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Association between body roundness index and weight-adjusted waist index with asthma prevalence among US adults: the NHANES cross-sectional study, 2005–2018

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This study investigated the connection between asthma in US individuals and their body roundness index (BRI) and weight-adjusted waist index (WWI). According to data from the 2005–2018 National Health and Nutrition Examination Survey (NHANES), 3609 of the 25,578 persons in the survey who were 18 years of age or older reported having asthma. After adjusting for all confounders, the probability of asthma prevalence increased by 8% for every unit rise in BRI (OR = 1.08, 95% CI 1.06,1.11). The probability of asthma prevalence increased by 16% for every unit rise in WWI (OR = 1.16, 95% CI 1.08,1.25). The BRI and WWI indices were associated with prevalence and were nonlinearly correlated. The inflection points for threshold saturation effects were 4.36 and 10.69, respectively (log-likelihood ratio test, $P < 0.05$). Relationship subgroup analyses showed that the positive associations between BRI and WWI and asthma were generalized across populations and there was no significant interaction in most subgroups. In addition, sensitivity analyses verified the robustness of these results, further confirming the conclusion of BRI and WWI as independent risk factors for asthma. Finally, receiver operating characteristic (ROC) analysis showed that BRI outperformed WWI in predicting asthma, suggesting the potential of BRI in early asthma screening. Overall, BRI and WWI are independent risk factors for asthma with important clinical applications.

Keywords BRI, WWI, Asthma, Obesity, NHANES, Cross-sectional studies

Asthma is a globally common chronic respiratory disease affecting 10% of Australians, 1–5% of Asian adults, and 300 million people worldwide[1,2]. The World Health Organization (WHO) reports that the prevalence of asthma is increasing globally, especially in urban areas and developed countries[3]. Approximately 10% of children and 8% of adults in the US have asthma, and this number is rising with time[4]. In addition to lowering patients' quality of life, asthma also raises the cost of healthcare, resulting in frequent acute exacerbations, hospitalizations, and excessive healthcare expenditures[5]. Obesity, particularly abdominal obesity, is well acknowledged as a significant independent risk factor for asthma, despite the complexity of its origins[6]. In addition, the accumulation of visceral fat is not only a marker of metabolic diseases, but can also lead to airway hyperresponsiveness and a decrease in lung function by activating the immune response, promoting airway inflammation, and increasing oxidative stress, which ultimately worsens asthma symptoms and frequency of attacks[7–9].

Traditional obesity indicators such as BMI and waist do not accurately reflect the central obesity characteristics of patients[10]. However, central obesity indicators are more closely correlated with the presence and severity of asthma[11]. Therefore, it is important to actively explore novel indicators that can accurately assess abdominal obesity to predict asthma risk. In recent years, WWI and the BRI have emerged as emerging tools for assessing

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abdominal obesity due to more in-depth research on obesity assessment tools. The WWI and BRI can more precisely forecast the health risks related to abdominal obesity because they are more focused on the buildup of abdominal fat, especially visceral fat. The WWI is calculated as a ratio of waist circumference to body weight[12], and research has indicated that higher WWI is closely linked to higher asthma prevalence and older age at first attack[13]. However, the BRI, as a novel abdominal obesity assessment tool, is still relatively limited in the field of asthma. The BRI assesses the degree of abdominal obesity through the ratio of waist circumference to height[14] and is able to provide a more accurate picture of abdominal fat distribution than traditional obesity assessment tools. Existing studies have shown that the BRI exhibits good sensitivity in prevalence prediction for a variety of health problems such as metabolic syndrome[15], non-alcoholic fatty liver disease[16], and osteoarthritis[17]. Given the high correlation between BRI and abdominal fat accumulation, exploring its relationship with asthma may help to further improve prevalence prediction for asthma. Therefore, this study explored BRI and WWI in a group of asthmatics and evaluated their value in predicting asthma prevalence using data from the NHANES from 2005 to 2018.

Materials and methods

Study design and participants

The National Centre for Health Statistics (NCHS) administers the NHANES, a nationwide study that evaluates the nutrition and health of American adults living outside of institutions using a stratified multistage sampling method. The NHANES data are publicly available, and all survey participants signed informed consent forms. Selected data from NHANES between 2005 and 2018 were used for the analyses in this article. Initially, data from 70,191 participants in NHANES for the period 2005–2018 were considered. Excluding 28,047 persons under 18 years of age, 13,950 persons with missing asthma data, and 2,616 persons with missing or outlier BRI and WWI data, a total of 25,578 cases were ultimately included, including 3,609 self-reported cases (Fig. 1).

