World Nutrition Journal |eISSN 2580-7013

SYSTEMATIC REVIEW

Effect of vitamin D supplementation regimens on clinical outcomes in asthma: A systematic review

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Received 5 May 2026
Accepted 6 July 2026
Published 31 August 2026

Link to DOI:
10.25220/WNJ.V10.i1.0004

Citation: Pratiwi D, Sumartini NK, Weta I W, Harimawan A I W. Effect of vitamin D supplementation regimens on clinical outcomes in asthma: A systematic review. World Nutrition Journal.2026 August 31,10(i1): 30-42.

Abstract

Background: Vitamin D has immunomodulatory properties that may improve asthma outcomes; however, randomized controlled trials (RCTs) have reported inconsistent findings. Variations in supplementation regimens, particularly bolus versus non-bolus dosing, may contribute to these discrepancies.
Objective: To systematically evaluate the effects of vitamin D supplementation on clinical outcomes in patients with asthma, with particular emphasis on dosing regimens.
Methods: A systematic review was conducted according to PRISMA guidelines and registered in PROSPERO (CRD420261378116). PubMed, Scopus, and the Cochrane Library were searched for RCTs investigating vitamin D supplementation in asthma. Studies were categorized into non-bolus (daily or weekly) and bolus (high-dose intermittent) regimens. Primary outcomes included asthma exacerbations, lung function, and asthma control. Risk of bias was assessed using the Cochrane Risk of Bias 2 tool.
Results: Six RCTs met the inclusion criteria. Non-bolus supplementation was more consistently associated with improved asthma control and modest improvements in lung function, whereas bolus regimens generally showed no significant clinical benefit. Limited benefits of bolus dosing were observed only among participants with severe vitamin D deficiency. Overall, the included studies demonstrated low risk of bias to some concerns.
Conclusions: Vitamin D supplementation may improve asthma outcomes, but its effectiveness appears to depend on the dosing regimen. Regular non-bolus supplementation may provide greater clinical benefits than intermittent bolus dosing, particularly in individuals with vitamin D deficiency. Further high-quality RCTs are needed to confirm regimen-specific effects.

Keywords: asthma, bolus, non-bolus, supplementation, systematic review, vitamin d

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Introduction

Asthma is a chronic inflammatory airway disease characterized by variable airflow limitation and recurrent episodes of wheezing, breathlessness, and coughing. Despite advances in pharmacological therapy, asthma control remains suboptimal in a significant proportion of patients, highlighting the need for adjunctive therapeutic strategies.[1-3]

Vitamin D has emerged as a potential modulator of asthma pathophysiology due to its effects on both innate and adaptive immune responses. It has been shown to enhance regulatory T-cell function, suppress pro-inflammatory cytokine production, and improve antimicrobial defense mechanisms. In addition, emerging evidence from nutritional intervention studies, including a recent systematic review and meta-analysis on astaxanthin supplementation in women with polycystic ovary syndrome (PCOS), has demonstrated that antioxidant supplementation may significantly reduce oxidative stress and improve inflammatory profiles. These findings further support the potential role of micronutrients, including vitamin D, in modulating inflammatory pathways relevant to asthma. Observational studies have consistently demonstrated an association between low serum vitamin D levels and increased asthma severity, reduced lung function, and higher risk of exacerbations.[4-9]

However, randomized controlled trials investigating vitamin D supplementation in asthma have yielded inconsistent results. While some studies report improvements in asthma control and lung function, others show no significant clinical benefit. Genetic and metabolic factors may also contribute to variability in disease susceptibility and treatment response. These discrepancies may be explained by differences in study populations, baseline vitamin D status, and importantly, the supplementation regimen.[5,10-14]
Emerging evidence suggests that the pattern of vitamin D administration particularly the distinction between bolus (high-dose intermittent) and non-bolus (daily or weekly) regimens may influence clinical outcomes. Large meta-analyses in respiratory diseases have demonstrated that regular daily dosing is associated with protective effects, whereas bolus dosing may not confer similar benefits.[6,15-17]

Given these considerations, it is important to systematically evaluate whether the efficacy of vitamin D supplementation in asthma is influenced by the dosing regimen. Therefore, this study aimed to systematically review the available evidence on vitamin D supplementation in asthma, with a particular focus on comparing bolus and non-bolus regimens in relation to clinical outcomes.

