Association between BMI and asthma in adults over 45 years of age: analysis of Global Burden of Disease 2021, China Health and Retirement Longitudinal Study, and National Health and Nutrition Examination Survey data

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Summary

Background Asthma is a major global health concern, and body mass index (BMI) is a key risk factor. This study aims to investigate the potential nonlinear relationship between BMI and asthma risk in populations over 45 years of age using large-scale, cross-national data.

Methods This cross-sectional study utilised three databases: GBD 2021, China Health and Retirement Longitudinal Study (CHARLS; cross-sectional data from baseline survey, January 01, 2011 to December 31, 2011), and National Health and Nutrition Examination Survey (NHANES; cross-sectional data from 2011 to 2012 cycle). Participants aged ≥45 years after excluding those with missing data on BMI, asthma history, smoking history, age, sex, and BMI outside 10–80 kg/m^2 were included. Asthma was defined by self-report in CHARLS and by physician diagnosis plus recent symptoms in NHANES. Smooth curve fitting was performed to visualise the BMI-asthma relationship, adjusting for multiple confounders. We applied segmented regression models to identify potential threshold effects, used likelihood ratio tests to compare linear and non-linear models, and employed bootstrap resampling for confidence intervals.

Findings High BMI was the primary risk factor for asthma-related DALYs globally (14.93% in 2021). From CHARLS, we included 13,393 participants, comprising 6267 males (46.79%) and 7126 females (53.21%). From NHANES, we included 2925 participants, comprising 46.6% males and 53.4% females. CHARLS data revealed a U-shaped relationship between BMI and asthma risk, with critical points at 19.9 kg/m^2 and 29.9 kg/m^2. For BMI < 19.9 kg/m^2, asthma risk increased by 28% with each unit decrease in BMI (OR = 1.28, 95% CI: 1.15–1.43). For BMI ≥ 29.9 kg/m^2, asthma risk increased by 25% with each unit increase in BMI (OR = 1.25, 95% CI: 1.05–1.49). NHANES data showed a non-linear relationship with a turning point at 21.6 kg/m^2. For BMI ≥ 21.6 kg/m^2, asthma risk increased by 5% with each unit increase in BMI (OR = 1.05, 95% CI: 1.03–1.06).

Interpretation This study elucidates a significant non-linear relationship between BMI and asthma risk in populations aged 45 years and older, providing insights for tailored asthma prevention strategies, although the cross-sectional design limits causal inference. Future studies should focus on collecting and stratifying longitudinal data and adjusting for asthma diagnosis timing to obtain more accurate results.

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Keywords: Asthma; Body mass index; Global burden of disease; Nonlinear relationship; Cross-cultural study

Introduction

Asthma is a chronic respiratory disease characterised by airway inflammation and structural remodeling, leading to airway hyperresponsiveness and airflow obstruction that may become fixed in long-standing disease.[1,2] In 2019, the global prevalence of asthma reached 3.33%, resulting

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Research in context

Evidence before this study

A preliminary review of literature through PubMed and Web of Science databases (up to September 2024) using search terms "BMI," "asthma," "obesity," and "underweight" revealed that existing studies predominantly focused on linear associations in general populations, with notable limitations in addressing age-specific patterns and potential nonlinear relationships. Most investigations were geographically restricted or employed varying asthma definitions, highlighting the need for more comprehensive, cross-national analyses. To address these gaps, we leveraged three major data sources: the Global Burden of Disease (GBD) 2021 database for global disease burden estimation, the China Health and Retirement Longitudinal Study (CHARLS) for insights from the Chinese population, and the National Health and Nutrition Examination Survey (NHANES) for U.S. population data. This multi-database approach enables a more nuanced investigation of the potential nonlinear relationship between BMI and asthma risk in populations over 45 years of age, offering broader geographical representation and methodological consistency.

Added value of this study

To our knowledge, this study is the first to assess and quantify asthma prevalence risk on a global scale by determining specific BMI ranges. This study revealed a significant nonlinear relationship between BMI and asthma risk in individuals aged 45 years and above, indicating that both low and high BMIs may increase asthma risk. CHARLS data revealed a U-shaped relationship between BMI and asthma risk, with critical points at 19.9 kg/m^2 and 29.9 kg/m^2. NHANES data showed a non-linear relationship with a turning point at 21.6 kg/m^2.

Implications of all the available evidence

These findings provide novel insights into the impact of BMI on asthma prevalence across different cultural contexts, with important implications for developing tailored asthma prevention and intervention strategies for diverse populations. However, the cross-sectional design limits causal inference, and differences in asthma definitions between databases may affect consistency, though sensitivity analyses supported the robustness of the results. Future studies should consider more comprehensive body composition measures and distinguish between adult-onset and childhood-persistent asthma to better elucidate this complex relationship.

in 4.57 million deaths and ranking as the second leading cause of mortality among chronic respiratory diseases.[3] Despite the implementation of asthma management and prevention strategies, which have somewhat reduced its prevalence and mortality, the overall global burden of asthma remains severe.[4] In China, a nationwide epidemiological survey revealed an asthma prevalence of 4.2% among individuals aged 20 years and above, with a total patient population of 45.7 million.[5] In addition to premature mortality, patients with asthma often experience various comorbidities, including allergic rhinitis, gastroesophageal reflux disease, obstructive sleep apnea, and anxiety,[6,7] significantly impacting their quality of life.

Body mass index (BMI), a crucial indicator for assessing individual nutritional status, has garnered considerable attention because of its relationship with asthma. Arjun et al., in their review, explored the complex interplay between obesity and asthma and noted that obesity not only increases asthma prevalence but also leads to poorer clinical outcomes.[8] Another study indicated that for every 5-unit increase in BMI, asthma risk increases by 32%, indicating a significant positive correlation.[9] However, being underweight may also influence asthma occurrence, warranting further investigation into the nonlinear relationship between BMI and asthma prevalence. BMI represents a crucial risk factor for asthma, a significant global health concern affecting millions worldwide. While previous research has established associations between BMI and asthma, comprehensive understanding of this relationship remains limited, particularly in populations aged 45 and above. Moreover, many studies are confined to specific regions or populations and lack broad representativeness.