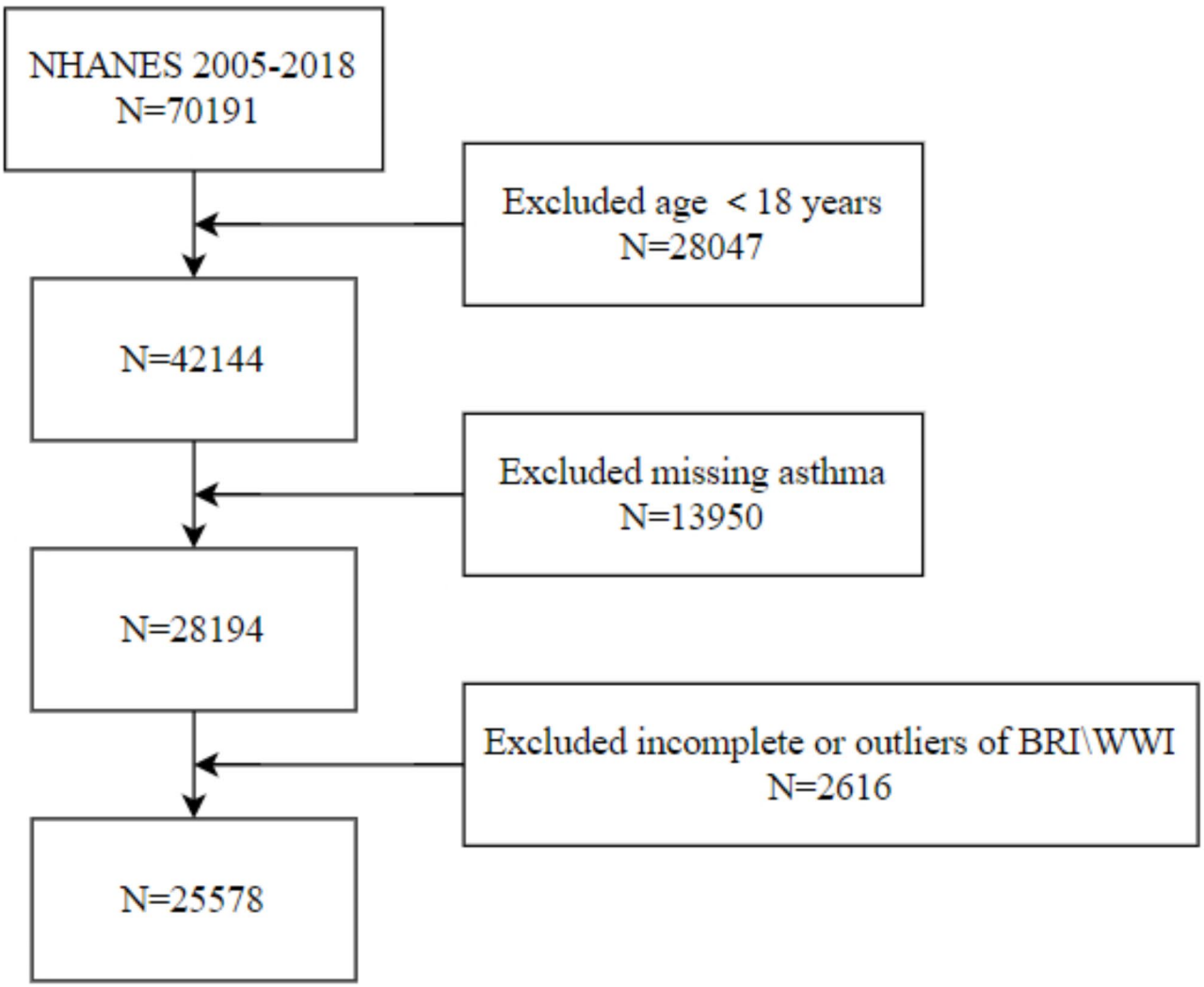

Fig. 1. Flowchart of the population selection from NHANES.

Data collection and definition

The diagnosis of asthma is based on a questionnaire. It has been established that the accuracy of the questionnaire is acceptable[18,19]. The BRI and WWI were used as exposure variables and were calculated as BRI = 364.2–365.5 × sqrt(1 - (wc / (2π))^2 / (Height / 2)^2), and WWI = wc / sqrt(bw), where wc and hight are in cm and bw is in kg. All NHANES staff received rigorous training to ensure consistency and accuracy of measurements.BRI and WWI data could be analyzed as either continuous or categorical variables. BRI values were categorized into three groups (first equal: $0.68 < BRI \leq 4.12$; second equal: $4.12 < BRI \leq 5.93$; third equal: $5.93 < BRI \leq 21.23$) and WWI values were categorized into three groups (first equal: $7.72 < BRI \leq 10.60$; second equal: $10.60 < BRI \leq 11.36$; third equal: $11.36 < BRI \leq 15.70$) for Analysis.

Covariates

To account for confounding factors, the study adjusted for common covariates, including age, gender, race, education level, marital status, PIR, smoking, alcohol use, physical activity, serum cholesterol, serum glucose, and serum uric acid. In addition, chronic diseases such as diabetes, high cholesterol, hypertension, coronary heart disease, cancer, and blood relatives of asthma are potential factors affecting asthma. These covariates were chosen because they are direct or indirect risk factors for asthma, e.g., females have a higher prevalence of asthma than males at certain ages, education level is strongly associated with health behaviors and access to healthcare resources and may indirectly affect asthma, poor lifestyle habits such as smoking and drinking significantly increase the risk of respiratory diseases, and asthma in blood relatives, as a hereditary factor, may have a significant impact on asthma through familial inheritance development, etc. Adjusting for these variables allows for more comprehensive control of potential confounders and enables us to more accurately assess the association of BRI and WWI with asthma. Specific income levels were categorized as low-income ($PIR \leq 1.3$), middle-income ($1.3 < PIR \leq 3.5$), and high-income ($PIR > 3.5$). Smoking was defined as consuming 100 or more cigarettes over one's lifetime. Alcohol use is classified according to the current drinking status into five categories: never, former, heavy, moderate, and mild drinking[20,21]. For detailed classification criteria, see Supplementary Document 1. Diabetes, high cholesterol, hypertension, coronary heart disease, cancer, blood relatives with asthma, and physical activity were determined by questionnaire. A 24-hour, two-day dietary questionnaire was used to collect dietary data. The HEI-2015 evaluates a person's dietary compliance with the Dietary Guidelines for Americans[22]. Higher ratings indicate better food quality and healthier eating habits; the values range from 0 to 100[23].

Statistical analysis

Every statistical analysis applied the proper sampling weights and considered the intricate sampling design of NHANES. Categorical data are given as weighted proportions, whilst continuous variables are provided as mean ± standard error (SE). Weighted chi-square and t-tests were used to evaluate group differences at baseline[24]. Model 1 (unadjusted), Model 2 (adjusted for age, gender, race, and education level), and Model 3 (further adjusted for the variables of marriage, PIR, smoking, alcohol use, diabetes, hypertension, high cholesterol, coronary heart disease, cancer, blood relatives with asthma, physical activity, serum cholesterol, serum glucose, serum uric acid, and HEI-2015) were the three weighted multivariate logistic regression models used to investigate the relationship between BRI and WWI and asthma. GAM was used to assess potential nonlinear relationships, and segmented regression analysis was used to explore threshold effects and inflection points, and to test whether inflection points were significant through log-likelihood ratios. Subgroup analyses and interaction tests were performed as well. ROC analyses were used to compare the ability of BRI with WWI in asthma prediction. DeLong tests were conducted to assess statistical differences in the ROC analysis results. Missing covariates were interpolated using Random Forest Multiple Interpolation. Sensitivity analyses consisted, among other things, of not interpolating missing covariates and further adjusting for medication for diabetes and high cholesterol. A two-tailed *p*-value was deemed statistically significant if it was less than 0.05. R software (version 4.4) and Empower States (version 4.2) were used for all statistical studies.

