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Evaluation of Peak Expiratory Flow Rate (PEFR) In Vitamin D Deficient Asthmatics

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KEYWORDS

Bronchial asthma, Vitamin D deficiency, Vitamin D supplementation; Peak expiratory flow rate (PEFR)

ABSTRACT:

Background: Bronchial asthma is a chronic inflammatory airway disorder influenced by multiple environmental and immunological factors. Vitamin D, a secosteroid hormone known for its anti-inflammatory and immunomodulatory properties, has been implicated in the pathogenesis and control of asthma. Vitamin D deficiency is prevalent in India and may adversely affect airway function and disease control. This study aimed to evaluate the association between serum Vitamin D levels and Peak Expiratory Flow Rate (PEFR) among Vitamin D deficient asthmatics and to assess changes in PEFR following Vitamin D supplementation.

Methods: This cross-sectional interventional study was conducted in the Department of Pulmonary Medicine, a tertiary care hospital in South India, among 38 stable adult asthmatics with serum 25(OH) Vitamin D levels ≤20 ng/mL. Baseline demographic, clinical, and asthma-related parameters were recorded. PEFR was measured using a mini-Wright peak flow meter, and the best of three attempts was taken. Participants received oral Vitamin D supplementation (60,000 IU weekly for 8 weeks) as per Endocrine Society guidelines. PEFR was reassessed after 8 weeks of therapy. Data were analyzed using paired t-test, with $p<0.05$ considered statistically significant.

Results: The study population demonstrated a female predominance (63.2%) with most participants aged 18–30 years. Severe Vitamin D deficiency (≤10 ng/mL) was present in 23.7% of subjects. There was no significant correlation between baseline Vitamin D levels and PEFR values. However, a statistically significant improvement in mean PEFR was observed following Vitamin D supplementation ($p<0.05$).

Conclusion: Vitamin D supplementation in deficient asthmatics resulted in improved PEFR, suggesting a beneficial effect on airway function and respiratory muscle performance. These findings highlight the potential role of Vitamin D optimization as an adjunctive measure in asthma management, particularly in populations with high prevalence of deficiency.

INTRODUCTION

The term asthma originates from the Greek word meaning “short of breath,” historically used to describe any individual experiencing breathlessness. Over time, bronchial asthma has been recognized as a distinct chronic inflammatory disorder of the airways, characterized by variable airflow limitation and airway hyperresponsiveness. It is now acknowledged as a major non-communicable disease that imposes a substantial

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global health and economic burden, both in terms of direct medical expenses and indirect losses related to productivity. According to the World Health Organization, approximately 262 million people were affected by asthma in 2019, with 455,000 associated deaths worldwide [1]. The Global Asthma Report estimates that nearly 35 million individuals in India suffer from bronchial asthma, reflecting its significant public health impact in developing nations [2].

Despite being one of the oldest known diseases in human history, the exact mechanism underlying asthma and the pursuit of a definitive cure remain elusive. The 1990s marked a major advancement in understanding its pathophysiology, particularly the discovery of early- and late-phase allergic responses and the mediators involved in airway inflammation. These include a complex interplay of inflammatory cells such as eosinophils, mast cells, T lymphocytes, and various cytokines, which contribute to airway remodeling and hyperresponsiveness. However, the heterogeneity of asthma, involving genetic, immunological, and environmental factors, makes the pathophysiological mechanisms intricate and multifactorial.

Among various emerging factors influencing asthma, Vitamin D has gained increasing attention for its potential role in modulating immune and airway responses. Vitamin D is a seco-steroid hormone synthesized in the skin upon exposure to ultraviolet B (UVB) radiation, with additional sources including diet and fortified foods. It exists in two main forms-ergocalciferol (vitamin D_2) derived from plant sources and cholecalciferol (vitamin D_3) derived from animal sources. Traditionally recognized for its importance in calcium metabolism and musculoskeletal health, Vitamin D is now known to exert pleiotropic effects on immune regulation and inflammatory processes.