Methods

Study Design

This study was conducted as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework.[18] The review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420261378116. The objective was to evaluate the effects of vitamin D supplementation on clinical outcomes in patients with asthma, with a specific focus on the role of different supplementation regimens.

Eligibility Criteria

Studies were considered eligible if they were randomized controlled trials involving patients with a clinical diagnosis of asthma and evaluated vitamin D supplementation in comparison with placebo or standard therapy. Only studies reporting clinically relevant outcomes, including asthma exacerbations, lung function parameters, or asthma control, were included in the analysis. Studies were excluded if they were observational in design, review articles, case reports, or conducted in animal models. In addition, studies that did not provide sufficient data on clinical outcomes were not included.

Literature Search

A comprehensive search of the literature was performed using electronic databases, including PubMed, Scopus, and the Cochrane Library. The search covered all available records up to the time of data collection. Keywords related to vitamin D and asthma were combined using Boolean operators to identify relevant studies. The search terms included variations of "vitamin D", "cholecalciferol", "asthma", "supplementation", and "randomized controlled trial". To ensure completeness, the reference lists of selected articles were also reviewed to identify additional studies that met the inclusion criteria.

Study Selection

All identified records were initially screened based on titles and abstracts to exclude studies that were clearly not relevant. Articles that appeared to meet the inclusion criteria were then assessed in full text. The selection process was conducted carefully to ensure that all included studies met the predefined criteria, and any discrepancies were resolved through discussion. The study selection process is illustrated in **Figure 1**.

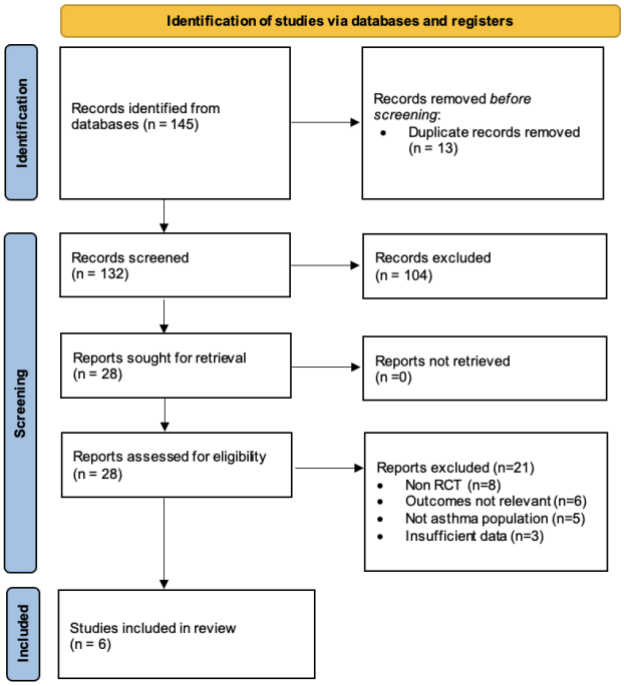

Figure 1. The study selection process by PRISMA flowchart

Data Extraction

Data from the included studies were extracted systematically using a predefined format. Extracted information included study characteristics, participant demographics, intervention details, and reported outcomes. Particular attention was given to the vitamin D supplementation protocol, including dosage, frequency, and duration, as these variables were essential for subsequent classification.

Classification of Supplementation Regimen

To evaluate the influence of dosing strategy, vitamin D supplementation protocols were classified according to the pattern of maintenance administration rather than the initial loading dose. Non-bolus regimens were defined as regular vitamin D supplementation administered daily or weekly to maintain relatively stable circulating 25-hydroxyvitamin D concentrations. Studies that included an initial loading dose followed by daily or weekly maintenance supplementation were also classified as non-bolus because sustained administration represented the principal therapeutic strategy.

Bolus regimens were defined as high-dose vitamin D administered intermittently at intervals of one month or longer without continuous daily or weekly maintenance dosing. This operational definition was adopted to distinguish intermittent pharmacological dosing from regular physiological replacement and to facilitate comparison between supplementation strategies across the included randomized controlled trials.

Outcomes of Interest

The main outcomes evaluated in this review included asthma exacerbations, lung function parameters such as forced expiratory volume in one second (FEV1) and the FEV1/FVC ratio, as well as measures of asthma control assessed using validated scoring systems. These outcomes were selected based on their clinical relevance and frequent reporting across studies.

