

OBESITY

Gender-specific differences in associations of overweight and obesity with asthma and asthma-related symptoms in 30 056 children: result from 25 districts of Northeastern China

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Abstract

Objective: The relationship between obesity and allergic respiratory diseases in childhood is still controversial. Furthermore, significant debate on the issue of whether or not gender modifies this association also exists due to inconsistent findings. The objective of this study is to evaluate the association between obesity and respiratory health in children, and to investigate the modifications of gender on this association. **Methods:** 30 056 children (aged 2–14 years) were randomly selected from 25 districts within 7 cities in Northeastern China in 2009. A standard questionnaire from the American Thoracic Society was used to characterize the childrens' histories of respiratory symptoms and illnesses. Child weight and height were measured, and obesity was calculated with an age and sex-specific body mass index. **Results:** The overall prevalence rates of obesity and overweightness were 14.08% and 12.32%, respectively. Compared to the children with normal body weights, asthma and asthma-related symptoms were more prevalent in overweight and obese children. Analysis stratified by gender showed that obesity was associated with more respiratory symptoms and diseases in females than in males. A significant association between obesity and diagnosed asthma [adjusted odds ratio (aOR) = 1.28; 95% confidence interval (CI): 1.02–1.60], as well as current wheezing (aOR = 1.46; 95%CI: 1.20–1.79) was found in females but not in males. **Conclusions:** There is an association between asthma symptoms and obesity in these Chinese children, and obesity had a significantly larger effect on females than males.

Keywords

Asthma, children, gender, obesity, overweight

History

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Introduction

Childhood asthma and obesity are two important public health issues that have increased in prevalence over the past two decades. According to National Health and Nutrition Examination Survey (NHANES) data from 2007 to 2008, 31.7% of children in the United States are overweight, and 16.9% are obese [1]. An analysis of 450 nationally representative cross-sectional surveys of preschool-aged children from 144 countries indicated that the worldwide prevalence of overweight and obesity in children has increased from 4.2% in 1990 to 6.7% in 2010 [2]. In addition, the prevalence of childhood asthma according to the International Study of

Asthma and Allergies in Childhood has shown to have significantly increase from 1992–1996 to 2000–2003 [3].

A possible connection between the increase in obesity and the increase in asthma is suspected as recent increases in the two appear to coincide. Although several studies have reported a positive association between asthma and obesity in children, the results of these studies are still inconsistent. Some researchers have found an association [4–7], but others have not [8–10]. Furthermore, whether or not gender modifies the association between obesity and asthma is up for debate due to inconsistent findings [11]. Castro-Rodriguez et al. discovered an increased incidence of asthma-like symptoms in females who become overweight or obese [12]. Mannino et al. found that males, with BMIs $\geq$ 85th percentile have an increased risk of developing asthma [13]. A recent systematic review showed strong evidence that obesity precedes the onset of persistence and intensity of the symptoms of asthma in adolescence, but the role of sex is not clear [14].

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However, results from the Genes-environments and Admixture in Latino Americans (GALA II) Study and the Study of African Americans, Asthma, Genes, and Environments (SAGE II) both reported that sex was indeed found to play a role in the relationship between BMI and asthma, but the direction of this difference varied with race [15].

In the past decade, rapid economic development and urbanization, accompanied by changes in lifestyle and diet, have caused a significant rise in the prevalence of asthma and obesity in Chinese children. However, information on the associations between obesity and asthma among Chinese children is scarce. The primary aim of this study is to evaluate the associations between asthma and obesity in 30 056 Chinese children aged 2–14-years. The secondary aim is to determine whether gender modifies the association between asthma and obesity in these Chinese children.

Materials and methods

Ethics statement

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation of China Medical University. All human experiments performed were approved by the China Medical University's Institutional Human Ethics Committee and were consistent with the principles outlined in NIH guidelines on the ethical conduct of human research. A written informed consent was obtained from the parent/guardian of each participant before data collection.

