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Association between adherence to a lifestyle behavior and the risk of asthma in overweight and obese adolescents

Xiao-jun Kang[1,2] and Xiao-dong Sui[1*]

Abstract

With the increasing prevalence of overweight and obesity in children and adolescents, to actively prevent the occurrence of asthma in this population is important for reducing the burden of the disease. Lifestyle factors, including diet and exercise, are importance for overweight and obese adolescents, as well as an important modifiable factor affecting airway inflammation and asthma, whether healthy lifestyle was correlated with the risk of asthma in adolescents ≥ 12 years has not been reported. We suspected that there might be correlation between healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents. This cross-sectional study aimed to explore the association between the adherence to a healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents based on the data of 945 participants aged between 12–18 years from the National Health and Nutrition Examination Surveys (NHANES). Univariable and multivariable weighted Logistic regression models were applied to evaluate the association between healthy lifestyle behaviors with asthma risk in overweight and obese adolescents. Odds ratio (OR) and 95% confidence interval (CI) were applied as estimates. We found that the risk of asthma was reduced in overweight and obese adolescents with intermediate (OR = 0.40, 95%CI: 0.17–0.94) or good lifestyle behaviors (OR = 0.33, 95%CI: 0.13–0.86) in comparison to those with poor lifestyle behaviors. In summary, intermediate or good lifestyle behaviors was correlated with decreased risk of asthma in overweight and obese adolescents, which might provide a reference for making further prevention strategies for asthma in adolescents.

Keywords Adolescents, Asthma, Healthy lifestyle behaviors

Introduction

Asthma is the main non-communicable disease causing the burden of disease in children and adolescents [1]. Although most children with asthma can be controlled with inhaled corticosteroids, some children may experience frequent and severe asthma attacks, causing worsening lung function and leading to increased disease burden [2]. Overweight and obesity are risk factors for asthma, and asthma patients with overweight and obesity have more symptoms and more frequent and severe attacks [3]. With the increasing prevalence of overweight and obesity in children and adolescents, to actively prevent the occurrence of asthma in this population is important for reducing the burden of the disease.

Lifestyle factors, including diet and exercise, are important for overweight and obese adolescents, as well as important modifiable factors affecting airway inflammation and asthma [4–7]. Following healthier lifestyle was significantly associated with lower risk of asthma in

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children < 12 years old [8, 9]. However, whether healthy lifestyle was correlated with the risk of asthma in adolescents ≥ 12 years has not been reported. In addition, among overweight and obese adults, greater health benefits could be achieved by following healthier lifestyle behaviors [10, 11]. Therefore, we suspected that there might be correlation between healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents.

This study aimed to explore the association between the adherence to a healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents based on the data from the National Health and Nutrition Examination Surveys (NHANES). Subgroup analysis was performed in terms of gender, poverty-to-income ratio, and homeostasis model assessment of insulin resistance (HOMA-IR).

Methods

Study design and population

In this cross-sectional study, a total of 4007 participants aged between 12–18 years from NHANES database between 2011–2018 were identified. The National Health and Nutrition Examination Survey (NHANES) is a comprehensive program of studies designed to evaluate the health and nutritional status of individuals, both adults and children, residing in the United States. This survey stands out due to its unique combination of interviews and physical examinations. NHANES serves as a significant initiative under the umbrella of the National Center for Health Statistics (NCHS), which operates within the Centers for Disease Control and Prevention (CDC). NCHS plays a crucial role in generating vital statistics and health-related data for the nation. The included criteria of our study were (1) 12 ≤ aged < 18 years old, (2) overweight or obesity in the NHANES 2011–2018 database. Participants without the assessment of asthma, missing complete information for healthy lifestyle behaviors assessment, or missing information of key co-variables were excluded.

