

Association between Obesity and Atopy in Chinese Schoolchildren

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Key Words

Asthma • Atopy, child • Immunoglobulin E • Obesity, child

Abstract

Background: Despite parallel increases in asthma and obesity prevalence, there is little data on obesity as a risk factor for atopy. The latter is an important phenotype in asthmatic patients. This study investigates the association between asthma traits, atopy and obesity-related markers in Chinese adolescents. **Methods:** 486 schoolchildren were recruited among participants of our population-based study on the epidemiology of obesity, and their allergy status was ascertained using a standardized questionnaire. Subjects' anthropometry was recorded on-site, and fasting blood was collected for allergen-specific immunoglobulin E (IgE), lipids and systemic inflammatory biomarkers. **Results:** 98 (20.2%) subjects were classified as overweight or obese. Obesity status was not associated with asthma, allergic rhinitis or eczema ($p > 0.25$). Atopy was not associated with age-adjusted body mass index (BMI) or waist circumference. Atopy and presence of allergen-specific IgE did not differ between overweight or obese children and those with normal BMI ($p > 0.25$), although subgroup analysis suggested that cockroach sensitization was more common among males who were obese or overweight ($p = 0.045$). White cell count (WCC)

was higher among atopic than nonatopic children (mean values $6.5 \times 10^9/l$ vs. $6.2 \times 10^9/l$, $p = 0.006$). Logistic regression revealed WCC to be the only risk factor for atopy (OR 18.97, $p = 0.004$). **Conclusions:** Obesity is not associated with asthma or atopy in Chinese children. High WCC is an important risk factor for atopy in both males and females. Gender does not exert any consistent effect on the association between obesity and allergen sensitization in children.

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Introduction

A number of epidemiological studies have reported rising prevalence rates of both asthma and obesity in children from developed countries. Obesity was associated with asthma diagnosis, respiratory symptoms and airway hyperresponsiveness [1–3]. These findings led to the speculation that obesity might be a causal factor in asthma susceptibility. However, a population-wide survey in the USA found an association between body mass index (BMI) and asthma, but not atopy or eosinophil count [4]. To complicate this issue, a number of studies suggested that such an association might be gender-specific [2, 5–7]. Recent meta-analyses of prospective studies challenged the relationship between obesity and overweight and in-

cident asthma in adults [8] but supported such an association in children [9]. Both obesity and asthma are complex traits determined by a wide variety of genetic and environmental factors. In a recent review, Weiss [10] proposed a number of mechanistic links (e.g. immunology, lung mechanics, endocrinology, diet and genetics) between asthma and obesity. Obesity is a proinflammatory state in which increased levels of leptin and proinflammatory cytokines (e.g. interleukin-1 and -6 and tumor necrosis factor- α) might up-regulate inflammation in the airway [11]. There is a paucity of data addressing the question whether obese subjects with asthma are more susceptible to have atopy or more intense airway inflammation. To this end, our group could not establish any association between obesity indexes (including BMI) and exhaled nitric oxide concentration, the latter being an important biomarker of asthmatic airway inflammation, in Chinese children [12]. Another study extended our finding to Caucasian children [13].

Atopy is characterized by the production of specific immunoglobulin E (IgE) to allergens. Asthma and atopy are different clinical phenotypes, but many studies have shown that atopy is an important risk factor for the susceptibility and severity of asthma in children [14–16]. Atopy is also a more objectively defined intermediate asthma phenotype. Investigation of any association between obesity indices and atopy helps to elucidate the mechanistic link between obesity and childhood asthma. While there have been a few reports in adults [17–19], there has not been any population-based study that investigated the relation between obesity, metabolic biomarkers and serum IgE measurements in children. We hypothesize that obesity and metabolic derangements are risk factors for aeroallergen sensitization in children, and that BMI, serum lipids and systemic inflammatory biomarkers are associated with the presence of specific IgE in serum. We tested this hypothesis in a community-based epidemiological study of obesity in Hong Kong Chinese adolescents.