Data Synthesis

A qualitative synthesis was conducted to summarize the findings of the included studies. Due to substantial heterogeneity in study design, population characteristics, intervention protocols, and outcome measures, a quantitative meta-analysis was not performed. The results were synthesized narratively, with a focus on differences between bolus and non-bolus supplementation regimens.

Results

Study Selection

A total of 132 records were identified through database searching. After removal of duplicates, 104 records were screened based on titles and abstracts. Of these, 28 articles were assessed for full-text eligibility, and 6 studies met the inclusion criteria.

Table 1. Characteristics of Included Studies on Vitamin D Supplementation Regimens and Clinical Outcomes in Asthma

Study	Design & Population	Regimen	Regimen Type	Outcomes	Main Findings
Watkins et al.,[16] 2024	RCT, adults with mild–moderate asthma (n=32)	125 µg/day (~5000 IU) for 12 weeks	Non-bolus (daily)	FEV1/FVC, ACT, inflammatory biomarkers	Small but significant improvement in FEV1/FVC; no significant effect on ACT or biomarkers
Denlinger et al.,[19] 2016	RCT, adults with asthma and vitamin D insufficiency (n=408)	Loading dose 100,000 IU + 4000 IU/day	Non-bolus (daily + loading)	Cold symptoms, exacerbations	No significant reduction in respiratory symptoms or clinical outcomes
Andújar-Espinosa et al.,[20] 2020	RCT, adults with asthma and vitamin D deficiency (n=112)	16,000 IU/week for 6 months (calcifediol)	Non-bolus (weekly)	ACT, quality of life, exacerbations	Significant improvement in asthma control and quality of life
Chiewchalermsri et al.,[21] 2023	RCT, HDM-allergic patients with/without asthma (n=34)	60,000 IU/week for 10 weeks	Non-bolus (weekly)	Symptom score, Treg function	Significant reduction in symptoms; improved regulatory T-cell function
Camargo et al.,[22] 2021	Post hoc RCT analysis, asthma/COPD subgroup (n=775)	100,000 IU/month	Bolus (monthly)	Exacerbations	No overall effect; benefit observed only in severe vitamin D deficiency
Sluyter et al.,[15] 2017	RCT, adults (n=442)	200,000 IU loading + 100,000 IU/month	Bolus (monthly)	FEV1 (lung function)	No significant overall improvement (benefit only in specific subgroups)

Abbreviations: ACT, Asthma Control Test; FEV1, forced expiratory volume in one second; FVC, forced vital capacity; ARI, acute respiratory infection. Non-bolus regimens refer to daily or weekly vitamin D supplementation, whereas bolus regimens refer to high-dose intermittent administration, typically given monthly or at longer intervals

Study Characteristics

The included studies were randomized controlled trials conducted in patients with asthma across different populations and settings. The sample sizes varied considerably, ranging from small-scale trials to larger multicenter studies. The duration of vitamin D supplementation also differed across studies, from short-term interventions to longer follow-up periods. There was notable variability in baseline characteristics, particularly in terms of vitamin D status, with several studies focusing specifically on patients with vitamin D deficiency or insufficiency. This variation in baseline status may have influenced the observed treatment effects.

In addition, substantial differences were observed in supplementation protocols. Some studies administered vitamin D on a daily or weekly basis, while others used high-dose intermittent regimens given monthly or at longer intervals. This variation in dosing strategy formed the basis for further subgroup classification.

Risk of Bias Assessment

The risk of bias of the included studies was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool.[23] Overall, most studies demonstrated a low risk of bias across several domains, particularly in the randomization process, measurement of outcomes, and completeness of outcome data. These findings suggest that the majority of included trials were methodologically sound in terms of study design and outcome assessment.

However, some concerns were identified in specific domains. A number of studies showed potential bias related to deviations from intended interventions, which may reflect issues such as adherence to the intervention protocol or lack of blinding. In addition, some studies were judged to have concerns regarding selective reporting of outcomes, indicating that not all prespecified outcomes may have been fully reported.

The overall risk of bias across studies was therefore considered to range from low to some concerns. Larger, well-designed trials generally demonstrated a lower risk of bias, while smaller studies were more likely to present uncertainties in certain domains due to limited reporting. The detailed assessment of risk of bias for each included study is presented in **Figure 2A**, while the overall distribution of risk across domains is summarized in **Figure 2B**.