Potential covariables and definitions

Age (years), gender (female or male), race (non-Hispanic White, Non-Hispanic Black, Mexican American or others), educational level (less than high school degree, high school grade/GED or equivalent, some college or AA degree or college graduate or above), poverty-to-income ratio [≤ 3.5 (low and middle income) and > 3.5 (high income)] [12], family history of asthma or not, hay fever or not, maternal smoking during pregnancy or not, low birth weight or not, body mass index (BMI) (kg/m^2), total cholesterol (< 200 or ≥ 200), high-density lipoprotein cholesterol (HDL-C) (> 35 or ≤ 35) (mg/dL), low-density lipoprotein cholesterol (LDL-C) (< 130, ≥ 130, or unknown) (mg/dL), triglyceride (< 150, ≥ 150 or unknown) (mg/dL), HOMA-IR (< 4.39, ≥ 4.39 or unknown), and total energy (kcal/day) were analyzed.

The BMI-for-age percentile growth charts are the most commonly used indicator to measure the size and growth patterns of children and teens in the United States. BMI-for-age weight status categories and the corresponding percentiles were based on expert committee recommendations (https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html). Overweight: 85th to less than the 95th percentile; Obesity: equal to or greater than the 95th percentile [13]. Poverty-to-income ratio was calculated by dividing family income by the poverty guidelines for the survey year. HOMA-IR = fasting plasma glucose (mmol/L) × fasting insulin (μU/mL)/22.5. According to National Cholesterol Education Program guidelines, abnormal serum TC, serum HDL-C, serum LDL-C, fasting TAG and fasting plasma glucose concentrations, and abnormal HOMA-IR score, were defined as follows: TC ≥ 200 mg/dl, HDL-C ≤ 35 mg/dl, LDL-C ≥ 130 mg/dl, TAG ≥ 150 mg/dl, glucose ≥ 100 mg/dl and HOMA-IR ≥ 4.39 [14].

Main and outcome variables

Asthma was identified according to "MCQ010 (Has a doctor or other health professional ever told you that you have asthma?)" and "MCQ035 (Do you still have asthma?)" in the questionnaire. If the answer to "MCQ035" was yes, asthma was present, and if the answer to "MCQ010" or "MCQ035" was no, asthma was not present.

Healthy lifestyle behaviors included diet quality [15, 16] (healthy eating index (HEI)-2015, the top 40% of the score is a healthy diet, assigned 1 point, otherwise 0 point), physical activity [17] (the sum of moderate and heavy physical activity time ≥ 60 min/ day, assigned 1 point, otherwise 0 point), tobacco exposure [18] (serum cotinine ≥ 0.05 was 0 point, otherwise 1 point), screen use time [19, 20] [PAQ710 (Over the past 30 days, on average how many hours per day did you sit and watch TV or videos) + PAQ715 (Over the past 30 days, on average how many hours per day did you use a computer or play computer games outside of work or school? Include Playstation, Nintendo DS, or other portable video games) ≤ 2 h is assigned 1 point, otherwise it is 0 point), the total score is 0–4 points, the higher the score, the healthier; It can be classified according to 0 (poor), 1–2 (intermediate), and 3–4 (good). The graph of the components of healthy lifestyle behaviors in adolescents was exhibited in Supplementary Fig. 1.

In the NHANES study, dietary quality was assessed using 24-h dietary recalls and evaluated based on HEI scores. The HEI-2015 was calculated for the survey cycles from 1999 to 2014, which aligns with the Dietary Guidelines for Americans from 2015 to 2020. A healthy diet was defined as having a healthy eating index score in the top two fifths of the distribution.

Supplementary Fig. 1 The graph of the components of healthy lifestyle behaviors in adolescents.

Statistical analysis

The measurement data were described as Mean ± standard error (Mean ± S.E), and the t test was used to compare the differences between the two groups. The enumeration data were described as the number of cases and constituent ratio, and the chi-square test was used to compare the differences between groups. A weighted univariate Logistic regression model was established to identify covariates associated with asthma in overweight and obese adolescents. Variables with statistical association with asthma were regarded as covariates. Univariable and multivariable weighted Logistic regression models were applied to evaluate the association between healthy lifestyle behaviors and asthma risk in overweight and obese adolescents. Random forest model was constructed to calculate the influence of each component of healthy lifestyle behaviors on the heterogeneity of observed values at each node of the classification tree, and the corresponding mean decrease gini value of each component was obtained. Higher mean decrease geni value indicated greater the importance of the component. Odds ratio (OR) and 95% confidence interval (CI) were applied as estimates. $P<0.05$ was considered statistical difference. SAS 9.4 was used for data extraction, and R version 4.2.3 was used for difference comparison, and weighted Logistic regression analysis.

