)	0.388

DISCUSSION

In this hospital-based, age- and sex-matched case-control study of 150 Pakistani school-aged children, serum 25-hydroxyvitamin D was significantly lower in children with asthma than in non-asthmatic controls, vitamin D deficiency was twice as prevalent in cases as in controls, and lower serum 25(OH)D was associated with greater GINA-classified severity, poorer asthma control, lower FEV_1% predicted, higher inhaled-corticosteroid requirement, and more frequent exacerbations and emergency-department visits in the preceding year. On multivariable analysis, vitamin D deficiency was independently associated with uncontrolled asthma.

These findings are consistent with a substantial body of observational evidence from diverse populations. The Costa Rica Childhood Asthma Study, which provided some of the earliest robust evidence linking vitamin D to paediatric asthma, found that lower serum 25(OH)D was associated with higher total IgE, higher eosinophil counts, increased airway responsiveness, and a higher rate of severe exacerbations [4]. Brehm and colleagues, in the CAMP cohort of mild-to-moderate asthmatic children, demonstrated that vitamin D insufficiency at baseline predicted an increased risk of hospitalisations and emergency-department visits over 4 years, independent of baseline severity and atopic status [5]. A meta-analysis pooling observational studies has confirmed an inverse association between 25(OH)D status and asthma exacerbation rates in children [11].

The gradient observed here—progressively lower 25(OH)D from mild to severe persistent disease, and from well-controlled to uncontrolled asthma—mirrors findings from Indian, Iranian and Turkish paediatric case-control studies. Bener *et al.*, demonstrated a similar gradient in Qatari children, with mean 25(OH)D 24.0 ng/mL in mild, 18.0 ng/mL in moderate and 12.0 ng/mL in severe asthma [12]. Indian work by Krishnaveni *et al.*, and by Sapkota *et al.*, has similarly reported substantially lower vitamin D status in asthmatic children compared with controls, with frank deficiency exceeding 50% of cases [13]. Reports from Pakistani tertiary centres have likewise documented high rates of vitamin D deficiency among asthmatic children, although heterogeneity in assay platforms and severity classification has limited cross-study comparability [14].

Mechanistically, vitamin D's effects on the asthma phenotype are biologically plausible and multilayered. The active hormone 1,25-dihydroxyvitamin D modulates dendritic-cell maturation, reduces production of pro-inflammatory cytokines (IL-4, IL-13, IL-17), enhances regulatory T-cell function, augments expression of antimicrobial peptides such as cathelicidin, and exerts direct effects on airway smooth muscle to reduce proliferation and contractility [2, 3]. Vitamin D may also modulate responsiveness to inhaled and systemic glucocorticoids by upregulating MAPK phosphatase-1 and downregulating IL-17, potentially explaining the association between lower vitamin D status and higher controller medication requirement observed in this and prior cohorts [15].

Despite observational consistency, randomized controlled trials of vitamin D supplementation in established asthma have yielded mixed results. The VIDA trial in adults found no significant benefit of vitamin D_3 100,000 IU loading followed by 4,000 IU daily over 28 weeks on the rate of treatment failure or asthma exacerbations [7]. In children, the VDKA trial similarly reported no significant reduction in severe asthma exacerbations with 4,000 IU/day vitamin D_3 supplementation in children with low baseline 25(OH)D [16]. However, Cochrane meta-analyses pooling both adult and paediatric trials have consistently demonstrated a modest reduction in the rate of asthma exacerbations requiring systemic corticosteroids, with the largest benefit in individuals with baseline 25(OH)D below 25 nmol/L [8, 17]. The discrepancy between observational association and trial outcomes may reflect reverse causation, residual confounding, threshold effects of repletion, supplementation regimen variability, and the inherent difficulty of separating vitamin D deficiency as a marker of overall ill-health from a true causal contributor.

The exceptionally high prevalence of vitamin D deficiency observed in this Pakistani paediatric cohort—both in cases (56%) and in non-asthmatic controls (28%)—is consistent with the regional South Asian literature and reflects the well-documented paradox of high deficiency rates despite abundant sunshine [9]. Contributory factors include sun avoidance because of cultural dress, modesty, indoor lifestyles, urban air pollution attenuating UV-B reaching ground level, darker skin pigmentation reducing cutaneous synthesis efficiency, limited dietary fortification of staple foods, and limited intake of vitamin D-rich foods. The very low prevalence of vitamin D sufficiency (≥30 ng/mL) even in healthy controls (32%) signals a substantial public-health concern transcending asthma.

Several limitations warrant acknowledgement. First, the case-control design precludes inference of causal direction; reverse causation—whereby reduced outdoor activity in asthmatic children leads to lower cutaneous vitamin D synthesis—cannot be excluded. Second, the single-centre, hospital-based recruitment may introduce selection bias and limit generalisability to community settings. Third, serum 25(OH)D was measured at a single time-point and may not fully capture longitudinal vitamin D status, although a single measurement is the standard clinical approach. Fourth, atopic markers such as serum IgE and skin-prick testing were not systematically assessed and could have refined phenotyping. Finally, dietary vitamin D intake and sun-exposure assessment relied on parental recall, with attendant misclassification risk. Despite these limitations, the strengths of this study include the matched design, contemporary GINA-based severity classification, use of validated control instruments, standardised electrochemiluminescence-based assay and integration of pulmonary function and pharmacological data.

CONCLUSION

In this Pakistani school-aged paediatric cohort, asthmatic children had significantly lower serum 25-hydroxyvitamin D concentrations than non-asthmatic controls, and lower vitamin D status was independently associated with greater GINA-classified severity, poorer asthma control, lower FEV_1% predicted, higher inhaled-corticosteroid requirement and more frequent exacerbations. Vitamin D deficiency was independently associated with uncontrolled asthma on multivariable analysis. These findings support the routine assessment of vitamin D status in Pakistani children with asthma—particularly those with moderate-to-severe or uncontrolled disease—and provide regional evidence supporting future randomized trials of vitamin D repletion as an adjunct to standard asthma controller therapy. Broader public-health measures to address the high baseline prevalence of vitamin D deficiency in Pakistani children, including food fortification and educational interventions on safe sun exposure, are also warranted.

Ethical Approval:

The study protocol was reviewed and approved by the Institutional Ethics Committee of Allama Iqbal Medical College & Jinnah Hospital, Lahore, Pakistan (Ethics Approval No.: IEC/AIMC/2023/011), approved on 25 Dec 2023. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from the parents or legal guardians of all participants, and age-appropriate assent was obtained from the children prior to enrollment.

Conflict of Interest: None declared by any author.

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