While the Global Burden of Disease (GBD) database provides a global perspective on asthma risk factors, it does not offer insights into the dose−response relationship between BMI and asthma. Therefore, this study integrates data from the GBD, China Health and Retirement Longitudinal Study (CHARLS), and the National Health and Nutrition Examination Survey (NHANES) to analyse the relationship between BMI and asthma comprehensively. Special attention should be given to the population aged 45 years and above, the impact of BMI on asthma risk should be validated, and potential threshold effects in this relationship should be explored. The utilization of cross-national data not only enhances the universality and reliability of the research findings but also provides new perspectives for understanding the BMI-asthma relationship across different cultural contexts.

Methods

Data collection and study population

Global burden of disease (GBD) database

The Global Burden of Disease (GBD) database provides estimates of incidence, prevalence, mortality, years of life lost (YLL), years lived with disability (YLD), and disability-adjusted life years (DALY) for 370 diseases and injuries across 204 countries and territories from 1990–2021. GBD database provides population-level data aggregated at the national and regional levels. In the GBD study, BMI as a risk factor was assessed through systematic review of epidemiological studies and national health surveys. The relationship between BMI and disease burden was quantified using relative risk assessment and population attributable fraction (PAF) analysis, with data standardization and uncertainty intervals calculated.[10] Epidemiological data on asthma incidence and associated risk factors were obtained from the Global Health Data Exchange online platform (https://vizhub.healthdata.org/gbd-results/). In the GBD 2021 study, asthma diagnosis was based on self-reported wheezing in the past 12 months and physician diagnosis (International Classification of Diseases, 9th Revision Code 493, 10th Revision Codes J45 and J46). Due to patient information desensitization in the GBD study, the Institutional Review Board of the University of Washington approved the waiver of informed consent.

China health and retirement longitudinal study (CHARLS) database

The CHARLS is a nationally representative survey of Chinese adults aged ≥45 years that employs multistage sampling and probability-proportional-to-size sampling in urban and rural administrative units.[11] CHARLS database collected individual-level data through comprehensive personal interviews and health assessments. The CHARLS sample encompasses 150 county-level units across 28 provinces. Face−to-face interviews were conducted to collect detailed information on demographics, health status, socioeconomic status, and lifestyle habits. Asthma status was self-reported in the CHARLS study. This study utilised data from the 2011 CHARLS baseline survey (http://charls.pku.edu.cn/), which initially included 17,708 participants. After individuals with missing data on BMI, asthma history, smoking history, age, sex, and BMI outside the range of 10–80 kg/m^2 were excluded, the final study population comprised 13,393 individuals. To exclude extreme outliers and ensure robust analysis, we limited the BMI range to 10–80 kg/m^2. This range aligns with prior studies on BMI and disease relationships and reflects the distributions observed in CHARLS and NHANES datasets.[12] The CHARLS study was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent.

National health and nutrition examination survey (NHANES) database

The NHANES is a program conducted by the National Centre for Health Statistics (NCHS) to assess the health and nutritional status of adults and children in the United States. NHANES provides individual-level data collected through interviews, physical examinations, and laboratory tests. In the NHANES, asthma is typically defined through questionnaire responses regarding physician-diagnosed asthma and asthma attacks in the past year. This study used data from the 2011–2012 NHANES cycle (https://wwwn.cdc.gov/Nchs/Nhanes/2011–2012). From an initial 9756 participants, individuals were excluded if they had missing data on BMI, asthma history, or smoking history; were younger than 45 years; or had a BMI outside the range of 10–80 kg/m^2. The final NHANES study population consisted of 2925 individuals. To measure BMI, we utilised Mobile Examination Centre (MEC) weights (WTMEC2YR) for our analyses. The NHANES protocol was approved by the Research Ethics Review Board (ERB) of the Centres for Disease Control and Prevention (CDC). All participants provided informed consent before participation, and for minors, parental or guardian consent was also obtained.

Variable description

To ensure data comparability, this study utilised the 2011–2012 survey cycles from both the CHARLS and the NHANES databases. Notably, the CHARLS 2011 cycle includes data collected through early 2012. The primary exposure variable was BMI. In the NHANES, weight and height were measured through standardised physical examination procedures at mobile examination centres, whereas in the CHARLS, these metrics were obtained during onsite surveys. BMI was calculated as weight in kilograms divided by height in meters squared. In the analysis, BMI was treated both as a continuous variable and categorised into tertiles.

Covariates extracted from both databases included age (continuous variable), sex (male/female), education level (low: middle school and below/high: high school and above), marital status (married: currently married, cohabiting, divorced, widowed/unmarried: never married), smoking status (smokers: including current and former smokers/never smokers), alcohol consumption (drinkers: including current and former drinkers/never drinkers), and history of chronic diseases (hypertension and diabetes, on the basis of self-reported physician diagnoses). Sex (male/female) was self-reported by participants in both CHARLS and NHANES datasets, with no additional information collected on gender identity. All covariates were collected through standardised household interview questionnaires.

The primary outcome variable was asthma status, which was defined on the basis of self-reported physician diagnosis (yes/no). To ensure data quality, missing data were thoroughly assessed. For variables with missing data rates exceeding 10%, multiple imputation methods were employed. Sensitivity analyses were conducted for all analyses to evaluate the robustness of the results.

This manuscript is reported as per the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) Guidelines. We utilised de-identified data from public databases, including GBD, CHARLS and NHANES. The ethical approval was covered by the original surveys and was not necessary for the present study.

Statistical analysis

This study utilised GBD 2021 data to analyse risk factors contributing to the burden of asthma, assessing the attributable DALYs for each risk factor. The relative attributable risk (RAR) was calculated following the comparative risk assessment (CRA) framework described by Murray et al. and implemented in the GBD 2021 study.[13] This approach estimates the proportion of disease burden that would be reduced if the exposure to a risk factor were reduced to the theoretical minimum risk exposure level (TMREL). The calculation involves comparing the current health status to a counterfactual scenario where exposure is at the TMREL, while controlling for other independent risk factors.[14] Time trend analysis and bar charts were used to illustrate the contribution of high BMI to the overall disease burden.