Results

Comparisons of characteristics in patients with or without asthma

In total, the data of 4007 participants aged between 12–18 years from NHANES database between 2011–2018 were extracted. Among them, 1589 were overweight or obesity. Participants without the assessment of asthma ($n=1$), missing complete information for healthy lifestyle behaviors assessment including tobacco smoke exposure ($n=161$), screen time ($n=36$), diet quality ($n=362$), or missing information on parents' educational level ($n=9$), poverty-to-income ratio ($n=74$), or total cholesterol ($n=1$) were excluded. Finally, 945 participants were included. The screen process of the participants was depicted in Fig. 1.

Among all the participants, 150 individuals had asthma, accounting for 15.9%. The percentage of participants with good lifestyle behaviors in the asthma group was lower than the non-asthma group (17.48% vs 27.82%). The percentage of adolescents with family history of asthma in the asthma group was higher than those without (66.07% vs 33.49%). The percentage of subjects with hay fever in the asthma group was higher than the non-asthma group (24.99% vs 4.09%). More data on the characteristics of participants were exhibited in Table 1.

Association between lifestyle behavior and the risk of asthma in overweight and obese adolescents

As exhibited in Table 2, race, poverty-to-income ratio, family history of asthma, hay fever, and HOMA-IR were covariates associated with asthma in overweight and obese adolescents. Compared individuals with poor lifestyle behaviors, overweight and obese adolescents with good lifestyle behaviors might be associated with decreased risk of asthma (OR = 0.26, 95%CI: 0.11–0.62). In the adjusted model, the risk of asthma was reduced in overweight and obese adolescents with intermediate (OR = 0.40, 95%CI: 0.17–0.94) or good lifestyle behaviors (OR = 0.33, 95%CI: 0.13–0.86) in comparison to those with poor lifestyle behaviors (Table 3). The most important component in lifestyle behavior for asthma was diet quality (gini score = 3.187), followed by physical activities (gini score = 3.101) and tobacco exposure (gini score = 3.016) (Fig. 2).

Subgroup analysis of association between lifestyle behavior and the risk of asthma in overweight and obese adolescents

In females, intermediate (OR = 0.37, 95%CI: 0.17–0.80) or good (OR = 0.13, 95%CI: 0.02–0.81) lifestyle behaviors were related to reduced asthma risk of overweight and obese adolescents. For those with poverty-to-income ratio ≤ 3.5, the risk of asthma was decreased in overweight and obese adolescents with intermediate (OR = 0.42, 95%CI: 0.18–0.97) or good (OR = 0.32, 95%CI: 0.11–0.96) lifestyle behaviors. The reduced risk of asthma was observed in overweight and obese adolescents with HOMA-IR ≥ 4.39 who had intermediate (OR = 0.06, 95%CI: 0.01–0.33) or good (OR = 0.03, 95%CI: 0.00–0.45) lifestyle behaviors (Table 4).

Discussion

The present study evaluated the association between the adherence to a healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents. The results indicated that the risk of asthma was decreased in overweight and obese adolescents with intermediate or good lifestyle behaviors, with diet quality, followed by physical