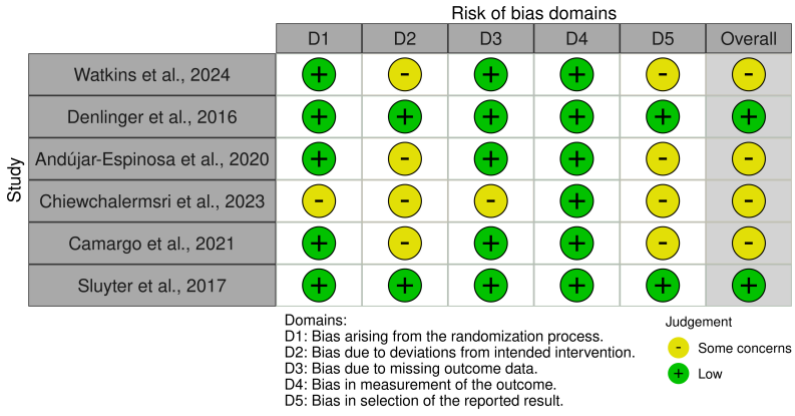

Figure 2A. Risk of bias assessment of included studies using the Cochrane Risk of Bias 2 (RoB 2) tool.

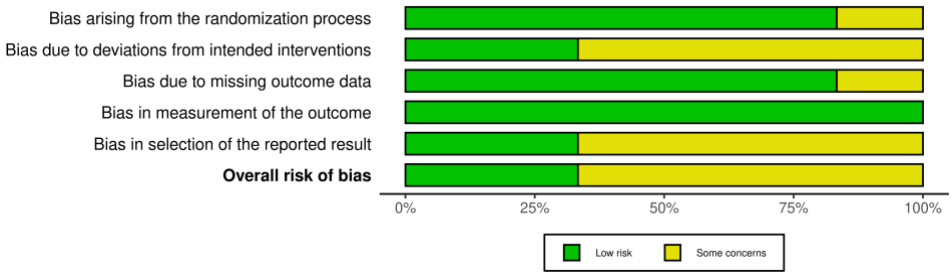

Figure 2B. Summary of risk of bias across included studies, presented as percentages for each domain.

Effects of Non-Bolus Supplementation

Studies that utilized non-bolus regimens, defined as daily or weekly administration of vitamin D, tended to demonstrate more consistent improvements in clinical outcomes. Several trials reported better asthma control, reflected by improvements in standardized assessment scores, along with modest gains in lung function parameters such as FEV1 and FEV1/FVC ratio.

The beneficial effects of supplementation appeared to be more evident in patients with lower baseline vitamin D levels. In these populations, regular supplementation was associated with a greater likelihood of improved clinical control. Although not all findings reached statistical significance, the overall trend suggested that consistent vitamin D intake may contribute to better disease management.

Effects of Bolus Supplementation

In contrast, studies employing bolus regimens, characterized by high-dose intermittent supplementation, generally reported less favorable outcomes. Most trials did not demonstrate significant improvements in asthma exacerbations, lung function, or symptom control when compared with placebo or standard treatment.

In some instances, potential benefits were observed in specific subgroups, particularly among individuals with marked vitamin D deficiency. However, these findings were not consistently replicated across studies. Overall, the results suggest that intermittent high-dose supplementation may not provide the same clinical advantages as more frequent dosing strategies.

Overall Synthesis of Evidence

To evaluate the influence of dosing strategy, vitamin D supplementation protocols were classified according to the pattern of maintenance administration rather than the initial loading dose. Non-bolus regimens were defined as regular vitamin D supplementation administered daily or weekly to maintain relatively stable circulating 25-hydroxyvitamin D concentrations. Studies that included an initial loading dose followed by daily or weekly maintenance supplementation were also classified as non-bolus because sustained administration represented the principal therapeutic strategy.

Bolus regimens were defined as high-dose vitamin D administered intermittently at intervals of one month or longer without continuous daily or weekly maintenance dosing. This operational definition was adopted to distinguish intermittent pharmacological dosing from regular physiological replacement and to facilitate comparison between supplementation strategies across the included randomized controlled trials. Overall, the available evidence suggests that regular non-bolus vitamin D supplementation is more consistently associated with improvements in asthma control than intermittent bolus administration. However, the magnitude of benefit appears to depend on baseline vitamin D status and study characteristics.