Patients and Methods

Study Population

The Hong Kong Secondary School Children Survey was a cross-sectional, population-based survey conducted between February and December 2003 to investigate the epidemiology and risk factors for obesity and metabolic syndrome in Hong Kong Chinese adolescents [20]. A total of 2,115 subjects were recruited from 14 randomly chosen secondary schools. Subjects in the present study represented a random selection of one-fifth of the original cohort. Information on the presence of asthma, allergic rhinitis and eczema in study participants was collected using the

respective International Study of Asthma and Allergies in Childhood (ISAAC) core questions [21]. Subjects and their parents gave informed written consent, and the clinical research ethics committee of our university approved this study.

Anthropometric Measurements

Body weight and height were measured, with the subject lightly clothed and bare-footed, using an electronic weighing scale (Tanita Corp., Tokyo, Japan) and Harpenden stadiometer. Overweight was defined as a BMI greater than the local age- and gender-specific 85th percentile (or 25 kg/m², whichever was smaller) and obesity was defined as a BMI greater than the 95th percentile (or 30 kg/m², whichever was smaller). These percentile standards were established by a local population survey [22]. Waist circumference was taken midway between the lowest rib and the superior border of the iliac crest in the mid-axillary line, and the measurement was taken to the nearest 0.1 cm [20, 23].

Serum Lipid Profile and Inflammatory Markers

Six milliliters of venous blood samples were collected from each participant after overnight fasting of at least 8 h. Total white cell count (WCC) was enumerated by Coulter STKS counter (Beckman-Coulter, Miami, Fla., USA). Serum and plasma were obtained following centrifugation at 2,772 g and 4°C for 10 min, and stored at –70°C until batch analysis. Glucose, total cholesterol, triglyceride and high- and low-density lipoprotein cholesterol concentrations in plasma/serum were measured by spectrophotometric methods using a Roche DP Modular Analyzer (Roche, Basle, Switzerland). Serum concentration of high-sensitivity C-reactive protein (hsCRP) was measured by chemiluminescence immunoassays using an Immulite® 2000 Analyzer (Diagnostic Products Corp., Los Angeles, Calif., USA). The sensitivity of this hsCRP assay was 0.1 mg/l.

Serum IgE Measurements

The presence of specific IgEs to the locally prevalent aeroallergens *Dermatophagoides pteronyssinus*, cat and cockroaches [24] in serum were measured by fluorescent enzyme immunoassay (Phadia AB, Uppsala, Sweden). Atopy was defined as having at least 1 positive allergen-specific IgE.

Statistical Analysis

Numerical data is expressed in median and interquartile range (IQR) unless stated otherwise, and categorical variables are presented as count and percentage. Our previous study suggested that BMI and waist circumference varied significantly with subjects' age, and so these variables were analyzed following age adjustment [23]. Because BMI, waist circumference and inflammatory biomarkers showed positively skewed distributions, these variables were log-transformed to correct for skewness before subsequent analysis. Univariate analyses between subgroups by gender or atopy status were performed using Student's t test, Mann-Whitney test, χ^2 or Fisher's exact test as appropriate. Logistic regression was used to analyze possible risk factors for atopy. All analyses were performed 2-tailed with SPSS 14.0 (SPSS Inc., Chicago, Ill., USA). $p < 0.05$ was considered statistically significant.

