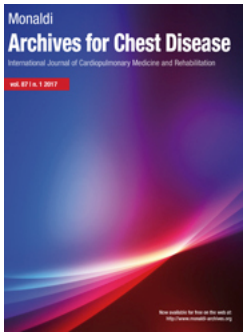

Monaldi Archives for Chest Disease

eISSN 2532-5264 https://www.monaldi-archives.org/

Monaldi Arch Chest Dis 2025 [Online ahead of print]

To cite this Article:
Chen Y, Li X, Wu M, et al. **Associations between sedentary behavior, physical activity frequency, and asthma: insights from the National Health and Nutrition Examination Survey 2009-2018.** *Monaldi Arch Chest Dis* doi: 10.4081/monaldi.2025.3491

Associations between sedentary behavior, physical activity frequency, and asthma: insights from the National Health and Nutrition Examination Survey 2009-2018

Yanhao Chen,[1*] Xiang Li,[1*] Mengqi Wu,[2*] Jiaqi Peng,[3] Jiao Zhang,[3]
Jie Bao,[3] Yongsheng Fan,[4] Shuo Huang[3]

[1]The Second School of Clinical Medicine, Zhejiang Chinese Medical University, Hangzhou; [2]Hangzhou Hospital of Traditional Chinese Medicine of Zhejiang Chinese Medical University, Hangzhou; [3]School of Basic Medical Sciences, Zhejiang University of Chinese Medicine, Hangzhou; [4]The Second Affiliated Hospital of Zhejiang Chinese Medical University (Xinhua Hospital of Zhejiang Province), Hangzhou, China

*These authors contributed equally to this work.

Correspondence: Shuo Huang, School of Basic Medical Sciences, Zhejiang Chinese Medical University, Hangzhou, China. E-mail: hs930928@163.com

Contributions: YC, conceptualization, writing – original draft, investigation, project administration; XL, data curation; SH, formal analysis, validation; JZ, methodology; YF, resources, supervision; JP, software; MW, visualization; JB, SH, writing – review and editing.

Conflict of interest: the authors report no competing interests.

Ethics approval and consent to participate: this study is based on data from the National Health and Nutrition Examination Survey (NHANES) 2009–2018. Ethical approval for the NHANES protocol was granted by the National Center for Health Statistics (NCHS) Research Ethics Review Board.

Informed consent: this study is based on publicly available and de-identified data from the National Health and Nutrition Examination Survey (NHANES). All participants provided informed consent at the time of data collection by the original institution, and no additional consent was required for this secondary analysis.

Patient consent for publication: as this study utilizes publicly available, de-identified data from NHANES, individual consent for publication was not required.

Availability of data and materials: the data that support the findings of this study are available in the National Health and Nutrition Examination Survey (NHANES) repository at [https://www.cdc.gov/nchs/nhanes/index.htm], reference number NHANES 2009-2018.

Funding: this work was supported by the Research Project of Zhejiang Chinese Medical University (2023RCZXZK03) and the Postdoctoral Fellowship Program of CPSF (GZB20230664).

Acknowledgments: the authors thank the Home for Researchers editorial team (www.home-for-researchers.com) for providing language editing services.

Abstract

This study aimed to explore the relationship between sedentary time and asthma prevalence and to examine the relationship between physical activity, sedentary behavior, and asthma symptom improvement among individuals with a history of asthma. As a cross-sectional study, the associations observed do not imply causation. Utilizing data from five survey cycles (2009-2018), the study analyzed sedentary time and physical activity frequency using multivariate logistic regression and generalized additive models. Subgroup analyses and interaction tests evaluated demographic influences on the relationship between sedentary behavior and asthma. Results indicated that extended sedentary behavior was significantly associated with a higher likelihood of asthma, with individuals sitting more than 8 hours daily having 35% greater odds of having asthma. Reduced sedentary time and moderate physical activity may be associated with a lower likelihood of reporting current asthma, with a significant reduction observed when moderate activity occurred ≤2 times per week.

Key words: sedentary behavior, physical activity, asthma prevalence, current asthma, NHANES.

Introduction

Asthma is a chronic respiratory condition marked by airway inflammation and hyperreactivity, causing repeated episodes of wheezing, breathlessness, chest tightness, and coughing [1]. Currently, there are approximately 300 million people with asthma worldwide, with an asthma prevalence rate of about 10% in children and adolescents, and 6-7% in adults [2]. The management of asthma mainly depends on inhaled corticosteroids and bronchodilators to control symptoms and prevent acute attacks [3,4]. Asthma pathogenesis is influenced by genetic predisposition, environmental factors, and immune system function. Ongoing research into these mechanisms has consistently led to new targeted therapies [5,6]. Despite the diverse treatment options, asthma is still associated with the significant health burden and the decline in quality of life [2,7,8].

Sedentary behavior refers to any stationary posture while awake, such as sitting, reclining, or lying down, with energy expenditure below 1.5 metabolic equivalents (METs) [9,10]. Sedentary behavior affects fat metabolism and blood lipid levels, leading to atherosclerosis, cardiovascular diseases, chronic low-grade inflammation, and increased cancer risk [11-14]. Given these health risks, managing sedentary behavior has become a significant public health concern [15]. For instance, the World Health Organization advises reducing sedentary time and incorporating standing activities during sedentary periods to reduce the health risks associated with prolonged inactivity. Physical activity refers to any skeletal muscle-induced movement that increases energy expenditure beyond resting levels [16]. Lack of physical activity is considered a risk factor for various chronic diseases and health problems, such as type 2 diabetes, coronary heart disease, and hypertension [17].