For both the CHARLS and NHANES databases, continuous variables are presented as the means ± standard deviations, whereas categorical variables are expressed as counts and percentages. In the CHARLS dataset, comparisons of baseline characteristics between the asthmatic and nonasthmatic groups were conducted via the Kruskal–Wallis test for continuous variables and the chi−square test for categorical variables. For the NHANES data, all analyses employed weighted methods accounting for the complex sampling design to ensure national representativeness.

To examine potential nonlinear relationships between BMI and asthma risk, we performed smooth curve fitting for both databases, adjusting for age, sex, marital status, education level, smoking status, alcohol consumption, hypertension, and diabetes. The smooth curve fitting method followed the detailed description of Motulsky. Further analysis involved segmented regression models, using the likelihood ratio test (LRT) to compare Model I (linear) and Model II (nonlinear), and bootstrap resampling to analyse threshold effects between BMI and asthma risk. For the NHANES weighted analysis, we incorporated sampling weights, primary sampling units (PSUs), and stratification variables provided by the NHANES to account for the complex sampling design. Weighted regression analyses and smooth curve fittings were conducted via appropriate functions from the 'survey' package in R.

All the statistical tests were two-sided, with $P < 0.05$ considered statistically significant. All the statistical analyses and graphical representations were performed via R software (version 4.3.0).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The first author had complete access to the data, while the corresponding author held final responsibility for the decision to submit the manuscript for publication.

Results

Global asthma burden and high BMI as predominant risk factors

Supplementary Table S1 summarises the global burden of asthma in 2021. The global incidence was estimated at 37.9 million cases (95% UI: 31.4–46.9 million), with an age-standardised incidence rate of 516.7 per 100,000 people (95% UI: 425.4–646.1). Asthma accounted for 21.4 million DALYs (95% UI: 17.0–26.9 million), with an age-standardised DALY rate of 264.6 per 100,000 (95% UI: 208.3–333.4). The estimated number of asthma-related deaths was 436,193 (95% UI: 357,795–555,604), corresponding to an age-standardised mortality rate of 5.2 per 100,000 (95% UI: 4.3–6.6).

Fig. 1 presents a comprehensive analysis of risk factors associated with asthma burden on the basis of GBD study data, emphasizing the growing impact of high BMI on asthma. The time trend analysis from 1990–2021 (Fig. 1A) revealed a significant increase in the contribution of high BMI to asthma burden. Fig. 1B illustrates the global contribution of four risk factors to asthma-related DALYs, with high BMI emerging as the leading contributor at 14.93%, followed by occupational risk (7.86%), tobacco use (6.14%), and air pollution (0.93%). The age-stratified analysis (Fig. 1C) further underscores the predominant role of high BMI across all age groups, peaking at approximately 20% in the 45–54 age range. This figure highlights the evolving landscape of asthma risk factors, particularly the increasing importance of high BMI in the global asthma burden.

BMI-stratified characteristics in the CHARLS population

The CHARLS database study population (n = 13,393) was stratified into three BMI tertiles, comprising 6267 males (46.79%) and 7126 females (53.21%). The participant selection process for the ChARLS database is depicted in Fig. 2. Among them, 507 participants (3.79%) had physician-diagnosed asthma. Significant differences ($P < 0.001$) were observed across BMI groups for all variables. Higher BMI was associated with younger age (T3: 57.35 ± 9.06 years vs T1: 61.44 ± 10.37 years) and female predominance (61.71% in T3). Education levels increased with BMI, with 58.29% highly educated at T3 compared with 46.66% at T1. The lower BMI groups had higher rates of smoking (48.94% at T1) and drinking (35.76% at T1). Notably, the prevalence of