Table 1. Clinical and laboratory characteristics of subjects according to gender

Characteristic	Male (n = 241)	Female (n = 245)	p
Age, years	15.0 (14.0–16.0)	15.0 (14.0–16.0)	0.159
BMI, kg/m ²	19.3 (17.3–22.3)	19.2 (17.8–21.1)	0.986
Waist circumference, cm	70.0 (65.0–76.3)	64.0 (61.0–69.0)	<0.001
Serum lipid profile			
Total cholesterol, mmol/l	4.1 (3.6–4.6)	4.2 (3.9–4.7)	0.013
LDL-cholesterol, mmol/l	2.2 (1.8–2.6)	2.3 (2.0–2.6)	0.100
HDL-cholesterol, mmol/l	1.45 (1.25–1.67)	1.58 (1.41–1.76)	<0.001
Triglyceride, mmol/l	0.78 (0.58–1.03)	0.72 (0.56–0.93)	0.101
Metabolic or inflammatory biomarkers			
WCC, × 10 ⁹ /l	6.1 (5.4–7.0)	6.6 (5.6–7.8)	0.003
hsCRP, mg/l	0.31 (0.15–0.64)	0.19 (0–0.51)	0.001
Fasting plasma glucose, mmol/l	4.8 (4.6–5.0)	4.7 (4.5–4.9)	0.003
Allergic diseases			
Asthma	14 (5.8)	12 (4.9)	0.655
Allergic rhinitis ^a	100 (41.5)	88 (36.2)	0.233
Eczema ^a	35 (14.6)	41 (16.9)	0.490
Atopy biomarkers			
Serum total IgE level, kIU/l	145 (47–383)	90 (28–308)	0.021
Atopy ^b , n (%)	127 (53.5)	112 (41.7)	0.124
DP-specific IgE, n (%)	119 (50.7)	107 (39.9)	0.207
Cat-specific IgE, n (%)	2 (0.7)	3 (1.1)	0.666
Cockroach-specific IgE, n (%)	9 (3.9)	17 (6.4)	0.117

Results are medians with IQRs in parentheses or numbers with percentages in parentheses. DP = *Der-matophagoides pteronyssinus*; HDL = high-density lipoprotein; hsCRP = high-sensitivity C-reactive protein; LDL = low-density lipoprotein.

^a History of allergic rhinitis and eczema were not reported by 2 and 3 subjects, respectively.

^b Defined as ≥1 positive allergen-specific IgE (i.e. DP, cat or cockroach).

Results

Subjects

We recruited 486 schoolchildren. Their median age was 15.0 years (IQR 14.0–16.0), their median BMI was 19.3 kg/m² (IQR 17.5–21.7) and their median waist circumference was 67.0 cm (IQR 63.0–73.0). Among the study population, 388 (79.8%) children had a normal BMI, 62 (12.8%) subjects were overweight and 36 (7.4%) subjects were obese. The demographic and anthropometric features of our subjects were representative of the total cohort sampled in the Hong Kong Secondary School Children Survey (data available upon request) [20]. Age-adjusted BMI showed significant correlations with WCC ($r = 0.197$, $p < 0.001$) and hsCRP levels ($\rho = 0.367$, $p < 0.001$). Subgroup analysis revealed similar associations in relation to gender, with the respective correlation coefficients being 0.252 ($p < 0.001$) and 0.374 ($p < 0.001$) for males, and 0.161 ($p = 0.012$) and 0.371 ($p < 0.001$) for females.

239 (49.2%) subjects were atopic, and 226 (46.5%), 5 (1.0%) and 26 (5.3%) of them had specific IgEs to *D. pteronyssinus*, cat and cockroach, respectively. Table 1 summarizes the clinical and laboratory characteristics among males and females. Serum total cholesterol, HDL-cholesterol and systemic inflammatory biomarkers differed significantly by gender. On the other hand, atopy and the presence of allergen-specific IgEs did not differ between males and females.

Relation between Obesity, Allergies and Aeroallergen Sensitization

Table 2 shows the distribution of asthma, allergic rhinitis and eczema in patients with normal BMI and who were overweight or obese. None of these clinical allergies showed significant association with obesity status in our subjects. Table 3 summarizes the pattern of IgE sensitization to 3 aeroallergens in relation to obesity status. Atopy or the presence of specific IgE to individual aeroallergens in overweight or obese children did not differ from those

Table 2. Relation between clinical allergies, gender and obesity status

	Normal	Overweight/ obese ^a	p ^b
<i>All subjects</i>	(n = 388)	(n = 98)	
Asthma	18 (4.6)	8 (8.2)	0.257
Allergic rhinitis ^c	148 (38.1)	40 (40.8)	0.739
Eczema ^c	59 (15.2)	17 (17.3)	0.737
<i>Males</i>	(n = 181)	(n = 60)	
Asthma	9 (5.0)	5 (8.3)	0.346
Allergic rhinitis ^c	75 (41.4)	25 (41.7)	0.905
Eczema ^c	26 (14.4)	9 (15.0)	0.916
<i>Females</i>	(n = 207)	(n = 38)	
Asthma	9 (4.3)	3 (7.9)	0.405
Allergic rhinitis ^c	73 (35.3)	15 (39.5)	0.786
Eczema ^c	33 (15.9)	8 (21.1)	0.608

Results are expressed as numbers with percentages in parentheses.