Results

Baseline characteristics of participants

The study population's basic characteristics are shown in Table 1. The study sample consisted of 25,578 individuals, with a mean age of 46.95 ± 18.69 years, 48.84% of whom were male and 51.16% of whom were female. The mean BRI was 5.32 ± 2.30 and the mean WWI was 10.97 ± 0.87. The asthma groups differed significantly in their fundamental traits.

Multivariate regression analysis

Table 2 compiles the results of the weighted multivariate logistic regression study that assessed the relationship between asthma and BRI and WWI separately. The results found that the higher the BRI group, the higher the risk of developing asthma, which was consistent with the results of WWI. The probability of prevalent asthma increased by 8% for every unit rise in BRI (OR = 1.08, 95% CI 1.06,1.11). The probability of prevalent asthma increased by 16% for every unit rise in WWI (OR = 1.16, 95% CI 1.08,1.25). In addition, continuous data were converted to categorical data to analyze sensitivity[25]. After grouping by the three classifications, asthma prevalence was substantially greater in the highest BRI category than in the lowest group (OR = 1.37, 95% CI 1.20,1.57). Asthma prevalence was considerably greater in the highest WWI group than in the lowest group (OR = 1.29, 95% CI 1.12,1.49), with *p*-values for all trends < 0.001.

Characteristics	Total	Asthma		*P* value
	(*n* = 25578)	NO(*n* = 21969)	YES(*n* = 3609)	
Age (years)	46.95 ± 18.69	47.37 ± 18.68	44.43 ± 18.57	< 0.001
Gender %				< 0.001
Male	12,493 (48.84)	10,954 (49.86)	1539 (42.64)	
Female	13,085 (51.16)	11,015 (50.14)	2070 (57.36)	
Race %				< 0.001
Mexican American	4261 (16.66)	3912 (17.81)	349 (9.67)	
Other hispanic	2291 (8.96)	1961 (8.93)	330 (9.14)	
Non-hispanic white	11,240 (43.94)	9490 (43.20)	1750 (48.49)	
Non-hispanic black	5601 (21.90)	4691 (21.35)	910 (25.21)	
Other race	2185 (8.54)	1915 (8.72)	270 (7.48)	
Education level %				< 0.001
Less than 9th grade	2748 (10.74)	2485 (11.31)	263 (7.29)	
9–11th grade	3976 (15.54)	3402 (15.49)	574 (15.90)	
High school graduate	5859 (22.91)	5048 (22.98)	811 (22.47)	
Some college or AA degree	7699 (30.10)	6423 (29.24)	1276 (35.36)	
College graduate or above	5296 (20.71)	4611 (20.99)	685 (18.98)	
Marry %				< 0.001
Married/living with partner	14,534 (56.82)	12,755 (58.06)	1779 (49.29)	
Widowed/divorced/separated	5261 (20.57)	4441 (20.21)	820 (22.72)	
Never married	5783 (22.61)	4773 (21.73)	1010 (27.99)	
PIR %				< 0.001
Low income	8091 (31.63)	6769 (30.81)	1322 (36.63)	
Med income	10,118 (39.56)	8790 (40.01)	1328 (36.80)	
High income	7369 (28.81)	6410 (29.18)	959 (26.57)	
Alcohol use %				< 0.001
Never	4155 (16.24)	3650 (16.61)	505 (13.99)	
Former	4558 (17.82)	3901 (17.76)	657 (18.20)	
Mild	7763 (30.35)	6696 (30.48)	1067 (29.56)	
Moderate	3727 (14.57)	3161 (14.39)	566 (15.68)	
Heavy	5375 (21.01)	4561 (20.76)	814 (22.55)	
Smoking %				< 0.001
No	14,510 (56.73)	12,647 (57.57)	1863 (51.62)	
Yes	11,068 (43.27)	9322 (42.43)	1746 (48.38)	
Diabetes %				< 0.001
No	22,680 (88.67)	19,572 (89.09)	3108 (86.12)	
Yes	2898 (11.33)	2397 (10.91)	501 (13.88)	
Hypertension %				< 0.001
No	17,207 (67.27)	14,988 (68.22)	2219 (61.49)	
Yes	8371 (32.73)	6981 (31.78)	1390 (38.51)	
High cholesterol %				0.004
No	17,174 (67.14)	14,826 (67.49)	2348 (65.06)	
Yes	8404 (32.86)	7143 (32.51)	1261 (34.94)	
Coronary artery disease %				0.048
No	24,660 (96.41)	21,201 (96.50)	3459 (95.84)	
Yes	918 (3.59)	768 (3.50)	150 (4.16)	
Cancer %				< 0.001
No	23,408 (91.52)	20,157 (91.75)	3251 (90.08)	
Yes	2170 (8.48)	1812 (8.25)	358 (9.92)	
Blood relative had asthma %				< 0.001
No	20,483 (80.08)	18,362 (83.58)	2121 (58.77)	
Yes	5095 (19.92)	3607 (16.42)	1488 (41.23)	
Physical activity %				0.004
Never	12,455 (48.69)	10,681 (48.62)	1774 (49.15)	
Moderate	6854 (26.80)	5961 (27.13)	893 (24.74)	
Vigorous	6269 (24.51)	5327 (24.25)	942 (26.10)	

Continued

Characteristics	Total	Asthma		*P* value
	(*n* = 25578)	NO(*n* = 21969)	YES(*n* = 3609)	
BMI (Kg/m^2)	28.72 ± 6.73	28.49 ± 6.50	30.16 ± 7.85	< 0.001
2Serum cholesterol (mg/dL)	193.29 ± 41.48	193.83 ± 41.38	190.02 ± 41.90	< 0.001
2Serum glucose (mg/dL)	101.31 ± 37.56	101.21 ± 37.43	101.93 ± 38.37	0.284
2Serum uric acid (mg/dL)	5.42 ± 1.41	5.41 ± 1.41	5.45 ± 1.42	0.159
2HEI–2015	51.08 ± 11.08	51.34 ± 11.10	49.46 ± 10.84	< 0.001
2BRI	5.32 ± 2.30	5.25 ± 2.23	5.75 ± 2.70	< 0.001
2WWI	10.97 ± 0.87	10.97 ± 0.86	11.01 ± 0.94	0.002

Table 1. The clinical characteristics of participants. Continuous variables were summarized using means with SE, and categorical variables were presented as proportions with SE. *BMI* body mass index, *BRI* body roundness index, *WWI* weight-adjusted-waist index, *PIR* income to poverty ratio.