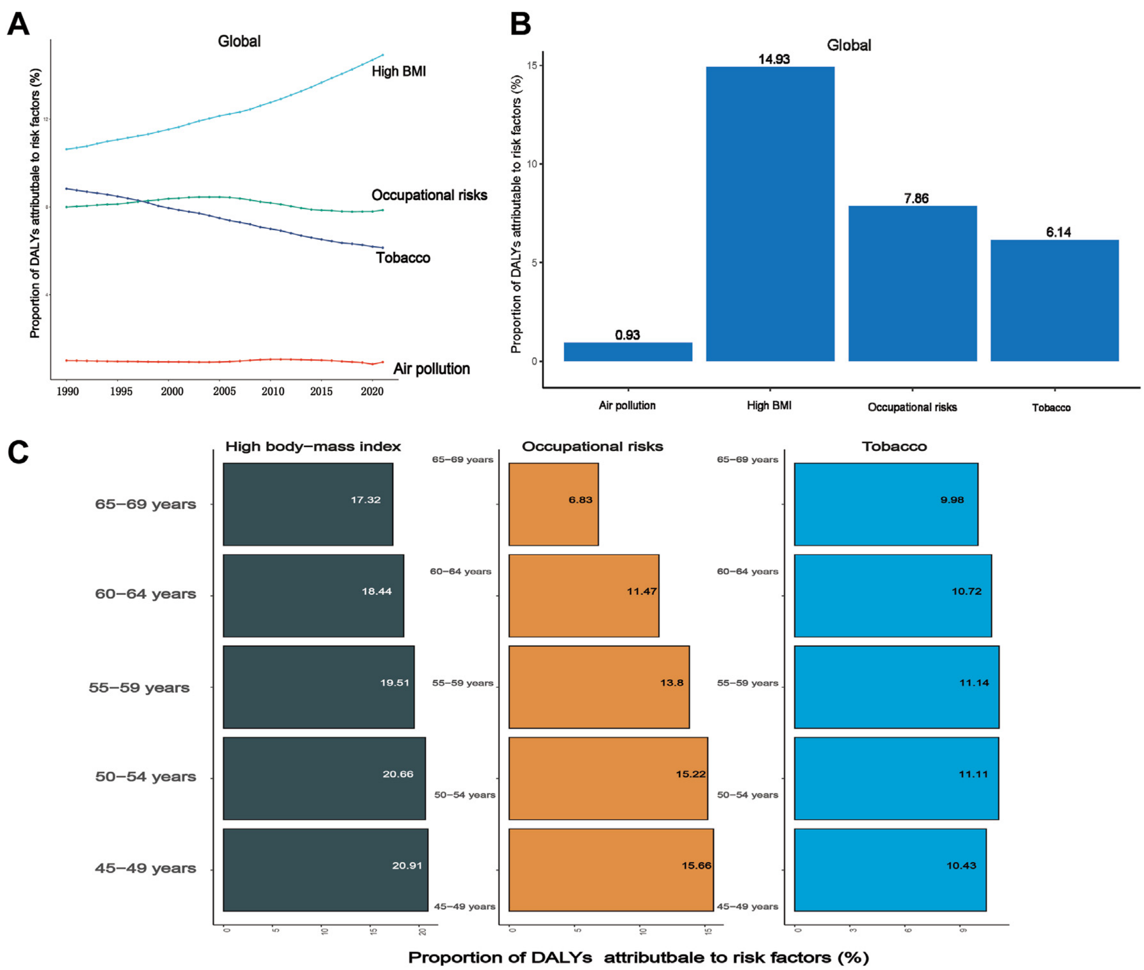

Fig. 1: **BMI as a major risk factor for asthma** A. Temporal changes in asthma risk factors B. Contribution of various risk factors to asthma-related DALYs in 2021 C. Proportionate contribution of asthma risk factors across different age groups for individuals aged 45 years and above in 2021.

hypertension (36.51% at T3 vs 13.62% at T1) and diabetes (9.55% at T3 vs 2.79% at T1) increased substantially with increasing BMI, whereas asthma prevalence was slightly elevated in the lowest BMI group (4.65% at T1) (Table 1).

BMI-stratified characteristics in the NHANES population

The NHANES dataset included 2925 participants, with a prevalence of 46.6% in males and 53.4% in females. The participant selection process for the NHANES database is depicted in Fig. 2. Within this cohort, 13.4% of participants were identified as having asthma based on self-reported diagnosis and symptoms. The weighted NHANES data revealed significant differences across BMI tertiles for most variables ($P < 0.05$), except education. Higher BMI was associated with younger age (T3: 59.46 ± 9.78 vs T1: 61.47 ± 10.92 years) and a greater prevalence of hypertension (59.76% vs 34.70%), diabetes (24.38% vs 8.12%), and asthma (18.23% vs 10.97%). The patients with the highest BMI at T3 were predominantly female (57.90%) and had lower marriage rates (83.44%). Smoking decreased with BMI (46.48% at T3 vs 53.81% at T1), whereas drinking was least prevalent in the highest BMI tertile (73.71% vs 76.95% at T1) (Table 2).

Analysis of the nonlinear relationship between BMI and asthma

Fig. 3A illustrates the relationship between BMI and asthma prevalence on the basis of data from the CHARLS. After adjusting for age, sex, marital status, education level, smoking status, alcohol consumption, hypertension status, and diabetes status, smoothed curve fitting revealed a U-shaped relationship between BMI and asthma prevalence. Further analysis via a