^a Overweight and obese subjects were combined for analyses because of the small numbers of cases in each subgroup.

^b Yates-corrected p values by χ^2 or Fisher's exact test.

^c History of allergic rhinitis and eczema were not reported by 2 and 3 subjects, respectively.

Table 3. Aeroallergen sensitization in normal versus overweight and obese schoolchildren

	Normal	Overweight/ obese ^a	p ^b
<i>For all subjects</i>	(n = 388)	(n = 98)	
Atopy	190 (49.0)	49 (50.0)	0.945
Positive DP-specific IgE	182 (46.9)	44 (44.9)	0.808
Positive cat-specific IgE	3 (0.8)	2 (2.0)	0.266
Positive cockroach-specific IgE	18 (4.6)	8 (8.2)	0.257
<i>For male subjects</i>	(n = 181)	(n = 60)	
Atopy	92 (50.8)	35 (58.3)	0.390
Positive DP-specific IgE	87 (48.1)	32 (53.3)	0.577
Positive cat-specific IgE	0	2 (3.3)	0.061
Positive cockroach-specific IgE	4 (2.2)	5 (8.3)	0.045
<i>For female subjects</i>	(n = 207)	(n = 38)	
Atopy	98 (47.3)	14 (36.8)	0.309
Positive DP-specific IgE	95 (45.9)	12 (31.6)	0.145
Positive cat-specific IgE	3 (1.4)	0	0.136
Positive cockroach-specific IgE	14 (6.8)	3 (7.9)	0.733

Results are expressed as numbers with percentages in parentheses. DP = *Dermatophagoides pteronyssinus*.

^a Overweight and obese subjects were combined for analyses because of the small numbers of cases in each subgroup.

^b Yates-corrected p values by χ^2 or Fisher's exact test.

with normal BMI ($p > 0.25$). Among male subjects, however, more obese/overweight children had cockroach-specific IgE than those with normal BMI (8.3 vs. 2.2%, $p = 0.045$).

When atopy phenotypes were compared between subjects with high age-adjusted BMI and hsCRP levels and those with low values for both variables, we could not detect any interaction between these obesity-related biomarkers in affecting serum IgE measurements (data not shown). Table 4 summarizes clinical and laboratory parameters in children with and without atopy. Age-adjusted BMI and waist circumference, serum lipid profiles and fasting glucose levels did not differ between these 2 groups. On the other hand, atopic children had higher WCC ($p = 0.006$). Subgroup analyses (table 5) revealed that this WCC difference was significant for males ($p = 0.018$) and borderline for females ($p = 0.053$). By logistic regression (table 6), WCC was the only independent risk factor for atopy among all our recruited schoolchildren (OR 18.97, 95% CI 2.56–140.46, $p = 0.004$) and in both male and female subgroups ($p = 0.030$ and 0.014, respectively).

Discussion

This study is among the first to investigate the association between allergic diseases, obesity and systemic inflammatory biomarkers, and the presence of serum aeroallergen-specific IgE in a community childhood population. About four-fifths of our schoolchildren had normal BMI, and 12.8% were overweight and 7.4% were classified as being obese. Obesity status was not associated with asthma or allergy diagnoses, or in general with atopy or IgE sensitization to individual aeroallergens. With the exception of a marginally significant rate of cockroach sensitization among obese/overweight males, we could not observe any gender-specific effect of obesity or metabolic indices on atopy. In our subjects, WCC was the only risk factor for atopy in both males and females.

Many epidemiological studies observed an association between asthma diagnosis and symptoms and obesity as evaluated by BMI [1, 2, 4]. In a prospective study involving 1,322 asthmatic children, the obese group used more asthma-related medicine, was more likely to wheeze and had more unscheduled emergency department visits [3]. In an Australian population-based study, Appleton et al.