Discussion

The findings of this systematic review demonstrate that the effects of vitamin D supplementation on clinical outcomes in patients with asthma remain inconsistent across randomized controlled trials. While some studies reported improvements in asthma control and lung function, others did not observe significant benefits. This variability has been widely reported in the literature and suggests that additional factors may influence treatment response beyond supplementation alone.[3,13,24-26]

One of the most notable observations in the present review is the potential influence of supplementation regimen on clinical outcomes. Studies employing non-bolus regimens, characterized by daily or weekly administration, were more likely to report favorable effects, particularly in terms of asthma control. In contrast, studies using bolus regimens, involving high-dose intermittent supplementation, generally failed to demonstrate consistent clinical benefit. This pattern aligns with findings from several randomized trials in which regular dosing strategies were associated with improved clinical parameters, whereas intermittent high-dose regimens yielded neutral results.[16,20,27,28]

A plausible explanation for this difference lies in the pharmacokinetic profile of vitamin D. Regular supplementation is believed to maintain more stable circulating concentrations of 25-hydroxyvitamin D, which may be necessary for sustained immunomodulatory activity. In contrast, bolus dosing may induce transient increases in serum vitamin D levels followed by rapid declines, potentially limiting long-term biological effects.[29,30] This hypothesis is supported by evidence from meta-analyses in respiratory diseases, which have demonstrated that daily or weekly vitamin D supplementation is associated with protective effects, whereas intermittent bolus dosing does not confer similar benefits.[4,10,31-35]

In addition to dosing regimen, baseline vitamin D status appears to be an important determinant of response. Previous meta-analyses have shown that the protective effects of vitamin D supplementation on asthma exacerbations are more pronounced in individuals with marked vitamin D deficiency. Similarly, several trials included in this review reported greater clinical improvements among patients with lower baseline vitamin D levels. These findings suggest a potential interaction between baseline vitamin D status and treatment efficacy, which may partially explain the heterogeneity observed across studies. These observations are consistent with evidence from other nutritional interventions targeting oxidative stress, such as astaxanthin supplementation in women with PCOS, where significant reductions in oxidative stress markers have been reported. This suggests that modulation of oxidative stress may represent a common pathway through which micronutrients exert beneficial effects in inflammatory conditions.[7,10,36,37]

The variability in study outcomes may also be attributed to differences in study design and population characteristics. The included trials varied considerably in terms of sample size, duration of intervention, dosage of supplementation, and outcome measures. Some studies included participants with sufficient baseline vitamin D levels, which may have reduced the likelihood of detecting a clinically meaningful effect. These findings are consistent with previous studies demonstrating the importance of nutritional status and metabolic factors in determining clinical outcomes. Furthermore, the use of different endpoints, ranging from lung function parameters to symptom scores and exacerbation rates, limited the comparability of results across studies.[10,15,16,38-40]

An important consideration in interpreting the present findings is the limited number of randomized controlled trials specifically designed to compare vitamin D dosing strategies in patients with asthma. Considerable heterogeneity was observed across studies regarding participant characteristics, baseline vitamin D status, intervention protocols, treatment duration, and clinical outcome measures. These differences limited direct comparisons and precluded definitive conclusions regarding the superiority of one supplementation regimen over another. Nevertheless, the overall pattern consistently favored regular maintenance supplementation over intermittent high-dose administration.

This review has several limitations that should be considered. The number of included studies was relatively limited, and the heterogeneity in study design and outcome reporting restricted the feasibility of conducting a comprehensive meta-analysis. In addition, the classification of supplementation regimens was based primarily on dosing frequency, which may not fully capture differences in cumulative dose or duration of treatment. Nevertheless, the consistent pattern observed between regimen type and clinical outcomes provides important insight into the potential role of dosing strategy.

Overall, the findings suggest that vitamin D supplementation may have a role in asthma management; however, its effectiveness appears to depend on the supplementation regimen and baseline vitamin D status. Non-bolus regimens may offer greater clinical benefit compared to bolus dosing, particularly in individuals with deficiency. Future randomized controlled trials should be designed to specifically evaluate regimen-dependent effects and to identify patient subgroups most likely to benefit from supplementation.

Conclusions

This systematic review suggests that vitamin D supplementation may contribute to improved asthma outcomes, although its effectiveness appears to depend on the dosing regimen. Regular non-bolus supplementation showed a more consistent association with improved asthma control and modest improvements in lung function than intermittent bolus administration. However, given the limited number of eligible randomized controlled trials and the substantial heterogeneity among studies, these findings should be interpreted cautiously. Additional high-quality randomized controlled trials directly comparing dosing strategies are needed before definitive recommendations can be established.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

Acknowledgments

The authors would like to thank the Department of Clinical Nutrition, Ngoerah Hospital/Faculty of Medicine, Udayana University, for the support provided during the preparation of this study.