Existing studies indicate that sedentary behavior and physical activity are associated with asthma. For example, in a survey of participants in the UK Biobank, Cao et al. found that sedentary individuals had a higher risk of various chronic diseases, including asthma [18]. Lack of Exercise is common in asthma and is regarded as the significant modifiable risk factor leading to adverse clinical outcomes [19]. Increasing physical activity in the clinical asthma control can significantly improve symptoms in asthma patients, and regular activity may serve as the potential non-pharmacological treatment for adult asthma patients [20]. While prior research has linked sedentary behavior to various chronic diseases, including asthma, the specific focus on asthma has been limited, restricting the applicability of these findings for asthma management. Furthermore, limited research exists on how sedentary behavior and

physical activities affect asthma symptom improvement in patients with a history of asthma, often involving small sample sizes. Previous research has also not specified an optimal frequency of physical activity that could reduce the recurrence of asthma symptoms in those with a history of the disease.

Therefore, this study aims to conduct a large-sample cross-sectional analysis based on the National Health and Nutrition Examination Survey (NHANES) to achieve two primary objectives: (1) to examine the association between sedentary behavior and asthma prevalence in the general population; and (2) to further explore the associations of both sedentary behavior and physical activity with reporting current asthma among individuals with a history of asthma. This cross-sectional study aims to contribute more comprehensive and specific insights into the associations between lifestyle factors and asthma.

Materials and Methods

Data sources and study population

The National Center for Health Statistics (NCHS) conducts NHANES, a large-scale cross-sectional study, to objectively assess the nutritional and health status of the US population [21]. A stratified, multistage probability cluster sampling method was employed to recruit a representative sample of the entire US population. All participants provided consent for their data to be used in research, and the NHANES study protocols received approval from the National Health Examination Center's research ethics review board [22].

The research analyzed data from five NHANES survey cycles spanning 2009 to 2018, with each participant assessed only once per cycle as part of the cross-sectional design. Given the cross-sectional nature of NHANES, all associations identified in this study are observational and do not imply causation. Initially, a total of 49,693 individuals were enrolled. The final analysis comprised 33,920 participants after excluding individuals under 12 years of age (N=14,304) and those with incomplete sedentary (N=1,356) or asthma data (N=133) (Figure 1).

Exposure and outcome definitions

In this study, the exposure variables are defined as the sedentary time and physical activity of the participants. All data were sourced from the NHANES physical activity questionnaire. The questionnaire inquires, 'How much time do you or does the specified person typically spend

sitting each day?' and records sedentary time in minutes, with values in multiples of 60. This study analyzed sedentary time by converting it into hours and classifying it into four categories: less than 4 hours, 4 to 6 hours, 6 to 8 hours, and more than 8 hours, following previous research [23,24]. This classification aids in differentiating the potential asthma impacts associated with varying sedentary levels, enhancing the analysis of the relationship between sedentary behavior and asthma outcomes. The questionnaire inquires if participants partake in high-intensity exercises, like running or basketball, that notably elevate breathing or heart rate for a minimum of 10 minutes. It also inquires if they participate in moderate-intensity activities, like brisk walking, cycling, swimming, or golf, that elevate breathing or heart rate for a minimum of 10 minutes.

The study included two outcome variables derived from participants' responses in the Medical Conditions Questionnaire of NHANES. The first outcome was the population-level current asthma classification, and the second was whether participants reported having current asthma (among those with a prior asthma diagnosis). Participants were initially asked if a healthcare professional had ever diagnosed them with asthma. If the answer was yes, they were further asked, 'Do you/Does SP still have asthma?' Based on these responses, two grouping strategies were applied. In the first strategy, participants were categorized into a current asthma group, defined as those who had been diagnosed with asthma and still reported having asthma, and a no current asthma group, which included individuals who had never been diagnosed with asthma or had a prior diagnosis but no longer had asthma. This strategy was used to estimate the overall prevalence of current asthma in the general population. In the second strategy, which focused only on participants with a prior asthma diagnosis, those who reported still having asthma were classified as the current asthma group, while those who reported no longer having asthma were classified as the no current asthma group (with prior diagnosis).

Covariates

According to previous research, the potential covariates in this study that might influence the association between sedentary behavior and asthma include demographic data, such as age (years), gender (male/female), race, education level, and poverty income ratio (PIR). Additional questionnaire data encompass smoking (categorized as never, current, past, or unknown), as well as the presence of hypertension, diabetes, and coronary heart disease [25-28]. Additionally, examination data include body mass index (BMI). The specific measurement

methods for the covariates are publicly available at www.cdc.gov/nchs/nhanes/.

Statistical analysis

We followed the guidelines of the Centers for Disease Control and Prevention (CDC) for statistical analysis. Kruskal-Wallis test was employed to analyze differences in continuous variables across various sedentary time groups, while the chi-square test assessed differences in categorical variables. Continuous variables are expressed as mean ± standard deviation, and categorical variables as percentages. Subsequently, multivariate logistic regression models were used to investigate the association between sedentary time and asthma prevalence. Model 1 was analyzed without adjusting for any covariates. Model 2 was adjusted for gender, age, race, education level, and poverty income ratio. Model 3 built upon Model 2 by additionally adjusting for health indicators (BMI, moderate and vigorous physical activities, smoking status), and medical history (coronary heart disease). To further evaluate the relationship between sedentary time and asthma prevalence, we used generalized additive models (GAM) and smooth curve fitting. Furthermore, to examine the stability of the association between sedentary time and asthma prevalence within different categorical variables, we conducted subgroup analyses and interaction tests. In addition to the categorical variables among the covariates, marital status, drinking status, and family history of asthma were also included in the subgroup analyses. We also employed multivariate logistic regression models to examine the associations of sedentary time and physical activity with reporting current asthma among participants with a prior asthma diagnosis. To further examine the association between moderate physical activity frequency and reporting current asthma, we utilized generalized additive models and segmented regression. Specifically, segmented regression was applied to fit distinct line segments to different intervals of physical activity frequency. We compared the segmented regression model with a single-line model using a log-likelihood ratio test to evaluate the existence of a threshold effect. For missing covariate data, mean imputation was used for continuous variables and mode imputation was used for categorical variables. Statistical analyses were conducted using Empower software (X&Y Solutions, Inc., Boston, MA, USA) and R version 3.4.3 (The R Foundation). The significance level was set at $p < 0.05$.