Table 4. Association between atopy status^a and clinical and laboratory parameters

	Atopy (n = 239)	No atopy (n = 247)	p ^b
Age, years	15.0 (14.0–16.0)	15.0 (14.0–16.0)	0.773
Male, n (%)	127 (53.1)	114 (46.2)	0.124
Age-adjusted BMI ^c	–0.04 (0.94)	0.04 (1.03)	0.372
Age-adjusted waist circumference ^c	–0.05 (0.95)	0.05 (1.02)	0.271
Serum lipid profile			
Total cholesterol, mmol/l	4.2 (3.8–4.6)	4.2 (3.7–4.6)	0.736
LDL-cholesterol, mmol/l	2.3 (2.0–2.6)	2.2 (1.9–2.6)	0.639
HDL-cholesterol, mmol/l	1.53 (1.32–1.72)	1.50 (1.33–1.72)	0.485
Triglyceride, mmol/l	0.76 (0.57–0.98)	0.74 (0.58–1.00)	0.824
Metabolic or inflammatory biomarkers			
WCC, × 10 ⁹ /l	6.5 (5.7–7.6)	6.2 (5.3–7.3)	0.006
hsCRP, mg/l	0.25 (0.12–0.51)	0.25 (0.12–0.64)	0.838
Fasting plasma glucose, mmol/l	4.8 (4.6–5.0)	4.7 (4.6–4.9)	0.235
Asthma, n (%)	22 (9.2)	4 (1.6)	<0.001
Allergic rhinitis, n (%)	136 (56.9)	52 (21.1)	<0.001
Eczema, n (%)	47 (19.7)	29 (11.7)	0.014
Atopy biomarkers			
Serum total IgE level, kIU/l	308 (162–600)	43 (16–90)	<0.001
DP-specific IgE, n (%)	226 (94.6)	0	<0.001
Cat-specific IgE, n (%)	5 (2.1)	0	0.028
Cockroach-specific IgE, n (%)	26 (10.9)	0	<0.001

Results are medians with IQRs in parentheses or numbers with percentages in parentheses. DP = *Dermaphagoides pteronyssinus*; HDL = high-density lipoprotein; LDL = low-density lipoprotein.

^a Defined as ≥1 positive allergen-specific IgE (i.e. DP, cat or cockroach).

^b Analyzed by Student's t test for log-transformed numerical variables (but by Mann-Whitney U test for hs-CRP), and χ^2 or Fisher's exact test for categorical variables.

^c Expressed as mean with standard deviation in parentheses.

Table 5. Univariate analyses of demographic, obesity and metabolic factors for atopy in male and female subjects

Characteristic	p values	
	male	female
Age	0.802	0.991
Age-adjusted BMI	0.634	0.068
Age-adjusted waist circumference	0.960	0.092
Total cholesterol	0.113	0.409
LDL-cholesterol	0.090	0.309
HDL-cholesterol	0.770	0.241
Triglyceride	0.925	0.953
WCC	0.018	0.053
hsCRP	0.883	0.141
Fasting glucose concentration	0.687	0.313

p values were obtained by univariate comparisons for subjects with and without atopy. HDL = High-density lipoprotein; LDL = low-density lipoprotein.

[25] investigated the relationship between asthma and alternative central obesity phenotypes (waist circumference and waist-to-hip ratio). They showed an association between asthma and waist circumference, waist-to-hip ratio and BMI ≥ 35 kg/m² only among nonatopic subjects [25]. Such association between obesity and nonallergic subtype of asthma was replicated in another community cohort of Canadian adults [26]. A recent meta-analysis revealed that children with high body weight, either at birth or later in childhood, were at increased risk for future asthma [9]. However, the present study could not detect any difference in asthma, allergic rhinitis or eczema between overweight/obese and non-obese children (table 2). Besides, the absence of any consistent relationship between obesity status and atopy suggests that the observed association between asthma and obesity may not be mediated through atopy. To supplement this observation, we and another group could not demonstrate any significant association between BMI and inflammatory

Table 6. Multivariable logistic regression analysis^a for factors associated with atopy in our subjects

Factor	All subjects			Males			Females		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Male	1.44	1.00–2.09	0.052	–	–	NA	–	–	NA
Age-adjusted BMI ^b	–	–	NA	–	–	NA	0.79	0.58–1.09	0.149
WCC	18.97	2.56–140.46	0.004	35.17	1.42–871.30	0.030	29.56	2.00–437.49	0.014
hsCRP	–	–	NA	–	–	NA	0.87	0.68–1.11	0.252
Fasting glucose	14.26	0.03–6,906.29	0.400	–	–	NA	–	–	NA
LDL-cholesterol ^b	–	–	NA	2.94	0.02–569.91	0.688	–	–	NA
HDL-cholesterol	–	–	NA	–	–	NA	1.72	0.67–4.38	0.258

HDL = high-density lipoprotein; LDL = low-density lipoprotein; NA = not analyzed.