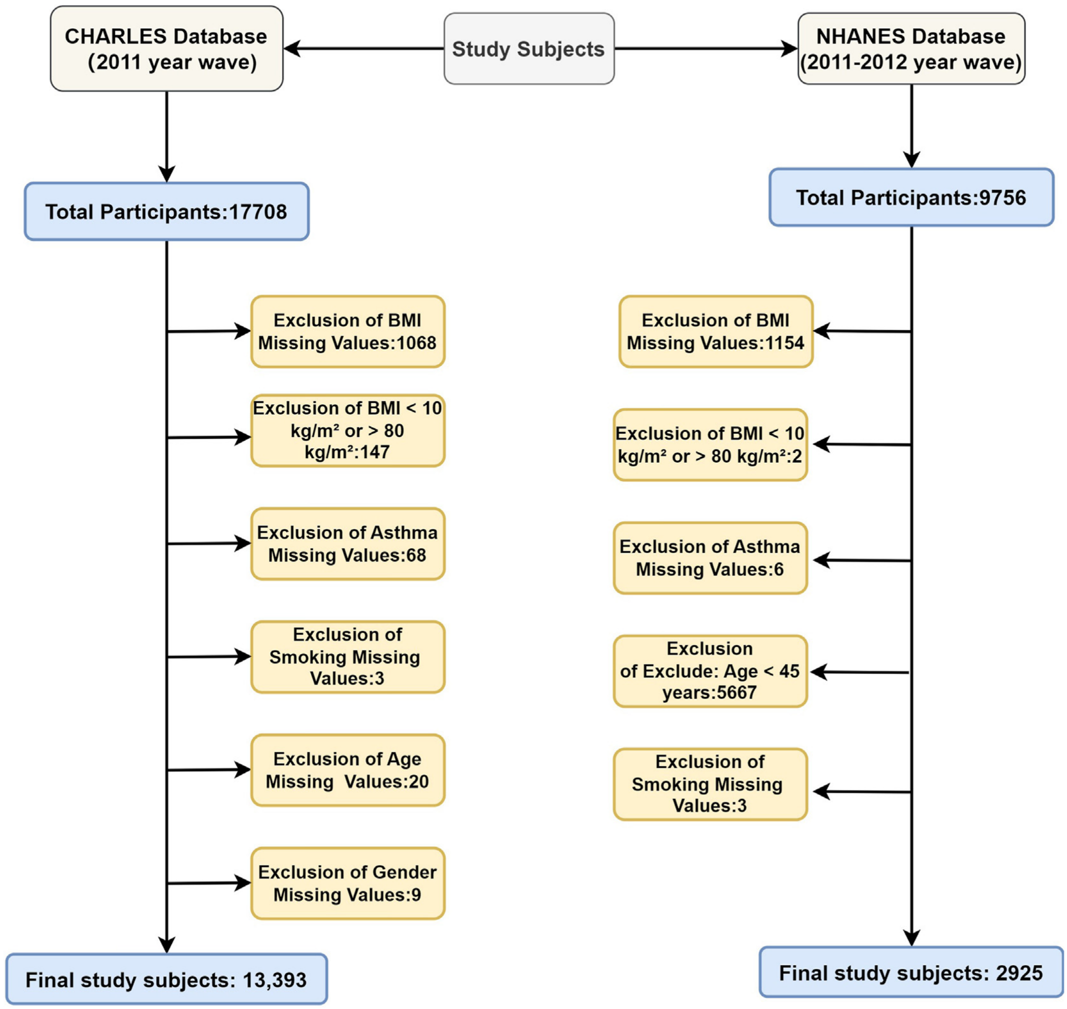

***Fig. 2:* Flow chart of the study population selection process.**

segmented regression model identified two critical BMI thresholds: 19.9 and 29.9 kg/m^2. The results demonstrated that in the low BMI range (BMI < 19.9 kg/m^2), asthma prevalence increased by 28% with each unit decrease in BMI (OR = 1.28, 95% CI: 1.15–1.43). For those with a BMI between 19.9 and 29.9 kg/m^2, the relationship between BMI and asthma prevalence remained relatively stable, with no significant changes (OR = 1.02, 95% CI: 0.98–1.06). However, for those with a BMI exceeding 29.9 kg/m^2, each unit increase in BMI corresponded to a 25% increase in asthma prevalence (OR = 1.25, 95% CI: 1.05–1.49). These findings suggest that both underweight and obesity may increase the risk of asthma, with obesity demonstrating a particularly pronounced effect on asthma prevalence (Table 3).

Fig. 3B depicts the relationship between BMI and asthma prevalence on the basis of NHANES data. After adjusting for demographic and health-related factors, the plot revealed a significant increase in asthma prevalence with increasing BMI. However, further segmented regression analysis revealed a nonlinear relationship between BMI and asthma prevalence, with a critical inflection point at 21.6 kg/m^2. In Model II, for BMI values below 21.6 kg/m^2, asthma prevalence increased by 20% with each unit decrease in BMI (OR = 1.20, 95% CI: 1.02–1.41, P = 0.029). Conversely, for BMI values above 21.6 kg/m^2, asthma prevalence increased by 5% with each unit increase in BMI (OR = 1.05, 95% CI: 1.03–1.06, P < 0.0001). The difference in effect between the two segments was statistically significant, with the second segment showing a 25% greater risk of asthma than the first segment did (OR = 1.25, 95% CI: 1.06–1.48, P = 0.0082). The log-likelihood ratio test results were significant (P = 0.015), indicating that the fit of the segmented model was significantly better than that of the linear model. These findings highlight the complex relationship between BMI and asthma, suggesting that a lower

Variable	Total n = 13,393	BMI_T1 n = 4452	BMI_T2 n = 4465	BMI_T3 n = 4476	P value
Age (years, mean ± SD)	59.10 ± 9.84	61.44 ± 10.37	58.52 ± 9.60	57.35 ± 9.06	<0.0001
Sex					<0.0001
Male	6267 (46.79%)	2437 (54.74%)	2116 (47.39%)	1714 (38.29%)	
Female	7126 (53.21%)	2015 (45.26%)	2349 (52.61%)	2762 (61.71%)	
Asthma					0.0012
No	12,886 (96.21%)	4245 (95.35%)	4318 (96.71%)	4323 (96.58%)	
Yes	507 (3.79%)	207 (4.65%)	147 (3.29%)	153 (3.42%)	
Marry					<0.0001
Married	13,290 (99.23%)	4383 (98.45%)	4442 (99.48%)	4465 (99.75%)	
Never married	103 (0.77%)	69 (1.55%)	23 (0.52%)	11 (0.25%)	
Education					<0.0001
Low-educated	6208 (46.37%)	2373 (53.34%)	1969 (44.10%)	1866 (41.71%)	
High-educated	7180 (53.63%)	2076 (46.66%)	2496 (55.90%)	2608 (58.29%)	
Smoke					<0.0001
Yes	5267 (39.33%)	2179 (48.94%)	1722 (38.57%)	1366 (30.52%)	
No	8126 (60.67%)	2273 (51.06%)	2743 (61.43%)	3110 (69.48%)	
Drink					<0.0001
Yes	4345 (32.44%)	1592 (35.76%)	1507 (33.75%)	1246 (27.84%)	
No	9048 (67.56%)	2860 (64.24%)	2958 (66.25%)	3230 (72.16%)	
Hypertension					<0.0001
Yes	3188 (23.93%)	603 (13.62%)	958 (21.59%)	1627 (36.51%)	
No	10,134 (76.07%)	3825 (86.38%)	3480 (78.41%)	2829 (63.49%)	
Diabetes					<0.0001
Yes	757 (5.71%)	123 (2.79%)	211 (4.76%)	423 (9.55%)	
No	12,512 (94.29%)	4287 (97.21%)	4218 (95.24%)	4007 (90.45%)	

Note: BMI tertiles were categorized as follows: T1 (lowest tertile), T2 (middle tertile), and T3 (highest tertile).

Table 1: **Basic characteristics of the population in CHARLS.**

BMI may reduce asthma risk, whereas a higher BMI significantly increases the prevalence of asthma (Table 3).

Sensitivity analysis of the CHARLS and NHANES databases

To validate the robustness of our findings, we conducted stratified analyses on both the CHARLS and NHANES databases. In the CHARLS database, we categorised body mass index (BMI) into three groups: BMI <19.9 kg/m^2, 19.9 ≤ BMI ≤29.9 kg/m^2, and BMI >29.9 kg/m^2. Consistent effect patterns were observed across all three BMI strata in the subgroup analyses. Specifically, in the BMI <19.9 kg/m^2 group, nearly all subgroup analyses indicated a decreasing trend in asthma risk with increasing BMI. The 19.9 ≤ BMI ≤29.9 kg/m^2 group showed no significant association between BMI and asthma risk. Conversely, in the BMI>29.9 kg/m^2 group, asthma risk significantly increased with increasing BMI (Supplementary Table S2).

Notably, parallel analyses via the NHANES database yielded similar trends, further corroborating our findings. For the NHANES data, we employed a BMI threshold of 21.6 kg/m^2 for stratification. For individuals with a BMI <21.6 kg/m^2, asthma risk decreased as BMI increased, whereas for those with a BMI ≥21.6 kg/m^2, asthma risk increased with increasing BMI (Supplementary Table S3). This cross-database consistency, despite slight differences in BMI categorization, enhances the credibility and generalizability of our results. We generated some E-values to assess the sensitivity to unmeasured confounding. The primary findings were robust, as it would require an unmeasured confounder with a strong relative risk to explain away the observed associations.