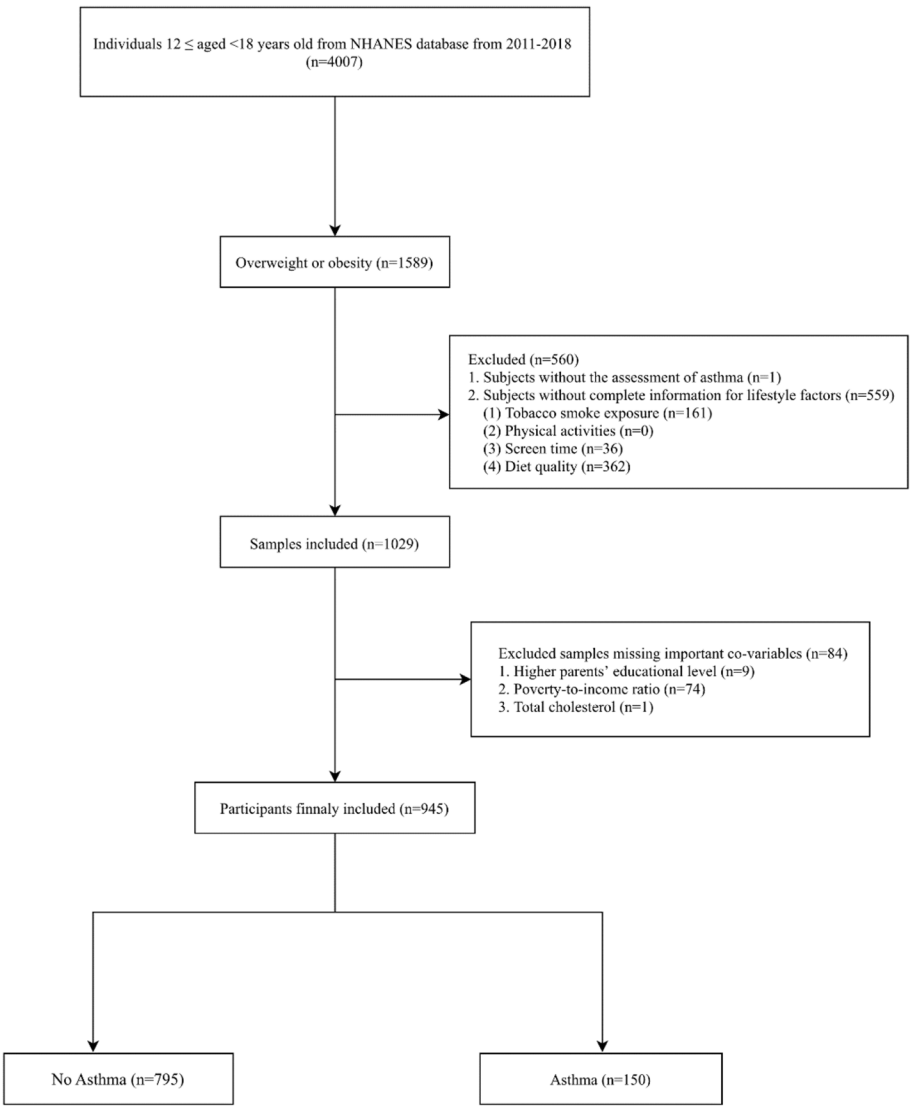

Fig. 1 The screen process of the participants

activities and tobacco exposure as the most important components in lifestyle behavior for asthma. The findings might provide a reference for the management of asthma in overweight and obese adolescents.

As an essential part of life, diet was reported to be a key factor influencing the development of allergic diseases [21]. Dietary intake might regulate the chronic inflammation of the airways, which is an important component of asthma [22]. Evidence from previous studies depicted that dietary nutrients including a use of vitamin A, vitamin C, vitamin E or polyunsaturated fatty acids for the prevention or treatment of asthma could not be recommended based on current data [23]. The findings were different from our study, and this might due to that the study was focused on nutrition supplements. A balanced diet may contribute to the prevention or amelioration of asthma symptoms, as the antioxidant properties inherent in fruits, vegetables, and whole grains have been shown to potentially mitigate both systemic and airway inflammation in individuals with asthma [24, 25]. Conversely, a pro-inflammatory diet characterized by high saturated fat and red meat consumption, as well as excessive intake of refined sugars but inadequate consumption of fruits and vegetables, may result in an elevated production of reactive oxygen species, heightened Th2 immune responses, and activation of the NF-kB factor [25].