Results

Baseline characteristics of participants

This study enrolled a total of 33,920 individuals, with males comprising 48.83% and females 51.17%. The average age was 44.32 ± 20.54 years, and the prevalence of asthma was 9.05%. Participants were categorized into four groups according to their daily sedentary time: less than 4 hours, 4 to 6 hours, 6 to 8 hours, and more than 8 hours. The average age significantly decreased with increasing sedentary time ($p < 0.001$), with the < 4 hours group having an average age of 46.62 ± 17.60 years and the > 8 hours group having the lowest average age of 39.88 ± 21.66 years. Asthma prevalence significantly rose with increased sedentary time, recorded at 7.04%, 8.74%, 9.38%, and 10.87% ($p < 0.001$).White blood cell count and eosinophil percentage were consistent across sedentary time groups, whereas hemoglobin levels differed significantly ($p = 0.003$).Statistically significant differences were observed in the distribution of race/ethnicity, marital status, education level, poverty income ratio (PIR), BMI, smoking, drinking, high-intensity activity, hypertension, coronary heart disease, and asthma across the different groups (all $p < 0.05$). These results are presented in Table 1.

The association between sedentary time and asthma prevalence

Table 2 illustrates the association between sedentary behavior and the prevalence of asthma. The findings indicate that extended sedentary periods are significantly associated with a higher likelihood of asthma. A positive association between sedentary time and asthma prevalence was observed in both unadjusted and adjusted models. To accurately assess the independent association between sedentary time and asthma, we adjusted for participants' physical activity levels in the fully adjusted model (Model 3) to minimize potential confounding from increased sedentary time due to asthma. After full adjustment, participants with sedentary time over 8 hours had a 35% higher odds of having asthma (Model 3: OR = 1.35, 95% CI: 1.20–1.52, $p < 0.001$). Additionally, we employed generalized additive models and smooth curve fitting to further explore the nonlinear relationship between sedentary time and asthma prevalence. As shown in *Supplementary Figure 1*, a clear upward trend in asthma prevalence was observed with increasing sedentary time.

Subgroup analysis

Our subgroup analysis results indicate that the association between sedentary time and increased asthma prevalence is inconsistent (*Supplementary Table 1*). For subgroups stratified by gender, PIR, drinking status, and diabetes, the significant association between sedentary time and asthma prevalence was evident in each subgroup (all $p < 0.05$). Interaction tests showed no significant differences across different strata, indicating no significant dependency of this positive association on gender, race/ethnicity, BMI, smoking status, hypertension, coronary heart disease, and hereditary asthma (all interactions $p > 0.05$).

The association between sedentary time and reporting current asthma among individuals with a prior asthma diagnosis

Based on the known positive association between sedentary time and asthma prevalence, we further explored whether sedentary time is associated with reporting current asthma among individuals with a prior asthma diagnosis. Table 3 presents the association between sedentary time and reporting current asthma. The results suggest that longer sedentary time is significantly associated with a higher likelihood of reporting current asthma. After full adjustment, participants with a history of asthma and sedentary time between 6 and 8 hours had 26% higher odds of reporting current asthma (Model 3: OR = 1.26, 95% CI: 1.07–1.50, $p = 0.006$).

The association between physical activity and reporting current asthma among individuals with a prior asthma diagnosis

This study further explores the role of physical activity in relation to reporting current asthma by analyzing its intensity and frequency. Table 4 and *Supplementary Table 2* respectively present the associations between moderate physical activities, vigorous physical activities, and reporting current asthma among individuals with a prior asthma diagnosis. Our findings suggest that engaging in moderate physical activities is associated with a lower likelihood of reporting current asthma. In the fully adjusted model, patients engaging in moderate physical activities had a 19% lower odds of reporting current asthma (Model 3: OR = 0.81, 95% CI: 0.71–0.92, $p < 0.001$), whereas the association between vigorous physical activities and reporting current asthma was not statistically significant after adjustment. To further explore the relationship between moderate physical activities and reporting current asthma, we used generalized additive models (*Supplementary Figure 2*) to analyze the weekly frequency of

activities and the likelihood of reporting current asthma. The plot suggested a potential threshold effect, with a noticeable decline in asthma probability when frequency increased from 0 to 2 times per week, followed by a plateau and then a slight increase. Based on this pattern, we categorized activity frequency into three groups (≤2, 2–4, and >4 times/week) for further threshold effect analysis. Segmented linear regression (*Supplementary Table 3*) showed that when the weekly frequency of activities was less than or equal to 2, an increase in frequency was significantly associated with a decreased likelihood of reporting current asthma (OR = 0.87, $p = 0.003$).