Participants and study procedures

The Seven Northeastern Cities of China (SNECC) study was designed using the guidelines set forth by the Ethical Standards of Responsible Committee on Human Experimentation of China Medical University. Seven cities (Shenyang, Dalian, Anshan, Fushun, Benxi, Liaoyang and Yingkou) were randomly selected from Liaoning Province in April of 2009. The numbers of districts in these seven cities were, five in Shenyang, four in Dalian and Fushun, and three in Anshan, Benxi, Liaoyang and Yingkou. Two kindergartens and one elementary school were randomly selected from each district, resulting in a total of 50 kindergartens and 25 elementary schools, and all their students were given a questionnaire and return envelope. After parents/guardians reviewed the questionnaire, we invited them to a Parents' Night and explained to them detailed information about the survey, including the objective of the survey and a revocable parental consent form, asking for the parents' permission for their children's voluntary participation in the survey. Parents or guardians who wished to complete the questionnaire at home would have their child return the completed questionnaire in an envelope to the teacher. Before the study, all parents were required to submit a completed consent form to the investigators or local study staff, permitting their children to participate. All procedures in the present study complied with the ethical standards of the Responsible Committee on Human Experimentation of China Medical University.

Definition of obesity and overweightness

The height and weight of all participants were measured using standardized protocol from the World Health Organization [16], in which, height is measured to the nearest 0.5 cm, back against a wall, no shoes, eyes straight forward, and using a right-angled triangle placed on top of the head and against the wall. Weight measurements also followed WHO protocol: a lever balance was used to measure weight to the nearest 100 g, without shoes, and in only minimal undergarments. Body mass index (BMI) was then calculated using the gathered weight data (kilograms) and dividing it by height (meters) squared (kg/m^2). The BMI distribution was stratified by age and sex. We categorized BMI into age and sex-specific percentiles, based on the Centers for Disease Control and Prevention (CDC) BMI growth charts, which use 1-month age intervals [17]. According to the CDC standards, overweight is defined as a BMI between age and sex-specific 85th and 95th percentile, and obesity, as BMI greater than the age and sex specific 95th percentile.

Definitions of respiratory symptoms and asthma

Five respiratory symptoms from the questionnaire were considered: diagnosed asthma, current asthma, current wheeze, persistent cough, and persistent phlegm. We used definitions similar to those used in the American Thoracic Society and the Division of Lung Diseases (ATS-DLD-78) questionnaire survey [18], the Harvard Six Cities [19] and 24 Cities Studies [20], Twelve Southern California Communities Study [21], and Four China Cities Study [22]. *Diagnosed asthma* is defined as having ever been diagnosed with asthma by a physician. *Current asthma* among previously asthma-diagnosed children was defined by a "yes" answer to the question "Has this child had an asthma attack in the last two years?" or a "yes" answer to the question "Does this child take medicine or treatment for asthma or asthmatic bronchitis?" *Current wheeze* was defined by a "yes" answer to the question "Does this child's chest ever sound wheezy or whistle, including times when he or she had a cold?" and a "yes" answer to the question "Has this child had two or more such episodes in last 12 months?" *Persistent cough* was measured by the child experiencing a cough on most days (≥ 4 d per week) during at least 3 months out of the past year, either with or without a cold. *Persistent phlegm* was measured by the child appearing congested, or producing phlegm or mucus from the chest on most days (≥ 4 d per week) during at least 3 months out of the past year, either with or without a cold.

Statistical analysis

We fitted a multivariable logistic regression analysis using each of the five outcome measures of respiratory symptoms and the predictor variables including overweightness, obesity, and all other covariates. From the fitted model, we selected the covariates that had a positive association with respiratory symptoms/diseases. Using these selected covariates, we carried out backward selection by dropping the variable that had a less than 10% decrease in the model fit statistic after the variable was removed from the model. The final

model calculated the adjusted odds ratios (aORs) and the associated 95% confidence intervals (CI) for each outcome measure (SAS 9.13, SAS Institute, Inc., Cary, NC). All statistical tests were two-tailed and *p* values less than 0.05 were considered statistically significant.