Previously, the promotion of moderate-to-vigorous physical activity among children with low activity levels is linked to a reduced risk of asthma [26]. The study conducted by Jaakkola et al. demonstrated that regular

Table 1 The characteristics of participants with or without asthma

Variables	Total ($n=945$)	Asthma		Statistics	P
		No ($n=795$)	Yes ($n=150$)		
Age, years, Mean ± S.E	14.51 ± 0.10	14.54 ± 0.10	14.35 ± 0.20	t = -0.996	0.324
Gender, n (%)				$\chi^2=1.104$	0.299
Female	476(50.39)	397(49.50)	79(55.24)		
Male	469(49.61)	398(50.50)	71(44.76)		
Race, n (%)				$\chi^2=3.358$	0.023
Non-Hispanic White	231(49.20)	192(49.72)	39(46.32)		
Non-Hispanic Black	264(15.53)	199(13.60)	65(26.18)		
Mexican American	225(17.15)	201(17.59)	24(14.73)		
Others	225(18.12)	203(19.09)	22(12.77)		
Higher parents' educational level, n (%)				$\chi^2=2.617$	0.065
Less than high school degree	197(14.88)	176(15.60)	21(10.88)		
High school grade/GED or equivalent	220(20.52)	185(20.46)	35(20.87)		
Some college or AA degree	323(36.34)	256(33.73)	67(50.71)		
College graduate or above	205(28.26)	178(30.21)	27(17.54)		
Poverty-to-income ratio, n (%)				$\chi^2=4.495$	0.039
≤ 3.5	790(77.41)	654(75.39)	136(88.52)		
> 3.5	155(22.59)	141(24.61)	14(11.48)		
Family history of asthma, n (%)				$\chi^2=18.622$	< 0.001
No	589(61.50)	539(66.51)	50(33.93)		
Yes	356(38.50)	256(33.49)	100(66.07)		
Hay fever, n (%)				$\chi^2=40.764$	< 0.001
No	885(92.70)	769(95.91)	116(75.01)		
Yes	60(7.30)	26(4.09)	34(24.99)		
Maternal smoking during pregnancy, n (%)				$\chi^2=0.376$	0.543
No	875(89.46)	738(89.10)	137(91.46)		
Yes	70(10.54)	57(10.90)	13(8.54)		
Low birth weight, n (%)				$\chi^2=1.132$	0.326
No	533(54.82)	449(54.64)	84(55.86)		
Yes	84(7.92)	65(7.34)	19(11.13)		
Unknown	328(37.26)	281(38.02)	47(33.01)		
Height, cm, Mean ± S.E	165.55 ± 0.50	165.70 ± 0.54	164.71 ± 1.29	t = -0.718	0.476
Weight, kg, Mean ± S.E	80.55 ± 0.97	80.37 ± 0.98	81.53 ± 2.43	t = 0.475	0.637
BMI, kg/m^2, Mean ± S.E	29.20 ± 0.25	29.07 ± 0.25	29.90 ± 0.71	t = 1.174	0.247
Total cholesterol, mg/dL, n (%)				$\chi^2=1.300$	0.260
< 200	858(87.64)	727(88.53)	131(82.74)		
≥ 200	87(12.36)	68(11.47)	19(17.26)		
HDL-C, mg/dL, n (%)				$\chi^2=0.002$	0.968
> 35	856(88.24)	718(88.27)	138(88.09)		
≤ 35	89(11.76)	77(11.73)	12(11.91)		
LDL-C, mg/dL, n (%)				$\chi^2=0.252$	0.774
< 130	401(36.79)	339(36.97)	62(35.77)		
≥ 130	27(2.65)	21(2.45)	6(3.74)		
Unknown	517(60.56)	435(60.58)	82(60.49)		
Triglyceride, mg/dL, n (%)				$\chi^2=0.601$	0.541
< 150	381(35.56)	321(35.90)	60(33.66)		
≥ 150	47(3.88)	39(3.52)	8(5.84)		
Unknown	517(60.56)	435(60.58)	82(60.50)		
HOMA-IR, n (%)				$\chi^2=3.862$	0.033