Discussion

This cross-sectional study of 33,920 participants found a significant association between longer sedentary time and increased asthma prevalence. *Supplementary Figure 1* complements the main findings by illustrating the continuous dose–response relationship between sedentary time and asthma prevalence, providing visual support for the observed nonlinear association. Subgroup and interaction analyses showed similar trends, though not all were statistically significant. When the weekly frequency of moderate physical activities was less than or equal to 2, a higher frequency was significantly associated with a lower likelihood of reporting current asthma among individuals with a prior asthma diagnosis. This potential threshold effect was initially observed in *Supplementary Figure 2*, which showed a decline in asthma probability from 0 to 2 times per week.

Sedentary time was classified into four categories (<4 h, 4–6 h, 6–8 h, and >8 h per day) based on thresholds commonly used in previous studies. Notably, a large harmonised meta-analysis of over 1 million participants adopted the same four-category classification and identified a curvilinear increase in mortality risk beyond 8 h/day of sitting [24]. The same classification method has also been applied in studies on other respiratory outcomes, supporting its relevance for evaluating sedentary behavior in asthma research [29]. To our knowledge, this is the first study to systematically examine the associations of sedentary time and moderate physical activity frequency with asthma prevalence and reporting current asthma using a nationally representative sample. By incorporating total daily sedentary time and evaluating physical activity based on frequency, our analysis better reflects the intensity of behavior. Additionally, the inclusion of a broad age range and comprehensive demographic data enhances the generalizability and relevance of our findings [18,30].

Although the mechanisms linking sedentary time and physical activities with asthma are unclear, there is some evidence to support their association. Some studies suggest that sedentary behavior may contribute to asthma through indirect pathways, such as promoting central obesity and systemic inflammation, both of which are known to affect lung health [31-33]. Sitting for less than 4 hours a day is a relatively healthy lifestyle habit for lung function [34].In terms of physical activities, aerobic physical activity can reduce the levels of serum pro-inflammatory cytokines and enhance the responsiveness of the immune system [35-37]. Secondly, exercise interventions increase plasma antioxidant capacity and circulating nitrate levels while reducing the ratio of reduced glutathione to oxidized glutathione, thereby reducing oxidative stress and improving asthma symptoms and lung function [38,39]. These mechanisms collectively explain the complex impact of sedentary behavior and physical activities on the immune response in asthma patients, highlighting the importance of reducing sedentary time and engaging in moderate activities.

Risk factors for asthma include gender, race, smoking, and obesity [40]. In our stratified analysis, the association between sedentary time and asthma prevalence was not observed in Asian participants. This may be influenced by unmeasured factors such as cultural adaptability, diet, and lifestyle, which should be considered in future research [41].

In the analysis of high-frequency moderate physical activity (>4 times/week), the regression coefficient suggested a slight inverse association with reporting current asthma (OR = 0.964), yet the adjusted means in *Supplementary Figure 2* showed an upward trend. This apparent inconsistency may be due to data variability and limited sample size in this subgroup, as indicated by the wide confidence interval and non-significant *p*-value ($p = 0.630$) in the threshold effect analysis (*Supplementary Table 3*). These results highlight the need for cautious interpretation and further investigation.

As far as we are aware, this study represents the largest sample size to date examining the association between sedentary time, physical activity, and reporting current asthma, which strengthens the reliability of the study's conclusions. Furthermore, previous studies have mostly quantified physical activity through step counts. In contrast, we subdivided daily physical activities and used the weekly frequency of activities as a quantitative indicator, helping to more accurately assess the association between physical activities and reporting current asthma. This study also has several limitations. First, due to the cross-sectional design, it can only reveal associations between sedentary time, physical activity, and asthma outcomes,

without establishing causality. We must critically acknowledge the potential for reverse causation, particularly in patients with more severe asthma symptoms who may reduce physical activity and increase sedentary time due to their condition, rather than sedentary behavior being the cause of symptom worsening. Second, each participant was assessed once, and the use of data spanning 2009–2018 may introduce some heterogeneity due to gradual changes in asthma diagnosis, environment, and lifestyle over time. Third, data on physical activity, sedentary behavior, and asthma status were primarily obtained through self-reported questionnaires, which may be subject to recall bias and misclassification. Although the instrument used to assess physical activity is relatively fragile and may not capture detailed activity patterns, it is generally regarded as acceptable for use in large-scale epidemiological studies [42,43]. Lastly, the potential for confounding must be acknowledged when interpreting the association between sedentary behavior and asthma. Although we adjusted for a number of relevant covariates, residual confounding may persist due to unmeasured or imprecisely measured factors. In addition, our study did not include information on maintenance therapy for asthma, a questionnaire assessing respiratory symptom intensity, or lung function testing. The absence of these indicators of clinical asthma control and severity limits our ability to explore how sedentary behavior or physical activity may vary by asthma severity, and prevents any firm conclusions from being drawn regarding their relationship.

Conclusions

In conclusion, our study indicates a significant positive association between sedentary time and asthma prevalence, with participants who have longer sedentary time showing a higher likelihood of having asthma. Additionally, we found that among individuals with a prior asthma diagnosis, longer sedentary time was significantly associated with a higher likelihood of reporting current asthma. Further analysis shows that moderate physical activities are positively associated with a lower likelihood of reporting current asthma, particularly when the weekly frequency is less than or equal to 2 times; an increase frequency was associated with a significant reduction in this likelihood.

Abbreviations

BMI: Body Mass Index; CDC: Centers for Disease Control and Prevention; CI: Confidence Interval; GAM: Generalized Additive Models; METs: Metabolic Equivalents; NHANES: National Health and Nutrition Examination Survey; NCHS: National Center for Health Statistics; OR: Odds Ratio; PIR: Poverty Income Ratio; SP: Specified Person.