^a Only included demographic factors and obesity and metabolic markers from tables 4 and 5 that showed significant results ($p < 0.25$) for atopy on univariate analysis.

^b Because age-adjusted BMI and age-adjusted waist circumference ($r = 0.880$, $p < 0.0001$) as well as total cholesterol and LDL-cholesterol ($r = 0.895$, $p < 0.0001$) were highly correlated, only age-adjusted BMI and LDL-cholesterol with better clinical correlates and smaller p values were entered into regression analysis.

biomarkers (i.e. nitric oxide or leukotriene B₄) in the exhaled breath [12, 13]. Other studies found that BMI was not a risk factor for childhood airway hyperresponsiveness [2, 7].

A number of factors are implicated in the pathogenetic link between asthma and obesity. These include altered lung mechanics (i.e. reduced tidal volume and functional residual capacity), enhanced systemic proinflammatory state, shared inherited predispositions (i.e. genes encoding inflammatory cytokines and β_2 -adrenoceptor), effects from sex hormones, dietary intake and in utero fetal 'programming' [10]. Although the causal pathway(s) leading to increased asthma in obese subjects is currently unclear, our results support the hypothesis that systemic inflammation (high WCC commonly found in obesity) may be an important factor mediating the susceptibility for atopy in both males and females.

Irrespective of the environmental factors, age and sex modified the pattern of concordance of high IgE levels, skin prick test positivity and eosinophilia among Caucasian subjects [15]. This gender effect on asthma-obesity relationship was also found in Caucasian children cohorts, which reported high BMI to be a risk factor for atopy among their obese girls [2, 7]. A recent study of 517 Hispanic preschoolers in New York found that asthma diagnosis was associated with high BMI among girls but not boys [27]. In the present study, however, allergen sensitization was not associated with age-adjusted BMI or waist circumference in both male and female subgroups.

Huang et al. [28] and colleagues reported the only study on obesity-atopy relationship in Chinese adolescents in Taiwan. They investigated the association between BMI and atopy as defined by skin prick tests in 1,459 students from 7 junior high schools from Taipei city ($n = 1$), towns ($n = 3$) and rural areas ($n = 3$). They found a higher prevalence of atopy among girls in the highest BMI quintile. In the contrary, we only observed a weak association between obesity and cockroach sensitization in our boys. The background of participants in these studies was different. Only 246 (16.9%) students from the Taiwanese study lived in Taipei city, whereas nearly two-fifths were recruited from rural areas, which represented a significant protective factor against asthma and atopy [29]. As both the average BMI and atopy rate of students from Taipei city were higher than those from towns or rural areas, that study was biased in detecting any association between obesity and atopy. On the other hand, our study involved a homogenous group of schoolchildren in Hong Kong (i.e. an urbanized city). Besides, the Taiwanese report did not measure objective obesity-related biomarkers (e.g. WCC, serum lipids and hsCRP).

This study has several limitations. The first is a lack of data on many environmental exposures (e.g. tobacco smoke, physical exercise, parasitic infestation) which may modulate serum total IgE [30–32]. Parasites are well recognized to be strong stimulants of IgE production, although epidemiologic data suggests that helminthic infections are uncommon in westernized cities (e.g. Hong Kong) [33]. This study did not collect subjects' stool sam-

ples for parasite examinations. The ISAAC questionnaire also does not contain any item on parasitic infestation. For these reasons, we were unable to test the association between serum total IgE and obesity-related factors. In addition, we did not measure other intermediate phenotypes of asthma such as exhaled nitric oxide and spirometric parameters [12, 24, 34].