	OR[a] (95% CI[b]) *P*-value		
	Model 1[c]	Model 2[d]	Model 3[e]
BRI			
Continuous	1.08(1.06,1.11)	1.10(1.08,1.13)	1.08(1.06,1.11)
P for trend	< 0.0001	< 0.0001	< 0.0001
Categories			
Tertile 1	Reference	Reference	Reference
Tertile 2	0.94(0.83,1.07)	1.10(0.97,1.26)	1.09(0.95,1.26)
Tertile 3	1.35(1.21,1.52)	1.57(1.38,1.78)	1.37(1.20,1.57)
P for trend	< 0.0001	< 0.0001	< 0.0001
WWI			
Continuous	1.09(1.03,1.15)	1.26(1.18,1.35)	1.16(1.08,1.25)
P for trend	0.003	< 0.0001	0.0002
Categories			
Tertile 1	Reference	Reference	Reference
Tertile 2	0.98(0.89,1.08)	1.16(1.04,1.29)	1.11(0.99,1.24)
Tertile 3	1.18(1.06,1.31)	1.52(1.34,1.74)	1.29(1.12,1.49)
P for trend	0.005	< 0.0001	0.001

Table 2. Association between BRI/WWI and asthma. OR[a], odds ratio; 95% CI[b], 95% confidence interval; Model1[c], adjusted for noncovariates; Model2[d], adjusted for age, gender, race, and education; Model3[e], further adjusted for marry, poverty income ratio, smoking, alcohol use, diabetes, hypertension, high cholesterol, coronary artery disease, cancer, blood relative had asthma, physical activity, serum cholesterol, serum glucose, serum uric acid and healthy eating index-2015.

Nonlinear analysis

When GAM was used to further evaluate the relationship between BRI, WWI, and asthma, it revealed a significant nonlinear link (Fig. 2; Table 3). The existence of a threshold effect was further supported by segmented regression analysis, with an inflection point of 4.36 for BRI and 10.69 for WWI (log-likelihood ratio test, $p < 0.05$). Further analysis revealed gender differences in the relationship between WWI and asthma. Both a threshold effect and a nonlinear impact were significant in males. In women, the prevalence of asthma was linearly related to WWI.

Subgroup analysis

We performed subgroup analyses that considered age, gender, race, education, marital status, PIR, HEI-2015, smoking, alcohol consumption, physical activity, and blood relatives with asthma in order to better examine the relationship between BRI and WWI and asthma in various groups. The results of the analysis showed that the risk of asthma prevalence in different groups was consistently positively correlated with BRI. There were no statistically significant interaction tests in most subgroups, which further strengthens the evidence that BRI and WWI are independent risk factors for asthma, respectively (Tables 4 and 5).

Sensitivity analysis

Since therapeutic drugs may alter certain physiological indicators, which in turn may affect the results of the study, several sensitivity assessments were performed, such as unplugging missing covariates and adjusting for the treatment of diabetes and high cholesterol medication, in order to further confirm the data's robustness. In addition, to ensure that the results were not confounded by extreme cases, sensitivity analyses were performed to