References

1. Porsbjerg C, Melén E, Lehtimäki L, Shaw D. Asthma. Lancet 2023;401:858-73.
2. Aaron SD, Boulet LP, Reddel HK, Gershon AS. Underdiagnosis and Overdiagnosis of Asthma. Am J Respir Crit Care Med 2018;198:1012-20.
3. Nwaru BI, Ekström M, Hasvold P, et al. Overuse of short-acting β(2)-agonists in asthma is associated with increased risk of exacerbation and mortality: a nationwide cohort study of the global SABINA programme. Eur Respir J 2020;55:1901872.
4. Suissa S, Ernst P, Boivin JF, et al. A cohort analysis of excess mortality in asthma and the use of inhaled beta-agonists. Am J Respir Crit Care Med 1994;149:604-10.
5. Hammad H, Lambrecht BN. The basic immunology of asthma. Cell 2021;184:1469-85.
6. Boboltz A, Kumar S, Duncan GA. Inhaled drug delivery for the targeted treatment of asthma. Adv Drug Deliv Rev 2023;198:114858.
7. GBD 2015 Chronic Respiratory Disease Collaborators. Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet Respir Med 2017;5:691-706.
8. Enilari O, Sinha S. The global impact of asthma in adult populations. Ann Glob Health 2019;85:2.
9. Kim Y, Yeung SLA, Sharp SJ, et al. Genetic susceptibility, screen-based sedentary activities and incidence of coronary heart disease. BMC Med 2022;20:188.
10. Biensø RS, Ringholm S, Kiilerich K, et al. GLUT4 and glycogen synthase are key players in bed rest-induced insulin resistance. Diabetes 2012;61:1090-9.
11. Huang Y, Xu P, Fu X, et al. The effect of triglycerides in the associations between physical activity, sedentary behavior and depression: an interaction and mediation analysis. JAffect Disord 2021;295:1377-85.
12. Cao J, Lei S, Zhao T, et al. Changes in fat oxidation and body composition after combined exercise intervention in sedentary obese Chinese adults. J Clin Med 2022;11:1086.
13. Jager A, van Hinsbergh VW, Kostense PJ, et al. von Willebrand factor, C-reactive protein, and 5-year mortality in diabetic and nondiabetic subjects: the Hoorn Study. Arterioscler Thromb Vasc Biol 1999;19:3071-8.

14. Ridker PM, Hennekens CH, Buring JE, Rifai N. C-reactive protein and other markers of inflammation in the prediction of cardiovascular disease in women. N Engl J Med 2000;342:836-43.
15. Owen N, Healy GN, Dempsey PC, et al. Sedentary behavior and public health: integrating the evidence and identifying potential solutions. Annu Rev Public Health 2020;41:265-87.
16. Rodriguez-Ayllon M, Acosta-Manzano P, Coll-Risco I, et al. Associations of physical activity, sedentary time, and physical fitness with mental health during pregnancy: the GESTAFIT project. J Sport Health Sci 2021;10:379-86.
17. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380:219-29.
18. Cao Z, Xu C, Zhang P, Wang Y. Associations of sedentary time and physical activity with adverse health conditions: outcome-wide analyses using isotemporal substitution model. EClinicalMedicine 2022;48:101424.
19. McLoughlin RF, Clark VL, Urroz PD, et al. Increasing physical activity in severe asthma: a systematic review and meta-analysis. Eur Respir J 2022;60:2200546.
20. Kuder MM, Clark M, Cooley C, et al. A systematic review of the effect of physical activity on asthma outcomes. J Allergy Clin Immunol Pract 2021;9:3407-21.e3408.
21. The National Health and Nutrition Examination Survey. Available from: https://www.cdc.gov/nchs/nhanes-participants/about.html.
22. CDC. Ethics review board approval. Available from: https://www.cdc.gov/nchs/nhanes/about/erb.html.
23. Li Y, Di X, Liu M, et al. Association between daily sitting time and kidney stones based on the National Health and Nutrition Examination Survey (NHANES) 2007-2016: a cross-sectional study. Int J Surg 2024;110:4624-32.
24. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. Lancet 2016;388:1302-10.

25. Cheng C, Lin J, Zhang Z, Zhang L. Association between dietary zinc intake and asthma in overweight or obese children and adolescents: a cross-sectional analysis of NHANES. World Allergy Organ J 2024;17:100900.
26. Zhang X, Han Y, Tian Q, et al. The association between n-3 polyunsaturated fatty acid intakes and asthma in US children and adolescents: a cross-sectional study from NHANES. Pediatr Allergy Immunol 2023;34:e14024.
27. Saeed MA, Gribben KC, Alam M, et al. Association of dietary fiber on asthma, respiratory symptoms, and inflammation in the adult national health and nutrition examination survey population. Ann Am Thorac Soc 2020;17:1062-8.
28. Di X, Yuan C, Xiang L, et al. Association between Sitting time and urinary incontinence in the us population: data from the national health and nutrition examination survey (NHANES) 2007 to 2018. Heliyon 2024;10:e27764.
29. Ma X, Zhang Q, Gao X, Sun M. Association between physical activity, sedentary behavior and sleep disorders in chronic obstructive pulmonary disease patients: a cross-sectional study. Int J Chron Obstruct Pulmon Dis 2025;20:1175-87.
30. de Lima FF, Dos Santos JMB, Lunardi AC, et al. Physical activity and sedentary behavior as treatable traits for clinical control in moderate-to-severe asthma. J Allergy Clin Immunol Pract 2024;12:2047-55.
31. Rodas L, Riera-Sampol A, Aguilo A, et al. Effects of habitual caffeine intake, physical activity levels, and sedentary behavior on the inflammatory status in a healthy population. Nutrients 2020;12:2325.
32. Galmes-Panades AM, Konieczna J, Varela-Mato V, et al. Targeting body composition in an older population: do changes in movement behaviours matter? Longitudinal analyses in the PREDIMED-Plus trial. BMC Med 2021;19:3.
33. Wu X, Zhong L, Hu Y, Ruan L, et al. Sedentary behavior is associated with systemic immune-inflammation index and systemic inflammation response index levels: a cross-sectional analysis of the NHANES 2011-2018. Front Public Health 2025;13:1431065.
34. Wang Y, Xie Y, Chen Y, et al. Joint association of sedentary behavior and physical activity with pulmonary function. BMC Public Health 2024;24:604.
35. França-Pinto A, Mendes FA, de Carvalho-Pinto RM, et al. Aerobic training decreases bronchial hyperresponsiveness and systemic inflammation in patients with moderate or severe asthma: a randomised controlled trial. Thorax 2015;70:732-9.