Results

Among the total of 35 527 children from 50 preschools and 25 elementary schools, 31 049 completed and returned the questionnaire, yielding an overall response rate of 87.40%. The participation rates varied from 81.32% in Yingkou to 94.71% in Dalian, which did not correlate with levels of pet exposure or disease prevalence. In total, 1593 children (600 residing in the current district <2 years, 993 with insufficient data) were excluded from further analyses. Among the 30 056 children analyzed, the average age was 8.43 years (SD = 2.70 years; range from 2 to 14), and 50.4% (15 137) were male. Table 1 contains detailed information about the study population. Among the participants, 12.32% (3704) were overweight and 14.08% (4233) were obese. Overweightness and obesity were more common among males (14.36% overweight, 18.20% obese) than among females (10.26% overweight, 9.91% obese). The prevalence of asthma and asthma-related symptoms were significantly higher in males than in females.

Table 2 displays the prevalence of asthma and asthma-related symptoms in children who suffered from overweightness and obesity. As shown in Table 2, there is a significant relationship between asthma and asthma-related symptoms which trend towards obesity ($p < 0.001$), with the significance confirmed in both males and females by statistical analysis.

After adjusting for the potentially relevant personal and residential covariates listed in Table 1, an increased prevalence of asthma and asthma-related symptoms was found to be significantly associated with overweightness and obesity, and the aORs for the association between BMI and asthma

and asthma-related symptoms were lower than those obtained from the unadjusted analyses (Table 3). Results stratified by gender also showed differences in association with risk factors for obesity between males and females, with obese females having a significantly larger statistical effect than obese males. For example, among females, there was a significant association between obesity and diagnosed asthma [adjusted OR (aOR) = 1.28; 95% CI: 1.02–1.60], and current wheeze (aOR = 1.46; 95% CI: 1.20–1.79). Among males, the association between obesity and the prevalence of diagnosed asthma (aOR = 1.10; 95% CI: 0.94–1.29) and current wheeze (aOR = 1.11; 95% CI: 0.95–1.31) was not significant. Even for persistent cough, persistent phlegm, and current asthma, most of the adjusted aORs among females were higher than those among males.

Discussion

In this large cross-sectional study, both overweight and obesity were strongly associated with asthma and asthma-related symptoms among these Chinese children, and obesity was associated with more respiratory symptoms and disease in females than in males. This suggests that obesity may be an important factor for asthma, an association that deserves far more focus among researchers. Previous studies are in agreement with these results. Tai et al. [7] studied 1509 children aged 4–5 years, and found that overweightness and obesity were associated with asthma symptoms. Phase Three of the International Study of Asthma and Allergies in Childhood (ISAAC) examined the association between BMI and symptoms of asthma among 76 164 children aged 6–7 years and 201 370 adolescents aged 13–14 years and found an association that has confirmed the association between overweightness and obesity with symptoms of asthma [4]. Okabe et al. [23] conducted a cohort study of 34 669 Japanese preschool children to investigate the possible association between obesity and asthma, and found that

Table 1. Socio-demographic characteristics of the study participants stratified by gender.