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Author Contributions

DP: Conceptualization, literature search, study selection, data acquisition, formal analysis, interpretation of results, drafting the manuscript, and final approval of the version to be published; NKS: Supervision, interpretation of results, critical revision of the manuscript for important intellectual content, and final approval of the version to be published; IWW: Conception and design of the study, interpretation of results, critical revision of the manuscript for important intellectual content, and final approval of the version to be published; AIWH: Supervision, interpretation of results, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.

References

1. Reddel, Helen K, Bacharier, Leonard B, Bateman, Eric D, et al. Global Initiative for Asthma Strategy 2021: executive summary and rationale for key changes. American journal of respiratory and critical care medicine. 2022;205:17-35.
2. Hammad, Hamida, Lambrecht, Bart N. The basic immunology of asthma. Cell. 2021;184:1469-85. https://doi.org/https://doi.org/10.1016/j.cell.2021.02.016
3. Jayasooriya, Shamanthi M, Devereux, Graham, Soriano, Joan B, et al. Asthma: epidemiology, risk factors, and opportunities for prevention and treatment. The Lancet Respiratory Medicine. 2025;13:725-38. https://doi.org/10.1016/S2213-2600(24)00383-7 External Link
4. Zhu, Yiqun, Jing, Danrong, Liang, Huaying, et al. Vitamin D status and asthma, lung function, and hospitalization among British adults. Frontiers in Nutrition. 2022;Volume 9 - 2022:https://doi.org/10.3389/fnut.2022.954768
5. Jolliffe, David A, Camargo, Carlos A, Sluyter, John D, et al. Vitamin D supplementation to prevent acute respiratory infections: a systematic review and meta-analysis of aggregate data

from randomised controlled trials. The lancet Diabetes & endocrinology. 2021;9:276-92. https://doi.org/10.1016/S2213-8587(21)00051-6 External Link
6. Busse, William W, Castro, Mario, Casale, Thomas B. Asthma management in adults. The Journal of Allergy and Clinical Immunology: In Practice. 2023;11:21-33. https://doi.org/https://doi.org/10.1016/j.jaip.2022.10.015
7. Pratiwi, Donna, Harimawan, Agustinus I Wayan, Weta, I Wayan, Sumartini, Ni Ketut, Awan, Syuma Adhy, Sutadarma, I Wayan Gede. Effect of astaxanthin supplementation on oxidative stress in adult women with polycystic ovary syndrome: a systematic review and meta-analysis of randomized controlled trials. Universa Medicina. 2026;45:125-34. https://doi.org/https://doi.org/10.18051/UnivMed.2026.v45.125-134
8. Mosnaim, Giselle. Asthma in adults. New England Journal of Medicine. 2023;389:1023-31. https://doi.org/DOI: 10.1056/NEJMcp2304871
9. Scott, Hayley A, Ng, Shawn HM, McLoughlin, Rebecca F, et al. Effect of obesity on airway and systemic inflammation in adults with asthma: a systematic review and meta-analysis. Thorax. 2023;78:957-65. https://doi.org/https://doi.org/10.1136/thorax-2022-219268
10. Asghari, Golaleh, Yuzbashian, Emad, Nikparast, Ali, et al. Impact of daily vitamin D3 supplementation on the risk of vitamin D deficiency with the interaction of rs2282679 in vitamin D binding protein gene (GC) among overweight and obese children and adolescents: A one-year randomized controlled trial. Frontiers in Nutrition. 2022;Volume 9 - 2022:https://doi.org/10.3389/fnut.2022.1061496
11. Pratiwi, Donna, Sidartha, Miko, Wiyarta, Elvan, et al. Comparison of the risk of obesity in the FTO rs9939609 genotype in a multiethnic group in Asia systematic review and meta-analysis. Frontiers in Medicine. 2025;Volume 12 - 2025:https://doi.org/10.3389/fmed.2025.1522318
12. Peng, Biao, Xiong, Yi, Ouyang, Ting, et al. High ratio of epi-25-(OH)-vitamin D3 to 25-(OH)-vitamin D3 increases the risk of asthma attack in American asthma adults: a population study. BMC Public Health. 2024;24:2670. https://doi.org/https://doi.org/10.1186/s12889-024-20185-6
13. Maison, Nicole, Omony, Jimmy, Illi, Sabina, et al. T2-high asthma phenotypes across lifespan. European respiratory journal. 2022;60:https://doi.org/https://doi.org/10.1183/13993003.02288-2021
14. Chen, Yuxiong, Kong, Dehui, Fu, Jia, et al. Associations between ambient temperature and adult asthma hospitalizations in Beijing, China: a time-stratified case-crossover study. Respiratory research. 2022;23:38. https://doi.org/https://doi.org/10.1186/s12931-022-01960-8
15. Sluyter, John D., Camargo, Carlos A., Waayer, Debbie, et al. Effect of Monthly, High-Dose, Long-Term Vitamin D on Lung Function: A Randomized Controlled Trial. Nutrients. 2017;9:1353. https://doi.org/https://doi.org/10.3390/nu9121353
16. Watkins, Stephanie, Harrison, Tanja, Mushtaq, Sohail. A 12-week double-blind randomised controlled trial investigating the effect of dietary supplementation with 125 µg/d vitamin D in adults with asthma. British Journal of Nutrition. 2024;132:738-49. https://doi.org/10.1017/S0007114524000953
17. Yu, Hang, Huang, Xi, Zhu, Hua-He, et al. Apigenin ameliorates non-eosinophilic inflammation, dysregulated immune homeostasis and mitochondria-mediated airway epithelial cell apoptosis in chronic obese asthma via the ROS-ASK1-MAPK pathway. Phytomedicine. 2023;111:154646. https://doi.org/10.1016/j.phymed.2023.154646
18. Page, Matthew J, McKenzie, Joanne E, Bossuyt, Patrick M, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj. 2021;372:https://doi.org/https://doi.org/10.1136/bmj.n71
19. Denlinger, Loren C., King, Tonya S., Cardet, Juan Carlos, et al. Vitamin D Supplementation and the Risk of Colds in Patients with Asthma. American Journal of Respiratory and Critical Care Medicine. 2016;193:634-41. https://doi.org/10.1164/rccm.201506-1169OC
20. Andújar-Espinosa, Rubén, Salinero-González, Lourdes, Illán-Gómez, Fátima, Castilla-Martínez, Manuel, Hu-Yang, Chunshao, Ruiz-López, Francisco José. Effect of vitamin D