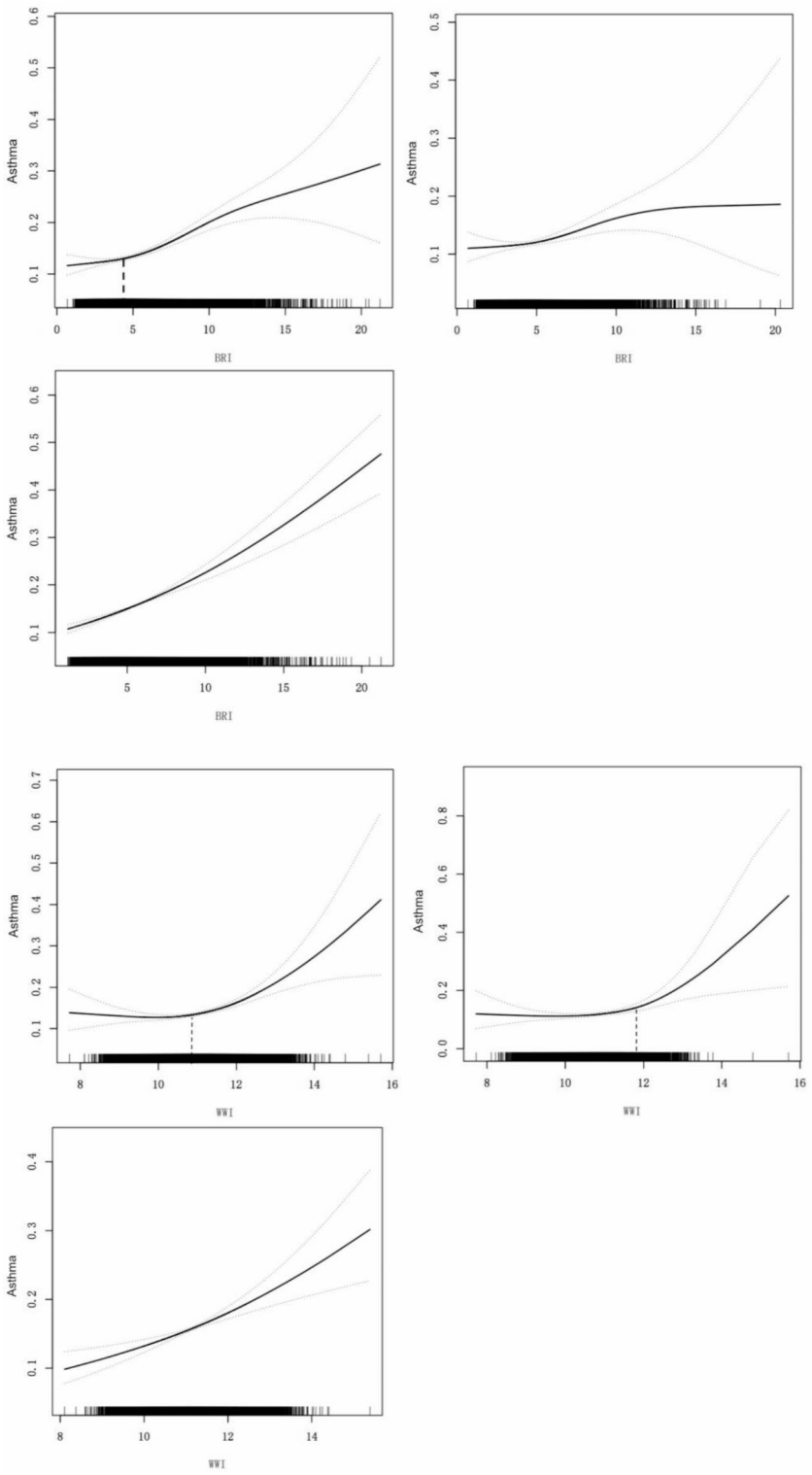

Fig. 2. Generalized additive regression. (**A**) GAM for total population BRI; (**B**) GAM for male BRI; (**C**) GAM for female BRI. (**D**) GAM for total population WWI; (**E**) GAM for male WWI; (**F**) GAM for female WWI. *Note*: The BRI had a nonlinear positive relationship in the total population, with an inflection point of 4.36 and no sex difference. WWI had a nonlinear positive relationship in the total population, with inflection points of 10.69 and 11.89 in the total and male populations, respectively.

	OR[a] (95% CI[b]) *P*-value		
	Total	**Males**	**Females**
BRI			
Segmented Model			
Turning point (K)	4.36	4.49	4.31
< K OR 1	1.00 (0.94, 1.07)	0.99 (0.91, 1.08)	1.07 (0.97, 1.17)
	0.898	0.876	0.156
> K OR 2	1.10 (1.08, 1.12)	1.07 (1.03, 1.11)	1.11 (1.08, 1.14)
	< 0.001	< 0.001	< 0.001
OR 2–1	1.09 (1.02, 1.17)	1.08 (0.97, 1.20)	1.04 (0.94, 1.15)
	0.016	0.146	0.471
Likelihood ratio test	0.016	0.147	0.471
WWI			
Segmented Model			
Turning point (K)	10.69	11.89	12.16
< K OR 1	0.95 (0.85, 1.06)	1.06 (0.96, 1.17)	1.17 (1.08, 1.27)
	0.342	0.233	< 0.001
> K OR 2	1.29 (1.20, 1.39)	2.28 (1.58, 3.27)	1.43 (1.10, 1.86)
	< 0.001	< 0.001	0.007
OR 2–1	1.36 (1.18, 1.58)	2.14 (1.44, 3.19)	1.23 (0.91, 1.65)
	< 0.001	< 0.001	0.179
Likelihood ratio test	< 0.001	< 0.001	0.182

Table 3. Segmented regression results. OR[a], odds ratio; 95% CI[b], 95% confidence interval.

exclude high-risk groups (smokers, extremely obese, and COPD patients). These populations are at higher risk of respiratory disease and may have a greater impact on the prevalence of asthma. The results of the sensitivity analyses consistently supported a significant association between BRI and asthma, indicating good stability of the results (Table 6). We found that the exclusion of high-risk groups (smokers and the extremely obese) had the greatest impact on the robustness of the results. Since smokers accounted for 43.3% of the total population and extremely obese people (BMI ≥ 30) accounted for 35.69%, both groups were at higher risk of developing asthma, and thus excluding these high-risk groups helped to validate the robustness of the association between BRI and WWI and asthma.

ROC analysis

The predictive ability of BRI, WWI, and Waist for asthma was assessed by ROC analysis[26,27]. The results showed that, both for the general population and for females, the BRI was a more accurate predictor of asthma than the WWI (Fig. 3; Table 7), and there was a significant difference. There was no significant difference in the predictive ability of BRI and Waist for asthma prevalence.

Discussion

This study evaluated the associations of BRI and WWI with asthma prevalence in US adults using data from the 2005–2018 NHANES. Asthma prevalence was shown to be significantly correlated with both BRI and WWI, and this correlation held true even after controlling for covariates. In the fully adjusted model, the highest group for BRI had a significant 37% increase in asthma prevalence over the lowest group. The highest group for WWI had a significant 29% increase in asthma prevalence over the lowest group. Through GAM analysis, we found a nonlinear relationship between BRI and WWI and asthma. Specifically, asthma prevalence increased by 10% for every unit increase in BRI when it was above 4.36. Asthma prevalence increased by 29% with every unit increase in WWI when it surpassed 10.69. This indicates that the effect of abdominal fat accumulation on asthma is significantly enhanced when it exceeds a certain threshold. In terms of predictive ability, through ROC curve analysis we found that BRI outperformed WWI in predicting asthma prevalence, and BRI's AUC value was significantly greater than WWI's ($P < 0.05$). This suggests that the BRI is able to more accurately reflect the accumulation of abdominal fat and has a high predictive value in asthma screening. This study also included sensitivity analysis and subgroup analysis to verify the results' robustness. After adjusting for the effect of medication status, the associations of BRI and WWI with asthma prevalence remained significant, further enhancing the reliability of the study findings. Subgroup analyses showed constant positive associations between BRI and WWI and the prevalence of asthma in different groups, indicating broad applicability and stable predictive ability.