	Total (<i>n</i> = 30 056)	Male (<i>n</i> = 15 137)	Female (<i>n</i> = 14 919)
Age (years)	8.43 ± 2.70	8.43 ± 2.72	8.43 ± 2.67
BMI (kg/m ²)	17.54 ± 4.77	18.04 ± 4.91	17.03 ± 4.58 ^a
BMI category			
Normal weight	22 119 (73.59)	10 208 (67.44)	11 911 (79.84)
Overweight	3704 (12.32)	2174 (14.36)	1530 (10.26)
Obesity	4233 (14.08)	2755 (18.20)	1478 (9.91) ^a
Breast fed	26 289 (87.47)	13 133 (86.76)	13 156 (88.18) ^a
Parental education <higher school	8211 (27.32)	4222 (27.89)	3989 (26.74) ^a
Family history of atopy	4140 (13.77)	2083 (13.76)	2057 (13.79)
Passive smoking exposure			
Father	11 492 (38.24)	5811 (38.39)	5681 (38.08)
Mother	262 (0.87)	139 (0.92)	123 (0.82)
Anyone ^b	14 889 (49.54)	7548 (49.86)	7341 (49.21)
Parents as responders	27 122 (90.24)	13 567 (89.63)	13 555 (90.86) ^a
Asthma and asthma related symptoms			
Persistent cough	2846 (9.47)	1487 (9.82)	1359 (9.11) ^a
Persistent phlegm	1365 (4.54)	739 (4.88)	626 (4.20) ^a
Current wheeze	1911 (6.36)	1051 (6.94)	860 (5.76) ^a
Current asthma	675 (2.25)	395 (2.61)	280 (1.88) ^a
Doctor-diagnosed asthma	1963 (6.53)	1143 (7.55)	820 (5.50) ^a

Values are *n* (%) or mean ± SD. BMI, body mass index.

^aComparing between male and female, $p < 0.05$.

^bIncluding parents and other household members.

Table 2. Non-adjusted trend association of overweightness and obesity on prevalence of asthma and asthma-related symptoms among males and females.

	Normal weight		Overweight		Obesity		<i>p</i> Value for trend
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	
Male (<i>n</i> = 15 137)	(n = 10 208)		(n = 2174)		(n = 2755)		
Persistent cough	947	9.28	218	10.03	322	11.69	<0.001
Persistent phlegm	454	4.45	124	5.70	161	5.84	<0.001
Current wheeze	667	6.53	153	7.04	231	8.38	<0.001
Current asthma	241	2.36	66	3.04	88	3.19	0.007
Diagnosed asthma	737	7.22	181	8.33	225	8.17	0.046
Female (<i>n</i> = 14 919)	(n = 11 911)		(n = 1530)		(n = 1478)		
Persistent cough	1000	8.40	172	11.24	187	12.65	<0.001
Persistent phlegm	456	3.83	81	5.29	89	6.02	<0.001
Current wheeze	202	1.70	38	2.48	40	2.71	0.001
Current asthma	615	5.16	107	6.99	138	9.34	<0.001
Diagnosed asthma	614	5.15	104	6.80	102	6.90	<0.001
Total (<i>n</i> = 30 056)	(n = 22 119)		(n = 3704)		(n = 4233)		
Persistent cough	1947	8.80	390	10.53	509	12.02	<0.001
Persistent phlegm	910	4.11	205	5.53	250	5.91	<0.001
Current wheeze	1282	5.80	260	7.02	369	8.72	<0.001
Current asthma	443	2.00	104	2.81	128	3.02	<0.001
Diagnosed asthma	1351	6.11	285	7.69	327	7.73	<0.001

Table 3. Crude and adjusted odds ratios for asthma and asthma-related symptoms in children.