Vitamin D receptors (VDR) are expressed in several immune cells including macrophages, dendritic cells, and activated T and B lymphocytes, indicating its broad immunomodulatory role. Activation of these receptors promotes the synthesis of anti-inflammatory cytokines, such as IL-10, and suppresses pro-inflammatory mediators including interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), interferon-gamma (IFN-γ), and interleukin-1β (IL-1β). Moreover, Vitamin D enhances the production of cathelicidin, an antimicrobial peptide involved in innate immunity, thereby providing defense against bacterial, viral, and fungal infections. Its anti-inflammatory action may also reduce chronic inflammation-induced airway remodeling, a hallmark of severe and persistent asthma.

Several studies have established an association between Vitamin D deficiency and increased susceptibility to respiratory diseases such as bronchial asthma, chronic obstructive pulmonary disease (COPD), pulmonary tuberculosis, and even severe COVID-19 infection. Additionally, Vitamin D deficiency has been linked to various non-respiratory conditions including diabetes mellitus, hypertension, metabolic syndrome, cardiovascular diseases, and autoimmune disorders, further highlighting its systemic importance. Given that airway inflammation and heightened airway sensitivity to environmental triggers are key mechanisms in asthma pathophysiology, Vitamin D's immunomodulatory and anti-inflammatory effects are hypothesized to play a pivotal role in asthma prevention and control.

India has one of the highest burdens of Vitamin D deficiency globally. According to the executive summary report by the Indian Council for Research on International Economic Relations (ICRIER), nearly one in five Indians are Vitamin D deficient, with prevalence rates ranging from 9.4% in North India to as high as 38.8% in Eastern India [3]. Factors contributing to this high prevalence include limited sun exposure, urban lifestyle, darker skin pigmentation, and low dietary intake of fortified foods. This widespread deficiency raises important clinical and public health implications, especially in the context of chronic diseases like asthma, where adequate Vitamin D levels may influence disease control and outcomes.

Assessment of pulmonary function is crucial in evaluating asthma control and response to therapy. Peak Expiratory Flow Rate (PEFR), first introduced by Håron in 1942 and later accepted in 1949 as a reliable spirometric index[4], provides a simple, rapid, and reproducible measure of airway obstruction. PEFR reflects the patient's maximal expiratory effort and is influenced by factors such as expiratory muscle strength, airway caliber, lung elastic recoil, and alveolar pressure [5]. It is a valuable self-administered tool in asthma management, allowing patients to monitor their respiratory status and detect early deterioration in lung function.

While numerous studies have investigated the role of Vitamin D in improving lung function among asthmatic individuals, most have focused on Forced Expiratory Volume in one second (FEV_1) or asthma severity scores as primary outcome measures[6-9]. However, there is relatively limited research assessing the relationship between serum Vitamin D levels and Peak Expiratory Flow Rate (PEFR), particularly in Vitamin D-deficient asthmatic populations.

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The present study aims to evaluate the association between Vitamin D levels and PEFR in individuals with bronchial asthma who are Vitamin D deficient. Additionally, it seeks to assess the variation in PEFR following Vitamin D supplementation. Understanding this relationship could provide insights into the potential role of Vitamin D as an adjunct in asthma management, contributing to improved respiratory outcomes and better disease control. Thus, it evaluates the association between Vitamin D level and Peak Expiratory Flow rate (PEFR) among Vitamin-D-deficient stable bronchial asthma patients and also to assess whether supplementation of Vitamin D in deficient asthmatic patients will improve lung function as measured by PEFR

METHODOLOGY

Study Design and Setting

This study was designed as a cross-sectional observational study and was conducted in the Outpatient Department of Pulmonary Medicine at a tertiary care hospital in South India. The research aimed to evaluate the association between serum Vitamin D levels and lung function, measured by PEFR, among stable adult asthmatic patients with Vitamin D deficiency. Additionally, the study assessed changes in PEFR following Vitamin D supplementation. The study was carried out over a period of one year, following approval from the Institutional Ethics Committee, with all participants recruited consecutively from patients attending the asthma clinic for regular follow-up and disease monitoring.

Study Population

The study population comprised adult patients diagnosed with bronchial asthma, who were clinically stable and on optimized treatment. The diagnosis of bronchial asthma was established based on characteristic symptoms such as episodic breathlessness, wheezing, and cough, along with objective evidence of variable airflow limitation as per the Global Initiative for Asthma (GINA) guidelines. Patients were considered stable if they had not experienced any exacerbation or change in medication for at least two months prior to enrolment. Those who fulfilled the inclusion criteria and provided written informed consent were included in the study.