supplementation on asthma control in patients with vitamin D deficiency: the ACVID randomised clinical trial. Thorax. 2021;76:126-33. https://doi.org/https://doi.org/10.1136/thoraxjnl-2019-213936
21. Chiewchalermsri, Chirawat, Sangkanjanavanich, Sasipa, Pradubpongsa, Panitan, et al. Randomized, double-blind, placebo-controlled trial of vitamin D supplementation in the build-up phase of house dust mite-specific immunotherapy. Allergy, Asthma & Immunology Research. 2023;15:336. https://doi.org/10.4168/aair.2023.15.3.336
22. Camargo, Carlos A., Toop, Les, Sluyter, John, et al. Effect of Monthly Vitamin D Supplementation on Preventing Exacerbations of Asthma or Chronic Obstructive Pulmonary Disease in Older Adults: Post Hoc Analysis of a Randomized Controlled Trial. Nutrients. 2021;13:521. https://doi.org/https://doi.org/10.3390/nu13020521
23. Crocker, Thomas Frederick, Lam, Natalie, Jordao, Magda, et al. Risk-of-bias assessment using Cochrane's revised tool for randomized trials (RoB 2) was useful but challenging and resource-intensive: observations from a systematic review. Journal of clinical epidemiology. 2023;161:39-45. https://doi.org/https://doi.org/10.1016/j.jclinepi.2023.06.015
24. Manousaki, Despoina, Paternoster, Lavinia, Standl, Marie, et al. Vitamin D levels and susceptibility to asthma, elevated immunoglobulin E levels, and atopic dermatitis: A Mendelian randomization study. PLOS Medicine. 2017;14:e1002294. https://doi.org/10.1371/journal.pmed.1002294
25. Thomas, Dennis, McDonald, Vanessa M., Pavord, Ian D., Gibson, Peter G. Asthma remission: what is it and how can it be achieved? European Respiratory Journal. 2022;60:2102583. https://doi.org/10.1183/13993003.02583-2021
26. Sharma, Sunita, Gerber, Anthony N, Kraft, Monica, Wenzel, Sally E. Asthma pathogenesis: phenotypes, therapies, and gaps: summary of the Aspen Lung Conference 2023. American journal of respiratory cell and molecular biology. 2024;71:154-68. https://doi.org/https://doi.org/10.1165/rcmb.2024-0082WS
27. Camargo, Carlos A, Jr, Sluyter, John, Stewart, Alistair W, et al. Effect of Monthly High-Dose Vitamin D Supplementation on Acute Respiratory Infections in Older Adults: A Randomized Controlled Trial. Clinical Infectious Diseases. 2020;71:311-7. https://doi.org/10.1093/cid/ciz801
28. Schleich, Florence, Bougard, Nicolas, Moermans, Catherine, Sabbe, Mare, Louis, Renaud. Cytokine-targeted therapies for asthma and COPD. European Respiratory Review. 2023;32:https://doi.org/https://doi.org/10.1183/16000617.0193-2022
29. Savin, Innokenty A, Zenkova, Marina A, Sen'kova, Aleksandra V. Bronchial asthma, airway remodeling and lung fibrosis as successive steps of one process. International journal of molecular sciences. 2023;24:16042. https://doi.org/https://doi.org/10.3390/ijms242216042
30. Feng, Kang-ni, Meng, Ping, Zou, Xiao-ling, et al. IL-37 protects against airway remodeling by reversing bronchial epithelial–mesenchymal transition via IL-24 signaling pathway in chronic asthma. Respiratory Research. 2022;23:244. https://doi.org/https://doi.org/10.1186/s12931-022-02167-7
31. Martineau, Adrian R, MacLaughlin, Beverley D, Hooper, Richard L, et al. Double-blind randomised placebo-controlled trial of bolus-dose vitamin D3 supplementation in adults with asthma (ViDiAs). Thorax. 2015;70:451-7. https://doi.org/http://doi.org/10.1183/20734735.121116
32. Stikker, Bernard S, Hendriks, Rudi W, Stadhouders, Ralph. Decoding the genetic and epigenetic basis of asthma. Allergy. 2023;78:940-56. https://doi.org/https://doi.org/10.1111/all.15666
33. Qian, Ling, Mehrabi Nasab, Entezar, Athari, Seyyede Masoume, Athari, Seyyed Shamsadin. Mitochondria signaling pathways in allergic asthma. Journal of Investigative Medicine. 2022;70:863-82. https://doi.org/https://doi.org/10.1136/jim-2021-002098
34. Cabrera López, Carlos, Sánchez Santos, Alejandra, Lemes Castellano, Angelina, et al. Eosinophil subtypes in adults with asthma and adults with chronic obstructive pulmonary