36. Maurer DJ, Liu C, Xepapadaki P, et al. Physical activity in asthma control and its immune modulatory effect in asthmatic preschoolers. Allergy 2022;77:1216-30.
37. Shi YH, Shi GC, Wan HY, et al. Coexistence of Th1/Th2 and Th17/Treg imbalances in patients with allergic asthma. Chinese Med J 2011;124:1951-6.
38. Freeman A, Cellura D, Minnion M, et al. Exercise training induces a shift in extracellular redox status with alterations in the pulmonary and systemic redox landscape in asthma. Antioxidants 2021;10:1926.
39. Margaritelis NV, Paschalis V, Theodorou AA, et al. Redox basis of exercise physiology. Redox Biol 2020;35:101499.
40. Stern J, Pier J, Litonjua AA. Asthma epidemiology and risk factors. Semin Immunopathol 2020;42:5-15.
41. Han YY, Forno E, Celedón JC. Acculturation and asthma in Asian American adults. J Allergy Clin Immunol Pract 2022;10:2752-3.e2751.
42. Li H, Tang X, Guo X, et al. Association of dietary patterns with chronic respiratory health among U.S. adults. Front Immunol 2024;15:1457860.
43. Shi J, Lin Y, Jiang Y, et al. Dietary choline intake and its association with asthma: a study based on the National Health and Nutrition Examination Survey database. Clin Transl Allergy 2024;14:e12359.

Online supplementary material:
Supplementary Figure 1. Association between sedentary behavior and asthma prevalence.
Supplementary Figure 2. Association between weekly frequency of moderate physical activity and reporting current asthma.
Supplementary Table 1. Results of subgroup analysis and interaction analysis.
Supplementary Table 2. Association of vigorous physical activity with current asthma status among individuals with a prior asthma diagnosis
Supplementary Table 3. Threshold effect analysis of weekly frequency of moderate physical activity on current asthma status among individuals with a prior asthma diagnosis.

Table 1. Baseline characteristics of participants by categories of sedentary time per day.

Characteristics	Overall	Sedentary time/day(h)				*p*
		< 4	4 to < 6	6 to 8	> 8	
Number（n）	33,920	7,897	7,425	10,579	8,019	
Age (year), mean ± sd	44.32±20.54	46.62±17.60	47.10±19.67	44.01±21.68	39.88±21.66	<0.001*
White blood cell count (1000 cells/uL), mean ± sd	7.20±3.14	7.15±2.07	7.25±5.28	7.19±2.30	7.22±2.16	0.206
Eosinophil percentage, mean ± sd	2.87±2.01	2.84±2.10	2.86±2.14	2.85±2.07	2.90±2.06	0.254
Hemoglobin level, mean ± sd	13.96±1.45	13.99±1.46	13.99±1.44	13.94±1.44	13.92±1.44	0.003*
Gender, n (%)						0.250
Male	16,56 (48.83%)	3,809 (48.23%)	3,679 (49.55%)	5,202 (49.17%)	3,872 (48.29%)	
Female	17,358 (51.17%)	4,088 (51.77%)	3,746 (50.45%)	5,377 (50.83%)	4,147 (51.71%)	
Race/ethnicity, n (%)						<0.001*
Mexican American	5,344 (15.75%)	1,894 (23.98%)	1,133 (15.26%)	1,417 (13.39%)	900 (11.22%)	
Other Hispanic	3,570 (10.52%)	1,161 (14.70%)	821 (11.06%)	956 (9.04%)	632 (7.88%)	
Non-Hispanic White	12,64 (37.27%)	2,343 (29.67%)	2,849 (38.37%)	4,215 (39.84%)	3,236 (40.35%)	
Non-Hispanic Black	7,468 (22.02%)	1,534 (19.43%)	1,584 (21.33%)	2,434 (23.01%)	1,916 (23.89%)	
Other race	4,895 (14.43%)	965 (12.22%)	1,038 (13.98%)	1,557 (14.72%)	1,335 (16.65%)	
Marital status, n (%)						<0.001*
Minor	5,358 (15.80%)	443 (5.61%)	651 (8.77%)	2,069 (19.56%)	2,195 (27.37%)	
Never married	5,389 (15.89%)	1,233 (15.61%)	1,258 (16.94%)	1,670 (15.79%)	1,228 (15.31%)	
Married/with partner	16,771 (49.44%)	4,612 (58.40%)	4,073 (54.86%)	4,891 (46.23%)	3,195 (39.84%)	
Divorced/separated/widowed	6,402 (18.87%)	1,609 (20.37%)	1,443 (19.43%)	1,949 (18.42%)	1,401 (17.47%)	
Education level, n (%)						<0.001*
Minor	5,358 (15.80%)	443 (5.61%)	651 (8.77%)	2,069 (19.56%)	2,195 (27.37%)	
Under high school	6,745 (19.89%)	2,563 (32.46%)	1,660 (22.36%)	1,743 (16.48%)	779 (9.71%)	
High school or equivalent	6,384 (18.82%)	1,750 (22.16%)	1,656 (22.30%)	1,871 (17.69%)	1,107 (13.80%)	
Above high school	15,433 (45.50%)	3,141 (39.77%)	3,458 (46.57%)	4,896 (46.28%)	3,938 (49.11%)	
PIR, n (%)						<0.001*
<1.3	10,585 (31.21%)	2,847 (36.05%)	2,332 (31.41%)	3,234 (30.57%)	2,172 (27.09%)	
>=1.3, <3.5	14,742 (43.46%)	3,660 (46.35%)	3,357 (45.21%)	4,518 (42.71%)	3,207 (39.99%)	
>=3.5	8,593 (25.33%)	1,390 (17.60%)	1,736 (23.38%)	2,827 (26.72%)	2,640 (32.92%)	
BMI, n (%)						<0.001*
<=20	2,655 (7.83%)	402 (5.09%)	445 (5.99%)	922 (8.72%)	886 (11.05%)	
>20, <=25	8,646 (25.49%)	2,026 (25.66%)	1,845 (24.85%)	2,714 (25.65%)	2,061 (25.70%)	
>25,<=30	11,421 (33.67%)	2,952 (37.38%)	2,692 (36.26%)	3,413 (32.26%)	2,364 (29.48%)	