Our univariate analysis found borderline significance for the association between atopy and age-adjusted BMI (table 5), and it is possible that such association may be significant if more female subjects are studied. Nonetheless, we also included this variable in our logistic regression and which turned out not to exert any significant effect on atopy when adjusted for other factors. The finding of significant correlations between age-adjusted BMI, WCC and hsCRP levels also causes multicollinearity problems when these variables were entered into multivariable logistic regression for atopy in females at the same time (table 6). This multicollinearity issue might result in biased estimates and inflated standard errors. However, we repeated logistic regression by entering each of these variables into the model separately. WCC was

again the only factor to be independently associated with atopy (odds ratio 17.95, $p = 0.032$). Lastly, the cross-sectional design of this study for studying the relationship between BMI and asthma or atopy may be influenced by confounders such as socioeconomic factors and environmental exposures. This important research question should ideally be answered by prospective studies of birth cohorts.

In conclusion, obesity is not associated with clinical asthma phenotypes or the presence of allergen-specific IgE in Chinese schoolchildren. Atopy was only associated with WCC but not gender or obesity indices. These findings did not support obesity or gender as important factors for atopy status in this population.

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References

- 1 Shaheen SO, Sterne JAC, Montgomery SM, Azima H: Birth weight, body mass index and asthma in young adults. *Thorax* 1999;54: 396–402.
- 2 Hancox RJ, Milne BJ, Poulton R, Taylor DR, Greene JM, McLachlan CR, Cowan JO, Flannery EM, Herbison GP, Sears MR: Sex differences in the relation between body mass index and asthma and atopy in a birth cohort. *Am J Respir Crit Care Med* 2005;171:440–445.
- 3 Belamarich PF, Luder E, Kattan M, Mitchell H, Islam S, Lynn H, Crain EF: Do obese inner-city children with asthma have more symptoms than nonobese children with asthma? *Pediatrics* 2000;106:1436–1441.
- 4 von Mutius E, Schwartz J, Neas LM, Dockery D, Weiss ST: Relation of body mass index to asthma and atopy in children: the National Health and Nutrition Examination Study III. *Thorax* 2001;56:835–838.
- 5 Chen Y, Rennie D, Cormier Y, Dosman J: Sex specificity of asthma associated with objectively measured body mass index and waist circumference: the Humboldt study. *Chest* 2005;128:3048–3054.
- 6 Mannino DM, Mott J, Ferdinands JM, Camargo Jr CA, Friedman M, Greves HM, Redd SC: Boys with high body masses have an increased risk of developing asthma: findings from the National Longitudinal Survey of Youth (NLSY). *Int J Obes* 2006;30:6–13.
- 7 Schachter LM, Peat JK, Salome CM: Asthma and atopy in overweight children. *Thorax* 2003;58:1031–1035.
- 8 Beuther DA, Sutherland ER: Overweight, obesity and incident asthma: a meta-analysis of prospective epidemiologic studies. *Am J Respir Crit Care Med* 2007;175:661–666.
- 9 Flaherman V, Rutherford GW: A meta-analysis of the effect of high weight on asthma. *Arch Dis Child* 2006;91:334–339.
- 10 Weiss ST: Obesity: insights into the origins of asthma. *Nat Immunol* 2005;6:537–539.
- 11 Visser M, Bouter LM, McQuillan GM, Wenner MH, Harris TB: Elevated C-reactive protein levels in overweight and obese adults. *JAMA* 1999;282:2131–2135.
- 12 Leung TF, Li CY, Lam CW, Au CS, Yung E, Chan IH, Wong GW, Fok TF: The relation between obesity and asthmatic airway inflammation. *Pediatr Allergy Immunol* 2004; 15:344–350.
- 13 Santamaria F, Montella S, Stefano SD, Sperli F, Barbarano F, Valerio G: Relationship between exhaled nitric oxide and body mass index in children and adolescents. *J Allergy Clin Immunol* 2005;116:1163–1164.
- 14 Platts-Mills TA, Rakes G, Heymann PW: The relevance of allergen exposure to the development of asthma in childhood. *J Allergy Clin Immunol* 2000;105:S503–S508.
- 15 Oryszczyn M-P, Bouzigon E, Maccario J, Siroux V, Nadif R, Wright A, Kauffmann F: Interrelationships of quantitative asthma related phenotypes in the Epidemiological Study on the Genetics and Environment of Asthma, Bronchial Hyperresponsiveness, and Atopy. *J Allergy Clin Immunol* 2007;119: 57–63.
- 16 Leung TF, Lam CW, Chan IH, Li AM, Ha G, Tang NL, Fok TF: Inhalant allergens as risk factors for the development and severity of mild-to-moderate asthma in Hong Kong Chinese children. *J Asthma* 2002;39:323–330.
- 17 Radon K, Schulze A: Adult obesity, farm childhood, and their effect on allergic sensitization. *J Allergy Clin Immunol* 2006;118: 1279–1283.
- 18 Vieira VJ, Ronan AM, Windt MR, Tagliaferro AR: Elevated atopy in healthy obese women. *Am J Clin Nutr* 2005;82:504–509.
- 19 Jarvis D, Chinn S, Potts J, Burney P, the European Community Respiratory Health Survey: Association of body mass index with respiratory symptoms and atopy: results from the European Community Respiratory Health Survey. *Clin Exp Allergy* 2002;32: 831–837.