	Normal weight	Crude OR (95%CI)		Adjusted OR (95%CI) ^a	
		Overweight	Obesity	Overweight	Obesity
Male (<i>n</i> = 15 137)					
Persistent cough	1.00	1.09 (0.93–1.27)	1.29 (1.13–1.48)	1.09 (0.93–1.27)	1.18 (1.03–1.36)
Persistent phlegm	1.00	1.30 (1.06–1.59)	1.33 (1.11–1.60)	1.30 (1.06–1.59)	1.29 (1.07–1.55)
Current wheeze	1.00	1.08 (0.90–1.30)	1.31 (1.12–1.53)	1.09 (0.91–1.32)	1.11 (0.95–1.31)
Current asthma	1.00	1.30 (0.98–1.71)	1.37 (1.07–1.75)	1.32 (0.99–1.74)	1.19 (0.93–1.54)
Diagnosed asthma	1.00	1.17 (0.99–1.38)	1.14 (0.98–1.34)	1.17 (0.99–1.39)	1.10 (0.94–1.29)
Female (<i>n</i> = 14 919)					
Persistent cough	1.00	1.38 (1.16–1.64)	1.58 (1.34–1.87)	1.23 (1.03–1.46)	1.35 (1.14–1.60)
Persistent phlegm	1.00	1.40 (1.10–1.79)	1.61 (1.27–2.03)	1.30 (1.02–1.66)	1.45 (1.14–1.85)
Current wheeze	1.00	1.38 (1.12–1.71)	1.89 (1.56–2.29)	1.11 (0.89–1.39)	1.46 (1.20–1.79)
Current asthma	1.00	1.48 (1.04–2.10)	1.61 (1.14–2.27)	1.26 (0.88–1.80)	1.35 (0.95–1.92)
Diagnosed asthma	1.00	1.34 (1.08–1.66)	1.36 (1.10–1.69)	1.26 (1.01–1.57)	1.28 (1.02–1.60)
Total (<i>n</i> = 30 056)					
Persistent cough	1.00	1.22 (1.09–1.37)	1.42 (1.28–1.57)	1.16 (1.03–1.30)	1.25 (1.12–1.39)
Persistent phlegm	1.00	1.37 (1.17–1.60)	1.46 (1.27–1.69)	1.32 (1.13–1.54)	1.35 (1.16–1.56)
Current wheeze	1.00	1.23 (1.07–1.41)	1.55 (1.38–1.75)	1.12 (0.97–1.29)	1.24 (1.09–1.40)
Current asthma	1.00	1.41 (1.14–1.76)	1.53 (1.25–1.86)	1.30 (1.04–1.61)	1.24 (1.01–1.53)
Diagnosed asthma	1.00	1.28 (1.12–1.46)	1.29 (1.14–1.46)	1.21 (1.06–1.39)	1.16 (1.02–1.32)

^aModels were adjusted for age, gender, parental education, family history of atopy, breast feeding, passive smoking exposure, districts.

current asthma was significantly more prevalent in overweight children compared with normal weight children (adjusted OR = 1.23; 95% CI: 1.10–1.38). Scholtens et al. [24] evaluated the changes in weight status in children aged 1–8 years in relation to asthma symptoms in childhood, and reported that children who had a persistently high BMI during childhood had a significantly increased risk of asthma symptoms at 8 years of age. Furthermore, results from eight European Birth Cohorts showed that children with a rapid BMI gain in the first 2 years of life had a higher risk for developing asthma up to age 6 than children with less pronounced weight gain in early childhood. This suggests that even in childhood, obesity is already associated with asthma [25]. However, other studies, such as studies from Bedolla-Barajas et al. [8], Dorevitch et al. [9], and Henkin et al. [10], found that obesity is not associated with asthma

in children. It is possible that the different results are related to the differences in the prevalence of asthma in the studied populations or to the sample size that we studied.

Though the associations between BMI and childhood asthma have been observed in a number of studies, including our own, the analyses presented in this article did not observe a dose–response effect of BMI on asthma prevalence. Compared with our results, Beuther and Sutherland reported a dose–response effect of elevated BMI on asthma incidence in adults [26]. In order to explore the potential reasons for this phenomenon, we have reanalyzed the differences between overweightness and obese groups, and the results showed that compared with overweight children, obese children tended to be younger and less likely to be breast-fed. In addition, obese children have significantly higher percentages of parents as responders than that among the

overweight group. All of the differences between overweight and obese groups may introduce bias in evaluating the associations between BMI and prevalence of asthma. For example, compared with other household members, parents were more likely to report a symptom or illness than other questionnaire respondents [22]. Furthermore, contrary to other studies, we do not know why the obesity rate (14.1%) is higher than the overweightness rate (12.3%) in the current study. However, similar results have been reported from recently published studies conducted in China. The Nutrition Education in Urban Area of Northeast Chinese Children Study (NENCC) has assessed the prevalence of overweightness and obesity among preschool-aged children living in northeastern China. They show a higher proportion of obese children than overweight children [27]. Another recent study also reported rates of overweightness and obesity in urban children of 11% and 11.8%, respectively, in 2010 among 18 366 Mongolian children in China [28].