Sample Size Estimation

The sample size was determined using the formula for estimating means with a known level of precision, 95% confidence level (1.96), the standard deviation of PEFR (90 L/min) derived from previous study [10], and the allowable error (30 L/min) of 5%. Substituting these values yielded a minimum sample size of approximately 33 participants. To account for potential attrition and to strengthen the study's statistical power, a total of 38 patients were recruited. This sample size was considered adequate for assessing the correlation between Vitamin D levels and PEFR with acceptable precision.

Inclusion and Exclusion Criteria

The study included adult patients aged 18 years and above, diagnosed with stable bronchial asthma, and having serum 25-hydroxyvitamin D [25(OH)D] levels of ≤20 ng/mL, which indicates Vitamin D deficiency according to the Endocrine Society guidelines [6]. Only those who were clinically stable, had not experienced any exacerbations or medication changes in the past two months, and were willing to provide written informed consent were enrolled. Patients with other chronic respiratory diseases such as chronic obstructive pulmonary disease (COPD), bronchiectasis, or sequelae of pulmonary tuberculosis were excluded. Those with recent asthma exacerbations or changes in treatment within two months, individuals who were on Vitamin D supplementation, or those with systemic conditions known to affect Vitamin D metabolism, such as chronic kidney disease, chronic liver disease, or malabsorption syndromes, were also excluded. Pregnant and lactating women and those unwilling to participate were not considered for inclusion in the study.

Study Procedure and Data Collection

After obtaining informed consent, participants underwent a comprehensive clinical evaluation that included documentation of demographic details, asthma history, and medication profile. Each participant's height, weight, and body mass index (BMI) were recorded. Serum 25(OH)D levels were measured at baseline using a chemiluminescent immunoassay (CLIA) performed in the hospital's central laboratory. Peak Expiratory Flow Rate (PEFR) was measured in the sitting position using a Mini-Wright Peak Flow Meter. Participants were instructed to take a deep breath and blow out forcefully into the device, and the best of three consistent readings was recorded as the baseline PEFR value. This ensured reproducibility and minimized inter-measurement variation.

Following the baseline assessment, all participants received oral Vitamin D3 (cholecalciferol) supplementation at a dose of 60,000 IU weekly for eight consecutive weeks. This dosage regimen was chosen based on the Endocrine Society guidelines for the management of Vitamin D deficiency [6]. Participants were advised to continue their regular asthma medications without alteration during the supplementation period. Compliance was reinforced during follow-up visits and monitored by direct

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questioning at each review. After eight weeks, participants were reassessed, and PEFR measurements were repeated under identical conditions. The change in PEFR after Vitamin D supplementation was used to assess the impact of Vitamin D repletion on lung function.

Ethical Considerations

The study was conducted following the ethical principles outlined in the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines. Ethical clearance was obtained from the Institutional Review Board and Ethics Committee of Grant Government Medical College, Mumbai (Approval No. 96/2016). Each participant received a detailed explanation about the study's objectives, procedures, benefits, and potential risks. Written informed consent was obtained before enrolment, and participants were assured of the confidentiality of their data. Participation was voluntary, and patients had the right to withdraw from the study at any point without affecting their routine medical care. Patient identifiers were anonymized, and data were stored securely with restricted access.

Statistical Analysis

All data collected were entered into Microsoft Excel and analyzed using IBM SPSS Statistics software version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables such as age, BMI, Vitamin D levels, and PEFR were expressed as mean ± standard deviation (SD), whereas categorical variables such as sex and clinical characteristics were expressed as frequencies and percentages. The association between baseline Vitamin D levels and PEFR was evaluated using Pearson's correlation coefficient to determine the strength and direction of the relationship. Pre- and post-supplementation PEFR values were compared using the paired t-test, and a p-value less than 0.05 was considered statistically significant. Data visualization was performed using bar charts and scatter plots to illustrate trends and correlations clearly.

RESULT

Most patients were young adults, with nearly half (47.4%) of the cohort aged 18–30 years (Table 1). The study sample was predominantly female (63.2%, Table 2). All patients had Vitamin D deficiency (25(OH)D < 20 ng/mL) by design; within this cohort, approximately one-quarter (23.7%) had severe Vitamin D deficiency (25(OH)D ≤ 10 ng/mL) and the remaining 76.3% had moderate deficiency (11–20 ng/mL) (Table 1).