disease. American journal of respiratory and critical care medicine. 2023;208:155-62. https://doi.org/https://doi.org/10.1164/rccm.202301-0149OC
35. Legaki, Evangelia, Arsenis, Christos, Taka, Styliani, Papadopoulos, Nikolaos G. DNA methylation biomarkers in asthma and rhinitis: Are we there yet? Clinical and translational allergy. 2022;12:e12131. https://doi.org/https://doi.org/10.1002/clt2.12131
36. Prietl, Barbara, Treiber, Gerlies, Pieber, Thomas R., Amrein, Karin. Vitamin D and Immune Function. Nutrients [Internet]. 2013; 5(7):[2502-21 pp.].
37. Liu, Lu, Zhou, Ling, Wang, Lingling, et al. MUC1 attenuates neutrophilic airway inflammation in asthma by reducing NLRP3 inflammasome-mediated pyroptosis through the inhibition of the TLR4/MyD88/NF-κB pathway. Respiratory Research. 2023;24:255. https://doi.org/https://doi.org/10.1186/s12931-023-02550-y
38. Pratiwi, Donna, Harimawan, Agustinus I Wayan. Prognostic performance of GNRI versus PNI for predicting mortality in elderly critically ill patients. World Nutrition Journal. 2026;9:1-12. https://doi.org/10.25220/WNJ.V09.i2.0001
39. Habib, Nazia, Pasha, Muhammad Asghar, Tang, Dale D. Current understanding of asthma pathogenesis and biomarkers. Cells. 2022;11:2764. https://doi.org/https://doi.org/10.3390/cells11172764
40. Olsthoorn, Simone EM, van Krimpen, Anneloes, Hendriks, Rudi W, Stadhouders, Ralph. Chronic inflammation in asthma: looking beyond the Th2 cell. Immunological Reviews. 2025;330:e70010. https://doi.org/https://doi.org/10.1111/imr.70010