>30	11,198 (33.01%)	2,517 (31.87%)	2,443 (32.90%)	3,530 (33.37%)	2,708 (33.77%)	
Smoking, n (%)						<0.001*
Never	16,997(50.11%)	4,503 (57.02%)	3,972 (53.49%)	5,047 (47.71%)	3,475 (43.33%)	
Current	4,617(13.61%)	1,216 (15.40%)	1,120 (15.08%)	1,387 (13.11%)	894 (11.15%)	
Former	6,716(19.80%)	1,556 (19.70%)	1,591 (21.43%)	2,089 (19.75%)	1,480 (18.46%)	
Unkown	5,590(16.48%)	622 (7.88%)	742 (9.99%)	2,056 (19.43%)	2,170 (27.06%)	
Drinking, n (%)						<0.001*
Never	3,343(9.86%)	953 (12.07%)	721 (9.71%)	1,005 (9.50%)	664 (8.28%)	
Current	14,628(43.12%)	3,319 (42.03%)	3,481 (46.88%)	4,530 (42.82%)	3,298 (41.13%)	
Past	2,758(8.13%)	685 (8.67%)	639 (8.61%)	896 (8.47%)	538 (6.71%)	
Unknown	13,191(38.89%)	2,940 (37.23%)	2,584 (34.80%)	4,148 (39.21%)	3,519 (43.88%)	
Moderate physical activity(n/%)						0.169
No	19,841(58.49%)	4,671 (59.15%)	4,315 (58.11%)	6,233 (58.92%)	4,622 (57.64%)	
Yes	14,079(41.51%)	3,226 (40.85%)	3,110 (41.89%)	4,346 (41.08%)	3,397 (42.36%)	
Vigorous physical activity(n/%)						<0.001*
No	24,503(72.24%)	6,057 (76.70%)	5,584 (75.21%)	7,513 (71.02%)	5,349 (66.70%)	
Yes	9,417(27.76%)	1,840 (23.30%)	1,841 (24.79%)	3,066 (28.98%)	2,670 (33.30%)	
Hypertension, n (%)						<0.001*
No	23,393(68.97%)	5,559 (70.39%)	4,970 (66.94%)	7,141 (67.50%)	5,723 (71.37%)	
Yes	10,527(31.03)	2,338 (29.61%)	2,455 (33.06%)	3,438 (32.50%)	2,296 (28.63%)	
Diabetes, n (%)						0.110
No	30,063(88.63%)	6,982 (88.41%)	6,577 (88.58%)	9,338 (88.27%)	7,166 (89.36%)	
Yes	3,857(11.37%)	915 (11.59%)	848 (11.42%)	1,241 (11.73%)	853 (10.64%)	
Coronary heart disease, n (%)						0.002*
No	32,725(96.48%)	7,671 (97.14%)	7,144 (96.22%)	10,172 (96.15%)	7,738 (96.50%)	
Yes	1,195(3.52%)	226 (2.86%)	281 (3.78%)	407 (3.85%)	281 (3.50%)	
Asthma, n (%)						<0.001*
No	30,851(90.95%)	7,341 (92.96%)	6,776 (91.26%)	9,587 (90.62%)	7,147 (89.13%)	
Yes	3,069(9.05%)	556 (7.04%)	649 (8.74%)	992 (9.38%)	872 (10.87%)	
Familial asthma, n (%)						<0.001*
No	26,534 (78.23%)	6,347 (80.37%)	5,890 (79.33%)	8,284 (78.31%)	6,013 (74.98%)	
Yes	7,386(21.77%)	1,550 (19.63%)	1,535 (20.67%)	2,295 (21.69%)	2,006 (25.02%)	

Abbreviations: BMI, body mass index; PIR, poverty impact ratio. *$p < 0.05$.

Table 2. Association of sedentary time with asthma prevalence.