Table 1: Distribution of patients by age group

Age Group (years)	Number of patients	Percentage
18–30	18	47.4%
31–40	5	13.2%
41–50	8	21.1%
51–60	4	10.5%
61–70	3	7.9%
Gender		
Male	14	36.8%
Female	24	63.2%
25(OH)D Level Category		
≤ 10 ng/mL (Severe deficiency)	9	23.7%
11–20 ng/mL (Moderate deficiency)	29	76.3%

At baseline, there was no significant association between Vitamin D level category and lung function (PEFR). The proportion of patients with low baseline PEFR was higher in the severe deficiency group (66.7%) than in the moderate deficiency group (48.3%), but this difference was not statistically significant ($\chi^2(1) = 0.93$, $p = 0.33$; Table 2).

Table 2: Association between Vitamin D level category and baseline PEFR status

Vitamin D category	Low baseline PEFR, n (%)	Normal baseline PEFR, n (%)	χ^2	*P-value*
≤ 10 ng/mL (Severe)	6 (66.7%)	3 (33.3%)	3.93	0.33
11–20 ng/mL (Moderate)	14 (48.3%)	15 (51.7%)		
Total	**20 (52.6%)**	**18 (47.4%)**		

Chi-square test

After Vitamin D supplementation, overall lung function improved. The number of patients with low PEFR decreased from 20 (52.6%) before supplementation to 5 (13.2%) after supplementation (Table 3). Among the 20 patients with low baseline PEFR, 15 (75%) achieved a

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normal PEFR after Vitamin D supplementation. Notably, none of the patients with normal baseline lung function had a decline in PEFR category following supplementation. This shift in PEFR status distribution was statistically significant ($\chi^2(1) = 5.18$, $p = 0.02$).

Table 3: Comparison of PEFR status before and after Vitamin D supplementation

Baseline PEFR status	Post-supplementation Low, n (%)	Post-supplementation Normal, n (%)	χ^2	*P-value*
Low (n = 20)	5 (25.0%)	15 (75.0%)	8.18	0.02
Normal (n = 18)	0 (0.0%)	18 (100%)		
Total	**5 (13.2%)**	**33 (86.8%)**		

Chi-square test

Among 38 vitamin D deficient patients 29 (76.3%) had a vitamin D level between 11-20 ng/mL and 9 (23.7%) patients had Vitamin D levels ≤10 ng/mL suggesting severe deficiency. Severely deficient patients are mostly females and belongs to 18-30 age group. 23.7% of our population had Vitamin D levels ≤10 ng/mL. Severe deficiency is more common in females than in males.

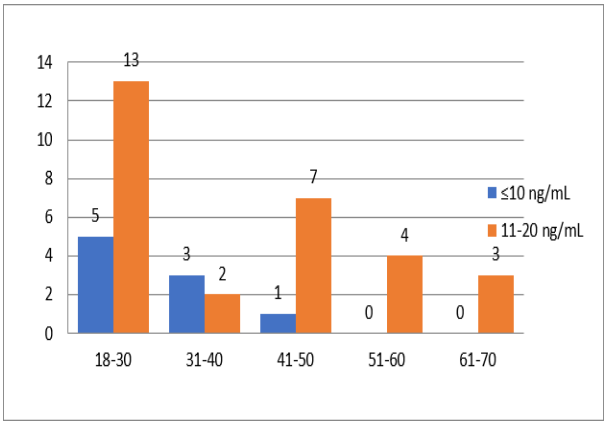

Figure 1: Age and Vitamin D Level distribution of the study population

The highest numbers of Vitamin D deficient patients are in 18-30 age group. (18 patients). 13 patients in this group had Vitamin D levels between 11-20 ng/mL and 5 patients had levels ≤10 ng/mL. (Figure 1)

Table 4: Association of Vitamin D levels with pre-PEFR

Correlations Table			
		Vitamin-D	**PEFR**
Vitamin-D	Pearson Correlation	1	-.111
	Sig. (2-tailed)		.507
	N	38	38
PEFR	Pearson Correlation	-.111	1
	Sig. (2-tailed)	.507	
	N	38	38

Correlation analysis between vitamin D levels and baseline PEFR in 38 patients showed a weak negative correlation ($r = -0.111$), which was not statistically significant ($p = 0.507$). This indicates that there was no meaningful linear relationship between vitamin D status and PEFR in this cohort. (Table 4)

Table 5: Association between PEFR before and after supplementation of Vitamin D.