Table 1 (continued)

Variables	Total ($n=945$)	Asthma		Statistics	*P*
		No ($n=795$)	Yes ($n=150$)		
< 4.39	237(21.90)	203(22.86)	34(16.62)		
≥ 4.39	191(17.22)	154(15.31)	37(27.68)		
Unknown	517(60.88)	438(61.83)	79(55.70)		
Total energy, kcal/day, Mean ± S.E	1914.62 ± 37.80	1914.00 ± 40.61	1918.04 ± 99.67	t = 0.038	0.970
Healthy lifestyle, n (%)				$\chi^2 = 5.255$	0.009
Poor	56(6.31)	40(5.18)	16(12.55)		
Intermediate	652(67.45)	547(67.00)	105(69.97)		
Good	237(26.24)	208(27.82)	29(17.48)		

S.E standard error, *HDL-C* high density lipoprotein cholesterol, *LDL-C* low density lipoprotein cholesterol, *HOMA-IR* homeostasis model assessment of insulin resistance

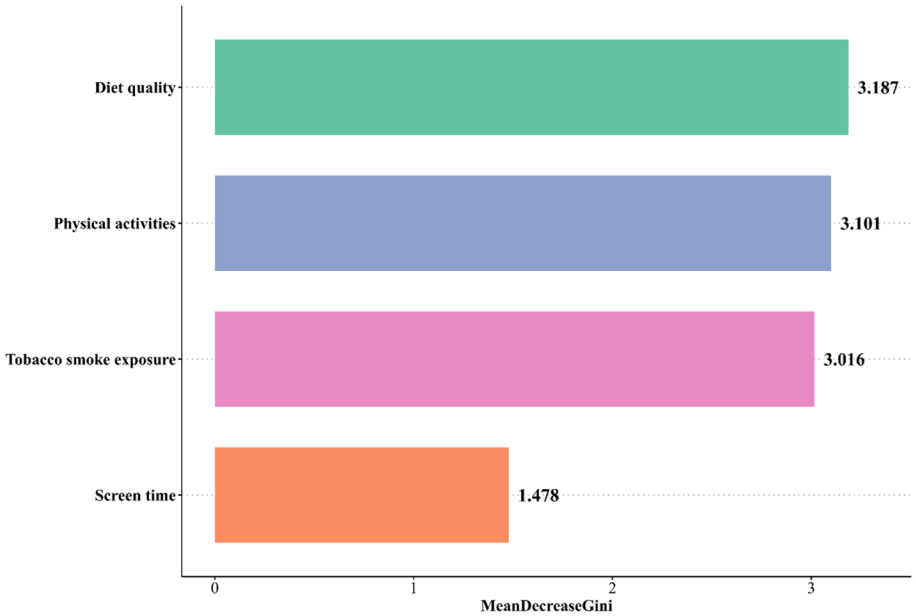

Fig. 2 The gini score of each component of lifestyle behaviors

physical activity enhances asthma management in adult individuals [27]. The cardiopulmonary fitness is enhanced through aerobic training, as evidenced by an elevated maximal oxygen consumption [28]. Physical activity was also reported to have short-term beneficial effects on airway smooth muscle [29], reducing airway responsiveness [30]. Kamps et al. indicated that physical activity level was not benefit asthma control in children during regular follow-up [31]. The possible reason might be the difference in the study population. Kamps et al. studied children aged 6–18 years, and the evaluation of physical activity in adolescents might be different from our study population.

The impact of cigarette smoke on the development and exacerbation of childhood asthma has been consistently observed in various research studies [32]. Second-hand smoke is widely recognized as a significant contributor to respiratory tract infections in children [33]. Exposure to second-hand smoke is associated with an increased incidence and severity of respiratory tract infections, such as neonatal respiratory syncytial virus (RSV) infection or pneumonia in younger children [34]. The impact of second-hand smoke on the respiratory health of adolescents was previously reported on the prevalence of asthma and lung function [35].