Although the mechanisms underlying the synergistic effects of overweightness and obesity on respiratory health is not clear, a possible mechanism to explain our findings may involve inflammatory condition, as pro-inflammatory cytokines are produced by adipocytes. Beuther et al. [29] summarized the findings from a variety of reported observations on the relationship between obesity and systemic inflammation, and suggested that visceral adiposity is correlated with circulating levels of pro-inflammatory cytokines, which in turn lead the immune system toward a TH₂ response. Such polarization might worsen a pre-existing sensitization, thus pushing the individual to develop asthma and rhinitis [30]. Another explanation for the effect of obesity on asthma is adipose tissue in the chest and abdomen leading to a reduction of lung tidal volume and functional residual capacity [31]. Previous studies have shown that obese individuals tend to have lower lung volumes than normal-weight individuals [32]. Additionally, owing to changes in the structure of the lungs, obese individuals have a reduced functional residual capacity compared with normal-weight individuals [33]. A third possibility is that overweightness and obesity correlate with the amount of visceral adipose tissue, and visceral adipose tissue is considered a risk factor for various metabolic disorders and cardiovascular conditions at all stages of life. Metabolic syndrome appears to increase the risk of asthma occurrence [34]. However, the mechanisms by which these illnesses promote wheezing/asthma have not yet been clearly elucidated. Finally, some authors have indicated that obesity and allergy may share common risk factors such as sedentary lifestyle and dietary factors that have not yet been elucidated [35].

Gender is understood to be a social construct, and gender role is a set of social and behavioral norms in male and female [36]. In our study, multivariable logistic regression analysis revealed that the association between obesity and asthma symptoms appeared to differ between males and females. In agreement with our findings in children, several studies indicate a stronger effect of obesity in females than males. Chen et al. [37] reported that, for all age groups above age 12, overweight and obese females were as much as 1.9 times more likely to have asthma than females who were not overweight. Shaheen et al. [38] using the

1970 British cohort study found that overweight and obese females aged 26 years were 1.5 and 1.8 times more likely to have asthma than females who were not overweight. Results from a recent longitudinal study reported that females who became overweight between 6 and 11 years of age were between 5.5 and 7 times more likely to develop new asthma symptoms at the ages of 11 and 13 compared with females who did not become overweight or obese at ages 6 [12]. Neither study above showed a significant association between BMI status and asthma prevalence in males. However, contrary to our results, a meta-analysis of prospective epidemiologic studies with regard to adult participants discovered that females do not disproportionately affect the obesity–asthma relationship compared to males ($p=0.232$ for the gender comparison) [26]. Furthermore, one of our recent studies, a systematic review and meta-analysis of prospective cohort pediatric studies with regard to the gender differences of childhood overweightness and obesity in predicting the risk of incident asthma found that obese males had a significantly larger effect than obese females (relative risk, males: 2.47; 95% CI: 1.57–3.87; females: 1.25; 95% CI: 0.51–3.03), with a significant dose-dependent effect [11].