Variable	Frequency	Mean PEFR	SD	Mean Difference	P-Value
Pre-Test	38	313.68	99.93027	55.52	0.01
Post Test	38	369.21	110.90248		

In the study cohort of 38 patients, the mean PEFR increased from 313.68 ± 99.93 L/min at pre-test to 369.21 ± 110.90 L/min at post-test, yielding a mean difference of 55.52 L/min. This change was statistically significant ($p = 0.01$). (Table 5)

DISCUSSION

This study titled "Evaluation of Peak Expiratory Flow Rate in Vitamin D Deficient Asthmatics" was conducted in the outpatient department of Pulmonary Medicine at a tertiary care hospital in South India. The study included 38 adult, stable asthmatic patients with serum vitamin D levels ≤20 ng/mL, as defined by the Endocrine Society criteria. The primary objective was to evaluate the relationship between serum vitamin D levels and Peak Expiratory Flow Rate (PEFR), a simple measure of lung

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function, and to assess the impact of vitamin D supplementation on PEFR among asthmatic individuals.

In the present study, a clear female predominance was observed, with 63.2% of participants being women. This aligns with previous findings that highlight gender-based differences in the epidemiology of asthma. Bhutia *et al.* [11], in a study conducted in Sikkim, reported that 67% of their study population was vitamin D deficient, with a higher prevalence among females. The observation of higher vitamin D deficiency in women has been consistently reported across various Indian and global studies. Possible explanations include reduced outdoor activity, cultural factors limiting sun exposure, increased adiposity affecting vitamin D bioavailability, and hormonal influences on vitamin D metabolism. Furthermore, multiple epidemiological studies have demonstrated that asthma incidence, severity, and hospitalization rates are more common among females, whereas childhood asthma tends to improve in males but worsen or persist into adulthood in females [12]. The reasons for this gender disparity are multifactorial and likely involve hormonal, immunological, and environmental factors. Estrogen and progesterone are known to modulate immune responses and airway inflammation, while androgens may exert a protective effect. Additionally, differences in airway caliber, perception of dyspnea, and behavioral exposure to allergens or pollutants may contribute to the observed gender differences in asthma expression [13].

In our study, participants were further classified based on the severity of vitamin D deficiency. Those with serum 25(OH)D levels between 11-20 ng/mL were categorized as having vitamin D deficiency, while those with ≤10 ng/mL were defined as severely deficient. Nearly one-fourth (23.7%) of the patients had severe deficiency, and the majority of these individuals were females belonging to the 18-30 years age group. The predominance of deficiency in younger females is of particular concern because this is an age group typically associated with high physical activity and exposure to sunlight, suggesting possible behavioral and lifestyle-related determinants. Factors such as indoor occupations, dietary insufficiency, and skin pigmentation might have contributed to this finding.

PEFR is a simple, inexpensive, and noninvasive test used to assess large airway function and ventilatory capacity. It reflects the maximum speed of expiration after a full inhalation and is influenced by airway caliber, expiratory muscle strength, lung elastic recoil, and maximum alveolar pressure. As a practical bedside test, it provides valuable insights into airway obstruction and can be effectively used for monitoring asthma control. In the present study, baseline PEFR values were compared with vitamin D levels, and no statistically significant correlation was found between the two. This suggests that vitamin D deficiency, while potentially contributing to airway inflammation, may not directly translate to immediate measurable decrements in PEFR in all patients, especially when asthma is clinically stable and well-controlled with pharmacotherapy.

The lack of baseline correlation in this study could be attributed to several factors. First, PEFR reflects large airway patency and is subject to daily variability influenced by circadian rhythm, patient effort, and technique. Second, the relatively small sample size and narrow range of vitamin D values might have limited statistical power to detect subtle associations. Third, since participants were stable asthmatics on regular treatment, the effect of chronic airway inflammation might have been mitigated, leading to less pronounced PEFR variability across vitamin D strata.