Table 2 The screening of potential confounding factors associated with asthma

Variables	OR (95% CI)	*P*
Age	0.94 (0.82–1.07)	0.331
Gender		
Female	Ref	
Male	0.79 (0.51–1.24)	0.300
Race		
Non-Hispanic white	Ref	
Non-Hispanic black	2.07 (1.16–3.67)	0.014
Mexican American	0.90 (0.45–1.79)	0.757
Others	0.72 (0.36–1.45)	0.346
Higher parents' educational level		
Less than high school degree	Ref	
High school grade/GED or equivalent	1.46 (0.67–3.21)	0.334
Some college or AA degree	2.16 (0.93–5.00)	0.072
College graduate or above	0.83 (0.30–2.33)	0.721
Poverty-to-income ratio		
≤ 3.5	Ref	
> 3.5	0.40 (0.16–0.98)	0.045
Family history of asthma		
No	Ref	
Yes	3.87 (2.00–7.48)	< 0.001
Hay fever		
No	Ref	
Yes	7.82 (3.75–16.31)	< 0.001
Maternal smoking during pregnancy		
No	Ref	
Yes	0.76 (0.31–1.86)	0.544
Low birth weight		
No	Ref	
Yes	1.48 (0.74–2.97)	0.260
Unknown	0.85 (0.52–1.39)	0.506
BMI	1.03 (0.98–1.07)	0.210
Total cholesterol		
< 200	Ref	
≥ 200	1.61 (0.69–3.76)	0.264
HDL-C		
> 35	Ref	
≤ 35	1.02 (0.44–2.36)	0.968
LDL-C		
< 130	Ref	
≥ 130	1.58 (0.47–5.29)	0.452
Unknown	1.03 (0.62–1.73)	0.902
Triglyceride		
< 150	Ref	
≥ 150	1.77 (0.67–4.68)	0.242
Unknown	1.07 (0.65–1.75)	0.799
HOMA-IR		
< 4.39	Ref	
≥ 4.39	2.49 (1.21–5.11)	0.014
Unknown	1.24 (0.76–2.02)	0.384
Total energy	1.00 (1.00–1.00)	0.970

Table 2 (continued)

OR odds ratio, *CI* confidence intervals, *Ref* reference, *BMI* body mass index, *HDL-C* high density lipoprotein cholesterol, *LDL-C* low density lipoprotein cholesterol, *HOMA-IR* homeostasis model assessment of insulin resistance

Table 3 Association between lifestyle behavior and the risk of asthma in overweight and obese adolescents

	Model 1		Model 2	
Variables	**OR (95%*CI*)**	***P***	**OR (95%CI)**	***P***
Healthy lifestyle				
Poor	Ref		Ref	
Intermediate	0.43 (0.18–1.02)	0.054	0.40 (0.17–0.94)	0.036
Good	0.26 (0.11–0.62)	0.003	0.33 (0.13–0.86)	0.024

OR Odds ratio, *CI* Confidence intervals, *Ref* Reference

Model 1 unvariable Logistic regression analysis adjusting for no confounders

Model 2 multivariable Logistic regression analysis adjusting for race, poverty-to-income ratio, family history of asthma, hay fever, and HOMA-IR

The excessive use of electronic screens is linked to the development of asthma in overweight youth from Manitoba [36]. These findings might give evidence to the results in the current study, which delineated that as parts of healthy lifestyle behaviors, diet, physical activity, smoking, and screen time were associated with the risk of asthma in overweight and obese adolescents.

Subgroup analysis indicated that the association between healthy lifestyle behaviors and the risk of asthma might have gender differences. In those with better family financial status, we found the association between good lifestyle behaviors with lowered risk of asthma. HOMA-IR was inversely related to spirometric parameters such as forced expiratory volume in 1 s/forced vital capacity ratio and forced expiratory flow [37]. A previous study showed that healthy lifestyle behaviors especially enhancing physical activity, especially among individuals with impaired insulin resistance, holds significant promise as a preventive strategy [38]. In this study, those with HOMA-IR ≥ 4.39 might benefit from healthy lifestyle behaviors.