Discussion

This study is the first large-scale investigation to assess and quantify population-specific BMI thresholds for asthma risk using global cross-national data. Despite the declining trend in global asthma incidence since 2019, our findings demonstrate that BMI continues to be the predominant risk factor for asthma-related DALYs worldwide, with its attributable burden showing an annual increase. Further analysis revealed a significant nonlinear relationship between BMI and asthma risk in populations aged 45 years and above, suggesting that both low and high BMIs may increase asthma risk. These discoveries provide novel insights into the impact

Variable	Total	BMI_T1	BMI_T2	BMI_T3	P value
Age	60.29 ± 10.48	61.47 ± 10.92	59.98 ± 10.61	59.46 ± 9.78	<0.0001
Gender					<0.0001
Male	46.6	42.41	54.52	42.1	
Female	53.4	57.59	45.48	57.9	
Asthma					<0.0001
No	86.6	89.03	88.88	81.77	
Yes	13.4	10.97	11.12	18.23	
Marry					0.0471
Married	14.27	12.93	13.37	16.56	
Never married	85.73	87.07	86.63	83.44	
Education					0.4855
Low-educated	19.31	19.89	18.1	20.05	
High-educated	80.69	80.11	81.9	79.95	
Smoke					0.0043
No	50.49	46.19	51.55	53.52	
Yes	49.51	53.81	48.45	46.48	
Drink					0.0016
No	22.82	23.05	19.33	26.29	
Yes	77.18	76.95	80.67	73.71	
Hypertension					<0.0001
No	53.27	65.3	54.5	40.24	
Yes	46.73	34.7	45.5	59.76	
Diabetes					<0.0001
No	85.37	91.88	88.5	75.62	
Yes	14.63	8.12	11.5	24.38	

Note: BMI tertiles were categorized as follows: T1 (lowest tertile), T2 (middle tertile), and T3 (highest tertile).

Table 2: **Basic characteristics of the population in the NHANES.**

of BMI on asthma prevalence across different cultural contexts, with significant implications for developing tailored asthma prevention and intervention strategies for diverse populations. Our study has several notable strengths in data validation and methodology. First, we utilised the most recent GBD 2021 database, which provides comprehensive and up-to-date insights into the global disease burden patterns and BMI-asthma relationships. Second, our analysis of CHARLS and NHANES 2011–2012 data demonstrated consistent BMI-asthma risk associations across different time periods, enhancing the reliability of our findings.

Compared with 2019, the age-standardised rates of asthma showed a notable decline in 2021, with substantial decreases observed in prevalence, modest reductions in mortality, and slight improvements in DALYs. However, the overall burden of asthma continues to rise, with an estimated 378.6 million patients with asthma globally. The decline in asthma incidence and mortality rates may reflect the effectiveness of global asthma control measures.[15] Our findings also indicate that high BMI is the most critical factor contributing to asthma-related DALYs globally, which is consistent with the findings of previous studies.[16–18] Li et al. reported that while smoking was the primary risk factor for asthma-related deaths and health loss from 1990–2013, high BMI has been the leading cause of asthma-related deaths since 2013 and the most significant contributor to asthma-related DALYs since 2003.[18] Research suggests that high BMI has a more substantial effect on women, middle-aged individuals,

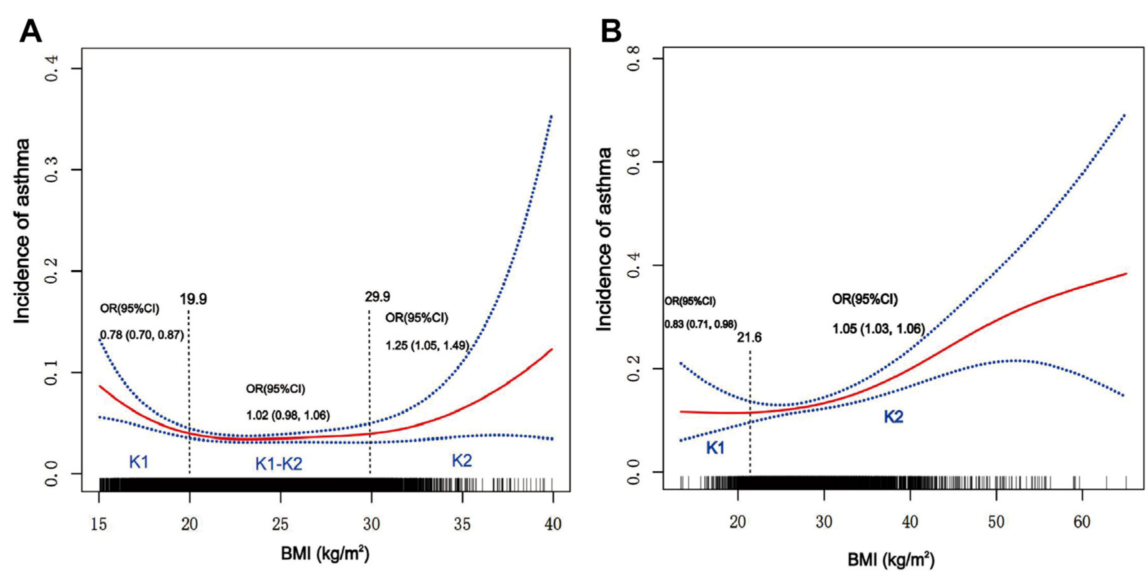

Fig. 3: **Nonlinear relationship between BMI and asthma.** A. U-shaped curve showing the prevalence of asthma in relation to BMI based on data from the CHARLS database. B. Smoothed curve fitting illustrating the prevalence of asthma in relation to BMI using data from the NHANES database.

CHARLS		P value	NHANES		P value
Model II[a]			Model II[a]		
Breakpoints (K1,K2)	19.9, 29.9		Breakpoints (K)	21.6	
	OR (95% CI)		OR (95% CI)		
Effect 1: < K1	0.78 (0.70, 0.87)	<0.0001	Effect 1: < K	0.83 (0.71, 0.98)	0.0294
Effect 2: K1–K2	1.02 (0.98, 1.06)	0.326	Effect 2: >K	1.05 (1.03, 1.06)	<0.0001
Effect 3: > K2	1.25 (1.05, 1.49)	0.0107			
Log-likelihood ratio test		<0.001	Log-likelihood ratio test		0.015

[a]Indicates the model adjusted for the following covariates: age, sex, marital status, education, smoking, alcohol consumption, hypertension, and diabetes.