It is commonly known that obesity, particularly abdominal obesity, is a risk factor for asthma on its own. By analyzing data from a prospective cohort, according to Wang et al. (2024), asthma development was significantly correlated with an increase in body weight, particularly in females[28]. This study provided preliminary evidence for the correlation between asthma and fat. Furthermore, Liu et al. (2024) showed a strong correlation between waist circumference and asthma, particularly in women, where a higher waist circumference was associated with

Subgroup	HR (95% CI)	P-value	P for interaction
Age			0.032
18-39	1.06 (1.03,1.08)	<0.001	
40-59	1.09 (1.06,1.13)	<0.001	
60-79	1.11 (1.08,1.15)	<0.001	
Gender			0.01
Male	1.06 (1.03,1.09)	<0.001	
Female	1.1 (1.08,1.13)	<0.001	
Race			0.016
Mexican American	1.09 (1.03,1.14)	0.001	
Other Hispanic	1.12 (1.06,1.19)	<0.001	
Non-Hispanic White	1.06 (1.04,1.09)	<0.001	
Non-Hispanic Black	1.08 (1.05,1.12)	<0.001	
Other Race	1.19 (1.12,1.27)	<0.001	
Education level			0.517
Less than 9th grade	1.11 (1.05,1.17)	<0.001	
9-11th grade	1.06 (1.02,1.1)	0.003	
High school graduate	1.09 (1.06,1.12)	<0.001	
Some college or AA degree	1.08 (1.05,1.11)	<0.001	
College graduate or above	1.1 (1.06,1.15)	0.093	
Marry			0.188
Married/Living with Partner	1.09 (1.06,1.12)	<0.001	
Widowed/Divorced/Separated	1.11 (1.07,1.15)	<0.001	
Never married	1.06 (1.03,1.1)	<0.001	
PIR			0.567
Low income	1.09 (1.06,1.12)	<0.001	
Med income	1.09 (1.06,1.11)	<0.001	
High income	1.06 (1.03,1.1)	<0.001	
HEI-2015			0.354
≤60	1.08 (1.06,1.1)	<0.001	
>60	1.1 (1.05,1.15)	<0.001	
Smoking			0.083
No	1.07 (1.04,1.09)	<0.001	
Yes	1.09 (1.07,1.12)	<0.001	
Alcohol use			0.011
No	1.11 (1.08,1.14)	<0.001	
Yes	1.07 (1.04,1.09)	<0.001	
Physical activity			0.568
Never	1.08 (1.06,1.11)	<0.001	
Moderate	1.09 (1.05,1.12)	<0.001	
Vigorous	1.06 (1.02,1.1)	0.002	
Blood relative had asthma			0.553
No	1.08 (1.05,1.1)	<0.001	
Yes	1.09 (1.06,1.11)	<0.001	

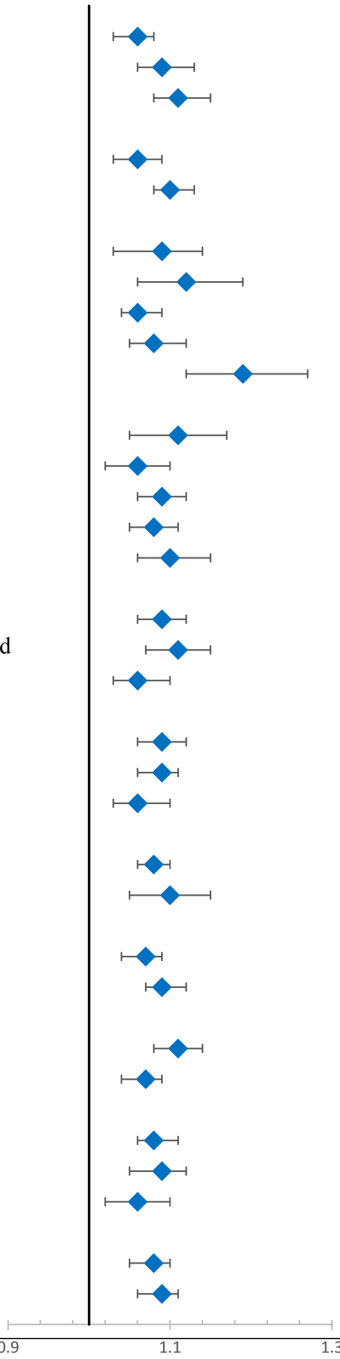

Table 4. Subgroup regression results of BRI.
Results of the subgroup analysis were adjusted for all covariates except the effect modifier.

a considerably higher prevalence of asthma[29]. Our study is consistent with it in that in the subgroup analysis of BRI, the risk of asthma was higher in the older age group and in the female group, and the interaction test was significant. Older adults may be more likely to perceive the effects of abdominal fat on lung function due to the accumulation of abdominal fat and progressive skeletal muscle relaxation[30]. It may also be associated with decreased lung function due to chronic disease and aging. Women have lower lung volumes, poorer airway ventilation[31], and more active and reactive immune systems[32]. As women age (especially peri-menopausal and post-menopausal), the pattern of fat distribution changes, and more fat begins to shift toward the abdominal and visceral regions[33]. Female estrogen also has an impact on the health of the immune system and airways. Studies have shown that estrogen may enhance airway reactivity in women, making them more susceptible to asthma symptoms when confronted with environmental pollutants, allergens, or other triggers[34]. Another

Subgroup	HR (95% CI)	P-value	P for interaction
Age			0.092
18-39	1.09 (1.01,1.18)	0.036	
40-59	1.23 (1.11,1.37)	<0.001	
60-79	1.23 (1.11,1.37)	<0.001	
Gender			0.42
Male	1.15 (1.05,1.26)	0.002	
Female	1.21 (1.13,1.29)	<0.001	
Race			0.173
Mexican American	1.08 (0.9,1.28)	0.412	
Other Hispanic	1.3 (1.07,1.57)	0.007	
Non-Hispanic White	1.13 (1.05,1.23)	0.002	
Non-Hispanic Black	1.2 (1.08,1.32)	<0.001	
Other Race	1.42 (1.16,1.75)	<0.001	
Education level			0.775
Less than 9th grade	1.14 (0.94,1.38)	0.190	
9-11th grade	1.08 (0.95,1.23)	0.222	
High school graduate	1.18 (1.06,1.32)	0.002	
Some college or AA degree	1.16 (1.07,1.27)	<0.001	
College graduate or above	1.21 (1.07,1.37)	0.002	
Marry			0.244
Married/Living with Partner	1.2 (1.11,1.3)	<0.001	
Widowed/Divorced/Separated	1.22 (1.09,1.37)	<0.001	
Never married	1.09 (0.98,1.21)	0.099	
PIR			0.777
Low income	1.18 (1.08,1.28)	<0.001	
Med income	1.18 (1.08,1.28)	<0.001	
High income	1.13 (1.02,1.25)	0.022	
HEI-2015			0.549
≤60	1.17 (1.1,1.24)	<0.001	
>60	1.12 (0.98,1.27)	0.100	
Smoking			0.154
No	1.11 (1.04,1.2)	0.003	
Yes	1.2 (1.11,1.3)	<0.001	
Alcohol use			0.744
No	1.17 (1.08,1.28)	<0.001	
Yes	1.15 (1.08,1.23)	<0.001	
Physical activity			0.021
Never	1.17 (1.08,1.26)	<0.001	
Moderate	1.28 (1.15,1.42)	<0.001	
Vigorous	1.04 (0.93,1.16)	0.532	
Blood relative had asthma			0.023
No	1.1 (1.03,1.18)	0.003	
Yes	1.24 (1.14,1.34)	<0.001	