The current study explored the association between healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents, which might provide a reference for lifestyle interventions in overweight and obese adolescents. The findings of this study indicate that incorporating information on diet, physical activity, smoke exposure, and screen time into the clinical assessment of asthma in overweight and obese adolescents can provide additional dimensions to the evaluation. Dietary instruction, smoking exposure, screen time controlling and physical activity might be counseled into asthma prevention practice [39]. Moreover, these insights may

Table 4 Subgroup analysis of the association between lifestyle behavior and the risk of asthma in overweight and obese adolescents

Subgroups (Asthma/Total)	Healthy lifestyle (Asthma/Total)	OR (95%*CI*)	*P*	*P* for interaction
Gender				0.108
Female (79/476)	Poor (11/33)	Ref		
	Intermediate (55/335)	0.37 (0.17–0.80)	0.013	
	Good (13/108)	0.13 (0.02–0.81)	0.030	
Male (71/469)	Poor (5/23)	Ref		
	Intermediate (50/317)	0.61 (0.13–2.86)	0.516	
	Good (16/129)	0.85 (0.17–4.17)	0.834	
Poverty-to-income ratio				0.699
≤ 3.5 (136/790)	Poor (15/53)	Ref		
	Intermediate (97/559)	0.42 (0.18–0.97)	0.043	
	Good (24/178)	0.32 (0.11–0.96)	0.042	
> 3.5 (14/155)	Poor (1/3)	Ref		
	Intermediate (8/93)	0.11 (0.01–1.33)	0.079	
	Good (5/59)	0.17 (0.01–2.70)	0.193	
HOMA-IR				0.332
< 4.39 (34/237)	Poor (4/13)	Ref		
	Intermediate (23/158)	0.33 (0.05–2.08)	0.229	
	Good (7/66)	0.19 (0.03–1.35)	0.094	
≥ 4.39 (37/191)	Poor (9/19)	Ref		
	Intermediate (23/125)	0.06 (0.01–0.33)	0.002	
	Good (5/47)	0.03 (0.00–0.45)	0.014	

OR Odds ratio, *CI* Confidence intervals, *Ref* Reference

Multivariable Logistic regression analysis, if not stratified, adjusting for race, poverty-to-income ratio, family history of asthma, hay fever, and HOMA-IR

offer valuable evidence for the development of primary prevention strategies and serve as a reference for public health policy. There were some limitations in this study. Firstly, this was a cross-sectional study, causal relationship between healthy lifestyle behaviors and the risk of asthma in this population was unclear. Secondly, alcohol use, sleep such as obstructive sleep apnea (OSA), gastroesophageal reflux (GER), and anxiety/depression are also important modifiable lifestyle factors affecting asthma, however, these data were not examined in adolescents in NHANES. Thus, the results require validation in more studies. Thirdly, this study did not compare the data of non-overweight/non-obese populations with overweight/obese populations, and this may be done in our future research to deep identify the association between asthma and obesity.

Conclusions

The association between healthy lifestyle behaviors and the risk of asthma in overweight and obese adolescents was assessed in this study. We identified that intermediate or good lifestyle behaviors was correlated with decreased risk of asthma in overweight and obese adolescents. The findings might provide a reference for the management of asthma in overweight and obese adolescents.

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Authors' contributions
XJK was involved in this study from data management, data analysis, drafting, and revising the final manuscript. XDS conceptualized the research problem, study design, and revising the manuscript. All authors critically reviewed and made substantial contributions to the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The dataset used and analyzed during the current study is openly available from NHANES database (https://www.cdc.gov/nchs/nhanes/index.htm).

Declarations

Ethics approval and consent to participate
This study did not require ethical approval, as it did not involve direct participation of individuals who would provide informed consent.

Consent for publication
Consent to publication is not applicable in this case.

Competing interests
The authors declare no competing interests.

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