Table 3: **Segmented regression models in two databases.**

and older individuals and that maternal obesity also increases the risk of asthma in children.[19–21] As the global rates of overweight and obesity continue to rise, weight loss should be incorporated into the management of patients with obesity and asthma.

Our study updated asthma burden data and determined the BMI range associated with reduced asthma risk for individuals aged 45 years and above through large-scale population data analysis. The CHARLS data analysis revealed a U-shaped relationship between BMI and asthma risk in the Chinese population, with breakpoints of 19.9 kg/m^2 and 29.9 kg/m^2. Analysis of CHARLS data revealed that below a lower BMI threshold, increasing BMI was associated with reduced asthma risk, while above a higher BMI threshold, further BMI increases led to elevated asthma risk. Similarly, NHANES data also demonstrated a nonlinear relationship between BMI and asthma risk in the U.S. population, though with different threshold points and risk magnitudes compared to the Chinese population. WHO data indicates that global obesity rates have nearly tripled over the past three decades, with over 1 billion people living with obesity by 2022, while 347 million adults remain underweight.[22] Our study is the first to quantify the non-linear relationship between BMI and asthma risk globally, a relationship whose biological mechanisms are well-studied. Since 2003, high BMI has become the primary risk factor for DALYs in patients with asthma. Ganeshkumar et al. reported that asthma risk progressively increases with BMI and weight gain. Their findings demonstrated a strong positive dose–response relationship between weight gain and asthma risk, with substantially higher risks observed as BMI increased from overweight to various degrees of obesity compared to normal weight individuals.[9] Celedon et al. demonstrated a significant dose−response relationship between weight gain and asthma risk, with high BMI increasing asthma prevalence, particularly in women and men. Overweight in women was associated with increased asthma prevalence,[23] which is consistent with our findings. Zhang et al.'s retrospective cohort study using NHANES data investigated the relationship between adult weight change patterns and asthma prevalence risk and reported that adults maintaining normal weight had the lowest asthma risk, whereas overweight, obese, and those transitioning from non-obese to obese had significantly increased asthma risk.[24] Additionally, our findings should be interpreted within the context of recent longitudinal evidence. A study from the Tasmanian Longitudinal Health Study (TAHS) identified five distinct BMI trajectories from childhood to mid-adulthood, revealing that both consistently high and low BMI trajectories were associated with contrasting patterns of lung function deficits.[25] While the TAHS study provides valuable insights into life-course BMI patterns and respiratory health, our cross-sectional study complements these findings by identifying specific BMI thresholds in middle-aged and older populations across different cultural contexts. The relationship between obesity and asthma is complex. Research indicates that obesity can lead to asthma development through multiple mechanisms and exacerbate existing asthma. Obesity can alter lung structure and function, increase oxidative stress, affect immune function, and modify neural control and cellular metabolism. These factors collectively make obesity a significant risk factor for asthma development and contribute to more difficult asthma control in patients with obesity.[26]

In individuals with obesity, pro-inflammatory factors secreted by adipose tissue increase asthma risk by inducing airway inflammation and hyperresponsiveness.[27,28] In underweight populations, malnutrition-related vitamin D deficiency, insufficient antioxidant intake, and impaired respiratory muscle function similarly elevate asthma risk.[29] This bidirectional association has important implications for global public health strategies. Developed countries need to integrate weight management into core asthma prevention strategies, while developing countries must address the dual challenges of malnutrition and obesity.

While the NHANES population did not exhibit the typical U-shaped curve observed in the CHARLS population, both studies consistently showed that low and high BMIs increase asthma prevalence. The discrepancies may be attributed to the different populations represented in the CHARLS and NHANES databases, as genetic backgrounds, lifestyles, living environments, and healthcare systems vary across ethnicities and nations, potentially influencing asthma susceptibility. Our study revealed significant differences in BMI-asthma risk association patterns between Chinese and U.S. populations, which may result from multiple interacting factors. Different racial and genetic backgrounds likely play a role in the BMI-asthma relationship.[30] Research has shown significant differences in fat distribution and metabolic characteristics between East Asian and Western populations.[31] Environmental factors are also noteworthy. Guarnieri found that higher PM2.5 exposure levels in certain Chinese regions are closely associated with asthma incidence,[32] while Arbes et al. demonstrated that U.S. populations may be more affected by indoor allergens. Additionally, differences in healthcare systems and diagnostic criteria are crucial factors.[33] Fang et al. showed that asthma diagnosis rates are relatively low in China, particularly in rural areas, while the U.S. healthcare system emphasises early screening and intervention.[34] These findings not only reveal the complexity of the BMI-asthma relationship but also emphasise the need to consider racial specificity and regional differences when developing prevention strategies. Meanwhile, we presented data showing significant differences between the two countries in asthma incidence, BMI, and other factors (Supplementary Figure S1).

The bidirectional risk pattern observed in the NHANES database with a threshold at BMI 21.6 kg/m^2 warrants attention. Although this value falls within the normal BMI range, previous studies have shown that weight gain can affect airway function through multiple mechanisms, including increased production of pro-inflammatory cytokines and altered adipokine levels secreted by adipose tissue.[35] Notably, recent research suggests that weight gain, even within the normal BMI range, may be associated with metabolic health risks and airway inflammation.[36,37] These findings provide potential biological explanations for our observed threshold phenomenon and indicate that population-specific physiological and pathological mechanisms, rather than traditional BMI classification criteria alone, should be considered when evaluating the relationship between BMI and asthma risk. Additionally, the multifactorial nature of asthma risk suggests that unaccounted confounding factors may influence the BMI−asthma risk relationship. Previous research has extensively investigated the relationship between childhood BMI trajectories and lifetime asthma risk. A comprehensive meta-analysis demonstrated that children with overweight and obesity had 1.64-fold and 1.92-fold higher risks of asthma, respectively, compared with normal-weight children.[38] A systematic review emphasised the significance of interactions between childhood obesity and other risk factors in asthma pathogenesis.[39] Gang et al. identified six BMI trajectory patterns from birth to early adulthood, showing persistent high BMI trajectories significantly correlated with increased asthma risk.[40] In a 14-year multicentre cohort study, Wang et al. Delineated five distinct infant BMI trajectory patterns, demonstrating that rapid BMI acceleration during childhood was significantly associated with adult-onset asthma risk.[41] Furthermore, evidence suggests that sustained elevated BMI between ages 6–10 years may increase asthma risk at age 18, while rapid BMI growth during the first two years of life might be associated with subsequent asthma development.[42] However, these longitudinal investigations predominantly originate from high-income countries, with limited reliable long-term BMI data available from low- and middle-income countries. In contrast, our cross-sectional study, analyzing data from populations aged 45 years and above across different nations, provides complementary insights into BMI-asthma relationships among middle-aged and older populations in diverse geographical and socioeconomic contexts.