Table 5. Subgroup regression results of WWI.
Results of the subgroup analysis were adjusted for all covariates except the effect modifier.

important study was conducted by Yu et al. (2023) which explored the relationship between WWI and asthma. They discovered that there was a nonlinear link between the WWI index and asthma and that the prevalence of asthma rose dramatically as WWI increased[13]. This conclusion was further supported by our research, which found a substantial correlation between WWI and BRI and an increased prevalence of asthma, that the relationship between BRI and WWI and asthma showed a significant nonlinear trend, and that there was a gender difference in the nonlinear trend between WWI and asthma. The inflection points for BRI and WWI in the total population were 4.36 and 10.69, respectively, suggesting that above these thresholds individuals are at significantly increased risk of developing asthma.BRI values above 4.36 are associated with central obesity and metabolic syndrome, which may increase the risk of asthma through a number of mechanisms, including chronic inflammation, whereas a WWI above 10.69 reflects abdominal fat accumulation, which is also a known asthma risk Factor. In addition, the ability of BRI to predict asthma by ROC analysis was significantly better than

BRI	OR[a] (95% CI[b]) *P*-value		
	Model 4[c]	Model 5[d]	Model 6[e]
Continuous	1.08(1.05,1.11)	1.15(1.08,1.23)	1.07(1.03,1.10)
P for trend	< 0.001	< 0.001	< 0.001
Categories			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.03(0.88,1.19)	1.49(0.70,3.18)	0.95(0.83,1.10)
Tertile 3	1.29(1.10,1.51)	2.88(1.38,5.98)	1.25(1.07,1.45)
P for trend	< 0.001	< 0.001	0.003
WWI			
Continuous	1.20(1.10,1.31)	1.63(1.26,2.10)	1.10(1.01,1.19)
P for trend	< 0.001	< 0.001	0.026
Categories			
Tertile 1	Reference	Reference	Reference
Tertile 2	1.12(0.96,1.31)	1.38(0.89,2.16)	0.94(0.82,1.08)
Tertile 3	1.31(1.11,1.55)	1.85(1.18,2.59)	1.16(0.99,1.36)
P for trend	0.001	0.025	0.168

Table 6. Further adjustment for covariates, disease, and excluding high-risk groups. OR[a]: odds ratio; 95% CI[b]: 95% confidence interval; Model 4[c]: missing covariates not interpolated; Model 5[d]: further adjustment of medication for diabetes and high cholesterol; Model 6[e]: Sensitivity analyses to exclude high-risk groups (smokers, extremely obese, and patients with COPD).

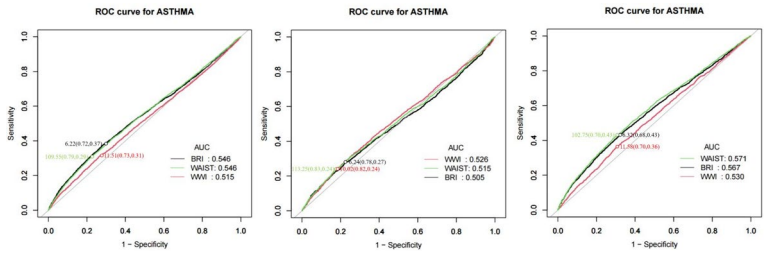

Fig. 3. ROC curve of BRI and WWI. (**A**) ROC for total population; (**B**) ROC for males; (**C**) ROC for females. Note: *BRI* body roundness index, *WWI* weight-adjusted-waist index. In the total and female populations, the AUC area of BRI was significantly larger than that of WWI; however, in the male population, there was no significant difference in the AUC areas of BRI, WWI, and WC.

	Variable	AUC (95% CI)	Threshold	Sensitivity	Specificity	Youden Index	*P* value
Total	BRI	0.55(0.53,0.56)	6.22	0.37	0.72	0.09	–
	WWI	0.51(0.50,0.53)	11.51	0.31	0.73	0.04	< 0.001
	WAIST	0.55(0.53,0.56)	109.55	0.29	0.79	0.08	0.693
Males	BRI	0.51(0.49,0.52)	6.24	0.27	0.78	0.05	–
	WWI	0.53(0.51,0.54)	10.02	0.24	0.82	0.06	0.204
	WAIST	0.52(0.50,0.53)	113.25	0.24	0.83	0.07	0.157
Females	BRI	0.57(0.55,0.58)	6.32	0.43	0.68	0.11	–
	WWI	0.53(0.52,0.54)	11.58	0.36	0.70	0.06	< 0.001
	WAIST	0.57(0.55,0.58)	102.75	0.43	0.70	0.13	0.328

Table 7. ROC analysis results. *BRI* body roundness index, *WWI* weight-adjusted-waist index.