Interestingly, similar studies conducted in other populations have reported variable associations between vitamin D status and lung function. A study among the Dutch elderly population demonstrated that vitamin D-deficient men had significantly lower PEFR compared to those with sufficient levels; however, this association was not observed among women [14]. The lack of consistent findings across studies may reflect differences in study design, population demographics, measurement methods, and definitions of vitamin D deficiency.

Despite the absence of a baseline association, our study found a statistically significant improvement in PEFR after vitamin D supplementation. Participants received vitamin D3 (cholecalciferol) 60,000 IU weekly for eight weeks, and a notable rise in PEFR values was observed upon reassessment. This improvement indicates that vitamin D repletion may exert beneficial effects on pulmonary function in asthmatics, possibly through both anti-inflammatory and musculoskeletal mechanisms. Several prior studies have reported similar improvements in lung function following vitamin D supplementation, though most used spirometric indices such as Forced Expiratory Volume in one second (FEV_1) rather than PEFR [15-16].

Vitamin D is increasingly recognized as an immunomodulatory hormone with pleiotropic effects extending beyond calcium homeostasis and bone health. Its receptors (VDRs) are expressed in a variety of immune cells, including macrophages, dendritic cells, and T and B lymphocytes. Activation of VDR leads to modulation of gene expression that promotes an anti-inflammatory milieu by downregulating pro-inflammatory cytokines such as IL-6, IL-1β, TNF-α, and IFN-γ while enhancing anti-inflammatory cytokines like

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IL-10. This regulatory balance plays a crucial role in attenuating chronic airway inflammation, which is central to asthma pathophysiology [17]. Moreover, vitamin D has been shown to enhance epithelial barrier integrity, reduce airway remodeling, and improve responsiveness to corticosteroids-an important aspect for patients with steroid-resistant asthma.

From a physiological perspective, vitamin D may influence lung function not only through immunomodulation but also by enhancing skeletal and respiratory muscle strength. Vitamin D deficiency has been associated with muscle weakness, reduced endurance, and impaired contractility of respiratory muscles. Improved vitamin D status can therefore enhance the efficiency of inspiratory and expiratory muscle performance, potentially explaining the observed rise in PEFR following supplementation in this study. PEFR, being a function of large airway flow and expiratory effort, is particularly sensitive to changes in respiratory muscle strength. This dual mechanism-reduction of airway inflammation and improved muscle performance-may underlie the improvement in PEFR observed in our study.

Another important aspect of our findings is the potential clinical implication of vitamin D as an adjunct in asthma management. While bronchodilators and inhaled corticosteroids remain the mainstay of therapy, optimizing vitamin D levels could serve as a complementary strategy to improve asthma control and reduce exacerbations. Several interventional studies have suggested that vitamin D supplementation reduces the frequency of asthma attacks, improves symptom scores, and enhances quality of life among deficient individuals. Our findings, showing improvement in PEFR, add further support to the hypothesis that vitamin D plays a functional role in respiratory health.

This study had few limitations. The sample size was relatively small and derived from a single tertiary care center, which may limit generalizability. Serum vitamin D measurements were performed only at baseline, and post-supplementation levels were not reassessed to confirm biochemical correction. Additionally, PEFR, though simple and useful, is effort-dependent and may be influenced by patient technique. The short follow-up duration of eight weeks may not fully capture the long-term impact of vitamin D supplementation on lung function or asthma control. Furthermore, potential confounders such as diet, sunlight exposure, seasonal variation, and baseline asthma severity were not fully quantified.

Despite these limitations, the findings from this study underscore the importance of assessing and correcting vitamin D deficiency in asthmatic patients. Given its safety, low cost, and potential immunomodulatory and musculoskeletal benefits, vitamin D supplementation could serve as an adjunct to conventional asthma therapy. Larger, randomized controlled trials with longer follow-up durations are warranted to confirm these results and to evaluate whether sustained vitamin D sufficiency can improve long-term asthma outcomes, reduce exacerbations, and enhance steroid responsiveness.

CONCLUSION

In conclusion, our study demonstrates that while baseline vitamin D levels did not show a significant association with PEFR among stable asthmatics, vitamin D supplementation significantly improved PEFR, indicating potential enhancement of lung function. This improvement may be mediated through reduced airway inflammation and strengthened respiratory musculature. The results highlight the role of vitamin D as an adjunctive measure in asthma management, reinforcing the importance of screening for and correcting vitamin D deficiency as part of comprehensive asthma care.

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