Since 2003, high BMI has become the primary risk factor for DALYs in patients with asthma. Ganeshkumar et al. reported that asthma risk progressively increases with BMI and weight gain. Their findings demonstrated a strong positive dose–response relationship between weight gain and asthma risk, with substantially higher risks observed as BMI increased from overweight to various degrees of obesity compared to normal weight individuals.[9] Celedon et al. demonstrated a significant dose−response relationship between weight gain and asthma risk, with high BMI increasing asthma prevalence, particularly in women and men. Overweight in women was associated with increased asthma prevalence,[23] which is consistent with our findings. Zhang et al.'s retrospective cohort study using NHANES data investigated the relationship between adult weight change patterns and asthma prevalence risk and reported that adults maintaining normal weight had the lowest asthma risk, whereas overweight, obese, and those transitioning from nonobese to obese had significantly increased asthma risk.[24] The relationship between obesity and asthma is complex. Research indicates that obesity can lead to asthma development through multiple mechanisms and exacerbate existing asthma. Obesity can alter lung structure and function, increase oxidative stress, affect immune function, and modify neural control and cellular metabolism. These factors collectively make obesity a significant risk factor for asthma development and contribute to more difficult asthma control in patients with obesity.[26]

A decrease in BMI has been associated with an increased risk of asthma prevalence, suggesting that lower body mass may act as a contributing factor to the development or exacerbation of asthma. Michael et al. reported that underweight and individuals with obesity had a greater risk of daily or near-daily asthma symptoms and poorer asthma-specific quality of life than did individuals with a normal BMI.[17] Schachter et al. reported that individuals with a BMI<18.5 experienced exacerbated wheezing symptoms, decreased lung function, and airway hyperresponsiveness.[43] In Negri et al.'s study, underweight males presented a significantly greater age-adjusted self-reported asthma prevalence than did normal-weight males.[44] The relationship between low BMI and asthma remains unclear. Patients with a low BMI may experience increased respiratory disease prevalence due to malnutrition and decreased immune function. Dysregulation of multiple cytokines and resulting immune dysfunction may be important factors leading to acute asthma exacerbation.[45] Chen et al. reported that serum inflammatory cytokines are elevated in individuals with a low BMI, which is unfavorable for asthma control.[46] Further in-depth research on the relationship between BMI and asthma is crucial for understanding and treating both conditions.

This study has several limitations that should be considered. First, the diversity of data sources may lead to discrepancies in asthma diagnostic standards and data collection methods, potentially affecting the consistency of the results. The cross-sectional design of this research limits the ability to infer causal relationships between BMI and asthma risk. Another limitation of this study is the different definitions of asthma between CHARLS and NHANES databases. CHARLS relied on self-reporting, while NHANES was based on physician diagnosis and recent symptoms. However, sensitivity analyses revealed consistent direction and magnitude of BMI-asthma associations when analyzing the databases separately. The E-value analysis further supported the robustness of this association, suggesting that the findings were unlikely to be appreciably affected by differences in asthma definitions. Additionally, the reliance on self-reported asthma status and covariates can introduce information bias, as participants may provide inaccurate responses due to recall errors or social desirability. Furthermore, using BMI as the sole indicator of body composition does not fully capture an individual's weight status or its impact on asthma risk, as it fails to differentiate between fat and muscle mass and cannot reflect variations in fat distribution. Most importantly, we cannot determine whether asthma cases represent new adult-onset or childhood-persistent cases, and the lack of BMI data before age 45 prevents us from examining how early-life weight status influences subsequent asthma development. Although cross-national data were utilised, cultural and ethnic differences might influence the relationship between BMI and asthma, and these factors may not have been adequately controlled for in the analysis. Despite adjustments for multiple covariates, unmeasured confounding factors could affect the interpretation of the results. Another limitation is that while our study identified associations between both high and low BMI and asthma risk, the GBD database's lack of stratified BMI data prevented us from quantifying the specific impact of low BMI on asthma burden. Future studies should examine the effects of both low and high BMI on asthma. Finally, the conclusions of this study are applicable specifically to populations aged 45 years and above in China and the United States, limiting their generalizability to other groups. These limitations suggest a cautious approach to interpreting the findings and highlight areas for future research, such as adopting longitudinal study designs, utilizing more comprehensive body composition and health metrics, and conducting deeper analyses within varied cultural contexts.

High BMI has emerged as the most significant global risk factor contributing to asthma-related DALYs. Analysis of data from the CHARLS and NHANES revealed a significant nonlinear relationship between BMI and asthma risk in individuals aged 45 years and above, indicating that both low and high BMIs can increase asthma risk. These findings provide new insights into the impact of BMI on asthma prevalence across different cultural contexts, underscoring the importance of developing tailored asthma prevention and intervention strategies for diverse populations.

Contributors

J.M. contributed to study concept and design. W.K. and X.Z. contributed to study concept, design, and writing. H.G., M.C., M.L. and X.Z. helped in extracting and analyzing the data. W.K. and X.Z. had full access to and verified the data in the study. J.M. was responsible for the decision to submit the manuscript.

Data sharing statement

The data reported in this paper is available from https://vizhub.healthdata.org/gbd-results/, http://charls.pku.edu.cn/, and https://wwwn.cdc.gov/Nchs/Nhanes/2011–2012.

Declaration of interests

All authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2025.103163.

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