WWI in the total population and in the female group. Although the AUC value of BRI in the ROC analysis was about 0.55, indicating its relatively limited predictive ability, BRI can still be used as a simple and low-cost initial screening tool, especially in resource-limited settings.BRI is significantly associated with the risk of asthma, especially for high-risk populations such as those with obesity and metabolic syndrome. Future studies may combine other clinical markers, environmental factors, and genetic information using multifactorial modeling to improve predictive accuracy and AUC values, thus providing a more precise tool for early screening and

risk assessment of asthma. The optimal BRI threshold for asthma risk stratification was 6.22. Comparison with existing clinical guidelines for obesity-associated asthma risk showed that his predictive accuracy was marginally better than that of waist circumference in the total population, but there was no significant advantage. The current single waist circumference may not effectively reflect the effect of abdominal fat on airways. Therefore, clinically, the use of BRI as a supplemental indicator may provide clinicians with a more personalized risk assessment, especially in patients who do not meet obesity criteria for waist circumference but have accumulated abdominal fat. Through the assessment of the BRI, public health systems can identify high-risk individuals and help public health agencies develop individualized intervention programs. For example, lifestyle interventions (e.g., weight loss, and increased exercise) or environmental improvements (e.g., reducing air pollution exposure) can be implemented to reduce the risk of asthma. This opens up new possibilities for early screening for asthma, especially in the female population, and if future studies further validate the reliability of the BRI in asthma prediction, public health authorities may consider incorporating the BRI into asthma screening guidelines.

Visceral fat exacerbates the onset and course of asthma through multiple biological mechanisms. Visceral fat is not only a marker of metabolic disease, but also directly influences the inflammatory response of the airways by secreting large amounts of pro-inflammatory factors[35]. When visceral fat accumulates, adipose tissue secretes pro-inflammatory factors such as leptin, lipocalin, and tumor necrosis factor-alpha, which enhance immune system activation and increase the degree of airway inflammation[36]. Barros et al. (2016) discovered a strong correlation between chronic airway inflammation and an increase in visceral fat, which in turn exacerbates the symptoms and course of asthma[37]. This heightened immune response not only increases airway allergic reactivity but may also lead to airway hyperreactivity, which can further exacerbate asthma symptoms. At the same time, the airway undergoes structural changes in response to long-term inflammatory stimuli, with thickening of the airway wall and smooth muscle hyperplasia, which makes the airway even narrower and thus exacerbates asthma symptoms[38]. The accumulation of visceral fat is strongly associated with increased oxidative stress. Accumulation of abdominal fat leads to the production of reactive oxygen species and free radicals[39], and increased oxidative stress may exacerbate the inflammatory response in the airways, leading to decreased airway function. Obesity and increased abdominal fat significantly increase levels of oxidative stress, which not only negatively affects the immune system but may also directly impair lung function[9,40]. Thus, oxidative stress may be an important mechanism by which abdominal fat affects asthma. Hormone fluctuations are directly linked to the buildup of abdominal fat, particularly visceral fat[41]. Obesity leads to insulin resistance, which in turn can exacerbate systemic inflammation and aggravate asthma symptoms[42]. It is also accompanied by abnormalities in fatty acid metabolism, especially elevated levels of free fatty acids, which activate inflammatory pathways and affect the immune response and inflammatory state of the airways[43]. The regulation of immunological response and fat distribution is significantly influenced by hormones like estrogen[44]. The results of this study are consistent with the nonlinear effect of abdominal fat on lung function[45]; at low levels of BRI and WWI, body fat is mainly distributed in the subcutaneous area, and there is relatively little abdominal fat, which has less compressive and inflammatory effect on the airways. As BRI and WWI increase, fat begins to concentrate more in the abdominal and thoracic cavities, and this accumulation of fat exerts a greater compressive effect on lung function, which in turn affects airway patency. Visceral fat is also highly metabolically active, secreting pro-inflammatory factors that can cause a systemic inflammatory response, which in turn can lead to chronic inflammation and airway hyperresponsiveness, exacerbating asthma onset and symptoms[46,47]. When abdominal fat increases, the pressure in the abdominal cavity rises, and diaphragmatic movement is restricted, leading to limited lung expansion, especially in people with high obesity, and a decrease in lung volume, thus increasing the likelihood of dyspnea. Also, the nonlinear correlation between BRI/WWI and asthma may stem from reverse causation. Asthma causes reduced exercise capacity, and long-term steroid use and chronic airway inflammation may trigger metabolic changes in the body, such as insulin resistance or other endocrine disorders, all of which can promote weight gain and fat accumulation. Therefore, BRI and WWI, as novel abdominal obesity assessment tools, provide a more precise perspective for understanding the relationship between abdominal fat and asthma.

The large and nationally representative sample size based on NHANES data is one of the study's main strengths, as it increases the validity of the findings. The study adjusted for multiple potential confounders, including age, sex, race, and lifestyle factors, enhancing the reliability of the findings. Subgroup analyses and sensitivity analyses showed that the associations of BRI and WWI with asthma were significant across populations, further supporting the robustness of the results. As the data came from cross-sectional surveys, it was not possible to determine the causal relationship between BRI and WWI and asthma, and the effect of the reverse nature of causality could not be ruled out, suggesting that future prospective or longitudinal studies could be conducted to confirm causality and that instrumental variable analyses could also be used to strengthen causal inference. Although the NHANES asthma self-report data are somewhat consistent compared with the clinical diagnosis data, possible misclassification biases still exist, especially if there are differences in patients' perceptions of asthma and their ability to self-diagnose. These biases may affect the accuracy of the results, especially when assessing the relationship between BRI and WWI and asthma. To further improve the accuracy of the study and reduce misclassification bias, it is suggested that future studies may consider validating self-reported data with clinical diagnostics or biomarkers. Examples include the use of pulmonary function tests, bronchial provocation tests, or serum characterization markers (e.g., IgE levels). Although we have adjusted for multiple covariates, we were unable to exclude all potential confounders, such as genetic background, environmental pollution, and additional elements that might have contributed to the onset of asthma. The study population consisted of American adults, and additional research is necessary to see whether the findings apply to other regions or to children.

Conclusion

This study showed that asthma, BRI, and WWI were significantly positively correlated among US adults. The predictive ability of BRI for asthma was superior to that of WWI, revealing the potential of BRI and WWI as emerging metrics for asthma prevalence prediction, and the finding of a threshold effect, in particular, is clinically important. Further validation in larger prospective studies is still needed in the future.

Data availability

Publicly available datasets were analyzed in this study. This data can be found here: www.cdc.gov/nchs/nhanes/.

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Author contributions
J.X. and JW.X. designed the research. J.X. collected, analyzed the data, and drafted the manuscript. J.X., XT. J.,M.S., M.C, and XB. L. revised the manuscript. All authors contributed to the article and approved the submitted version.

Declarations

Competing interests
The authors declare no competing interests.

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