There are several likely explanations for the pattern of sex-specific associations that we have observed in this study. First, it is possible that obesity may influence female sex hormones, and this in turn alters asthma risk. It has been shown that female hormones increase the production of interleukin-4 (IL-4) and IL-13 by peripheral blood mononuclear cells [39]. These interleukins are known to be the two main T-helper signals needed for the production of IgE [40]. Castro-Rodriguez et al. [12] reported that females who would become overweight or obese were more likely to be atopic than those whose BMI did not change or decreased. One study from Taiwan indicated that increased BMI was significantly associated with positive skin test reactivity to local allergens among females but not among males [41]. Increased susceptibility to allergens in overweight females may explain increased risk both for persistent asthma and for the abnormalities in the regulation of airway tone associated with it. The second reason lies in the fact that males and females respond differently to exposure to environmental factors due to the differences in their airways from fetal life to adult life, with females having smaller lungs and therefore having slightly greater airway reactivity than males [42,43]. Third, a recent study showed that obesity could enhance the effects of environmental factors such as air particle pollutants, on respiratory health [44]. It has been reported that the deposition of particles in the lung varies by gender, with greater lung deposition fractions of particles in all regions of the lung in females [45,46]. Sunyer et al. suggested that females and males have different deposition patterns, which might be partly accountable for the difference in their response to particles [47]. Based on the above results, we conjecture that obese females may be more susceptible to the environmental factors than obese males. However, much still remains unknown about why obese females had a significantly larger effect than obese males. Therefore, further investigation is required to determine the cause of such differences and new methods are needed for this purpose.

In the present study, the prevalence of diagnosed asthma in children was 6.5%, which is consistent with previous studies among Chinese children. For comparison, in 2007, the third phase of the International Study of Asthma and Allergies in Childhood (ISAAC) reported that the prevalence of asthma was 5.4% among Chinese children aged 13–14 years from the mainland, and 7.8% among Chinese children aged 6–7 years from Hongkong [48]. The prevalence of diagnosed asthma in children aged 0–14 years reported in three Chinese cities studied in 2008–2009 was 3.2–7.5% [49]. A recent systematic review summarized a total of 74 articles and reported that the lifetime prevalence of asthma among Chinese children aged 0–14 years varied between 1.1% in Lhasa (Tibet) and 11.0% in Hong Kong [50]. Although recent studies have indicated that asthma prevalence has plateaued or may be declining in English-speaking countries and Western Europe, the increase in the prevalence of asthma symptoms in developing countries is continuing to rise, which leads to a major public health problem among young people in those countries, including China [48]. Considering the current epidemic of childhood obesity on a global scale, our findings indicate an urgent need to develop a better technology and public health policy for the protection of people suffering from both asthma and obesity.

Our study has several limitations. First, we have studied respiratory prevalence, rather than respiratory symptom incidence, which is known to be prone to the effects of disease duration rather than disease incidence. Second, we cannot establish a temporal relationship between exposure and the outcome from a cross-sectional study. On the other hand, we must also acknowledge that large epidemiological studies of asthma often rely on the self-reported symptomatic history and physicians' diagnosis of asthma as they are generally easier, faster and less expensive to access. Finally, the standardized skin testing to aeroallergens was not required for the present study, which may effect interpretation of findings related to allergic versus non-allergic status.

Conclusions

In conclusion, this study showed that there is an association between obesity and asthma, and this association is stronger in obese females than in obese males who have been diagnosed with asthma. These results have important implications for public health. The marked increase in obesity observed during the last few decades may in part be causing the increase in asthma prevalence observed concomitantly. Specific interventions aimed at preventing excessive weight gain during the school years, both in males and in females, may thus be a valuable tool in preventing asthma-related morbidity.

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Declaration of interest

The authors report no declarations of interest.

Author Contributions

Conceived and designed the experiments: G.-H.D. Performed the experiments: D.W. Analyzed the data: G.-H.D., Y.-L.L. Contributed reagents/materials/analysis tools: J.W., G.-H.D., M.-M.L., D.W., Y.-Q.L., Y.Z., M.-M.H., Y.L., J.S., Y.-Z.L., C.-C.W., L.-R.C. Wrote the paper: D.W. Revised the paper: G.-H.D., J.W., M.Y., Y.L.L. Contributed the investigation: D.W., M.-M.L., Y.-Q.L., Y.Z., M.-M.H., Y.L., J.S., Y.-Z.L., C.-C.W., L.-R.C.

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