Exposure	Model 1	Model 2	Model 3
	(*n*=33,920)	(*n*=33,920)	(*n*=33,920)
Sedentary time/day(h)			
< 4 OR(95%CI), *p*	Reference	Reference	Reference
4 to 6 OR(95%CI), *p*	1.26 (1.12, 1.42) <0.001*	1.23 (1.09, 1.39) <0.001*	1.19 (1.06, 1.34) 0.004*
6 to 8 OR(95%CI), *p*	1.37 (1.23, 1.52) <0.001*	1.29 (1.15, 1.44) <0.001*	1.19 (1.06, 1.33) 0.002*
> 8 OR(95%CI), *p*	1.61 (1.44, 1.80) <0.001*	1.51 (1.34, 1.70) <0.001*	1.35 (1.20, 1.52) <0.001*

Model 1: crude model. Model 2: adjusted for age, gender, race, education level, and PIR. Model 3: adjusted for age, gender, race, education level, PIR, smoking status, hypertension, diabetes, moderate physical activities, vigorous physical activities, and coronary heart disease.
*$p < 0.05$.

Table 3. Association of sedentary time with reporting current asthma among individuals with a prior asthma diagnosis.

Exposure	Model 1	Model 2	Model 3
	(*n*=5,191)	(*n*=5,191)	(*n*=5,191)
Sedentary time/day(h)			
< 4 OR(95%CI), *p*	Reference	Reference	Reference
4 to 6 OR(95%CI), *p*	1.25 (1.05, 1.49) 0.011*	1.28 (1.07, 1.54) 0.006*	1.25 (1.05, 1.50) 0.013*
6 to 8 OR(95%CI), *p*	1.30 (1.11, 1.52) 0.001*	1.32 (1.12, 1.56) 0.001*	1.26 (1.07, 1.50) 0.006*
> 8 OR(95%CI), *p*	1.24 (1.05, 1.45) 0.010*	1.34 (1.13, 1.60) 0.001*	1.25 (1.05, 1.49) 0.013*

Model 1: crude model. Model 2: adjusted for age, gender, race, education level, and PIR. Model 3: adjusted for age, gender, race, education level, PIR, smoking status, hypertension, diabetes, moderate physical activities, vigorous physical activities, and coronary heart disease.
*$p < 0.05$.

Table 4. Association of moderate physical activity with reporting current asthma among individuals with a prior asthma diagnosis.

Exposure	Model 1	Model 2	Model 3
	(*n*=5,191)	(*n*=5,191)	(*n*=5,191)
Moderate physical activity			
No OR(95%CI), *p*	Reference	Reference	Reference
Yes OR(95%CI), *p*	0.67 (0.60, 0.76) <0.001*	0.78 (0.69, 0.88) <0.001*	0.81 (0.71, 0.92) <0.001*

Model 1: crude model. Model 2: adjusted for age, gender, race, education level, and PIR. Model 3: adjusted for age, gender, race, education level, PIR, smoking status, hypertension, diabetes, sedentary time, vigorous physical activities, and coronary heart disease.
*$p < 0.05$.

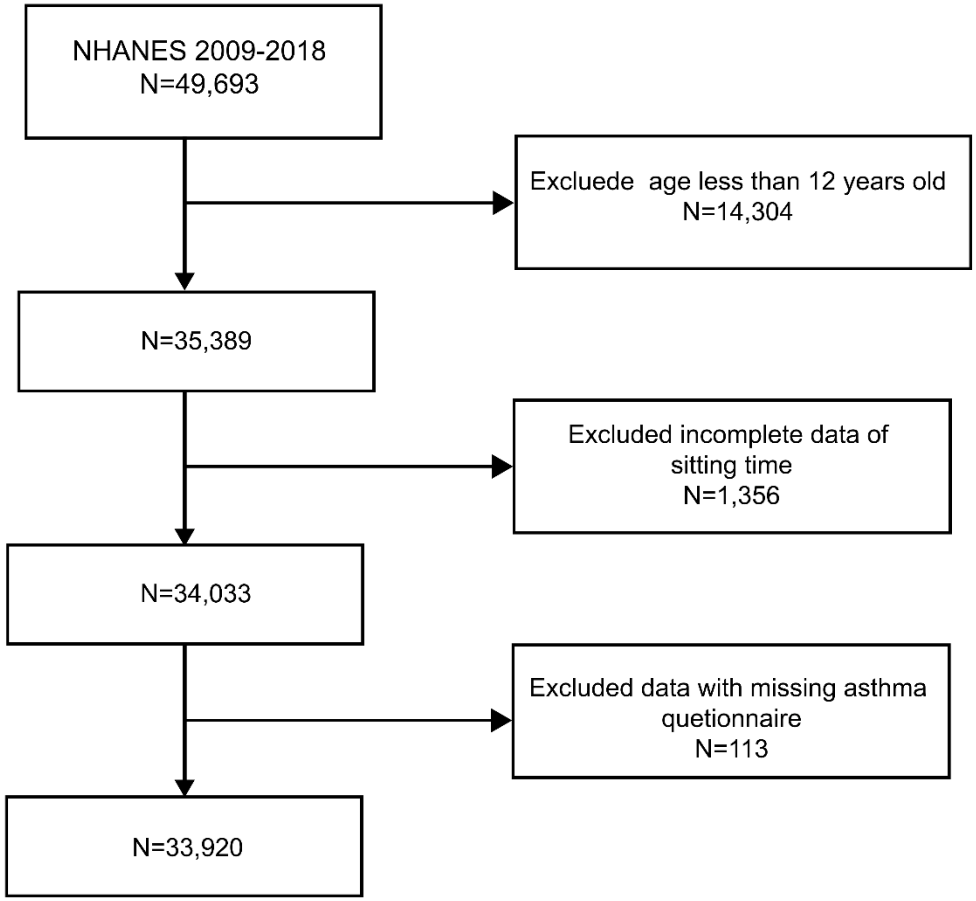

Figure 1. Flowchart of this study.