- 20 Ozaki R, Qiao Q, Wong GW, Chan MH, So WY, Tong PC, Ho SC, Ko GT, Kong AP, Lam CW, Tuomilehto J, Chan JC: Overweight, family history of diabetes and attending schools of lower academic grading are independent predictors for metabolic syndrome in Hong Kong Chinese adolescents. *Arch Dis Child* 2007;92:224–228.
- 21 Wong GW, Leung TF, Ko FW, Lee KK, Lam P, Hui DS, Fok TF, Lai CK: Declining asthma prevalence in Hong Kong Chinese school-children. *Clin Exp Allergy* 2004;34:1550–1555.
- 22 Leung SS, Cole TJ, Tse LY, Lau JT: Body mass index reference curves for Chinese children. *Ann Hum Biol* 1998;25:169–174.
- 23 Ng VW, Kong AP, Choi KC, Ozaki R, Wong GW, So WY, Tong PC, Sung RY, Xu LY, Chan HM, Ho CS, Lam CW, Chan JC: Use of BMI and waist circumference to predict clustering of cardiovascular risk factors in Hong Kong Chinese adolescents. *Obesity* 2007;15: 1–10.
- 24 Leung TF, Tang NL, Li CY, Lam CW, Wong GW, Fok TF: Association between TARC C-431T and atopy and asthma in children. *J Allergy Clin Immunol* 2004;114:199–202.
- 25 Appleton SL, Adams RJ, Wilson DH, Taylor AW, Ruffin RE, on behalf of the North West Adelaide Health Study Team: Central obesity is associated with nonatopic but not atopic asthma in a representative population sample. *J Allergy Clin Immunol* 2006;118: 1284–1291.
- 26 Chen Y, Dales R, Jiang Y: The association between obesity and asthma is stronger in non-allergic than allergic adults. *Chest* 2006;130: 890–895.
- 27 Jacobson JS, Mellins RB, Garfinkel R, Rundle AG, Perzanowski MS, Chew GL, Andrews HF, Goldstein IF: Asthma, body mass, gender, and Hispanic national origin among 517 preschool children in New York City. *Allergy* 2008;63:87–94.
- 28 Huang SL, Shiao GM, Chou P: Association between body mass index and allergy in teenage girls in Taiwan. *Clin Exp Allergy* 1999;29:323–329.
- 29 Braun-Fahrlander C, Riedler J, Herz U, Eder W, Waser M, Grize L, Maisch S, Carr D, Gerlach F, Bufe A, Lauener RP, Schierl R, Renz H, Nowak D, von Mutius E, for the Allergy and Endotoxin Study Team: Environmental exposure to endotoxin and its relation to asthma in school-age children. *N Engl J Med* 2002;347:869–877.
- 30 Borish L, Chipps B, Deniz Y, Gujrathi S, Zheng B, Dolan CM, and TENOR Study Group: Total serum IgE levels in a large cohort of patients with severe or difficult-to-treat asthma. *Ann Allergy Asthma Immunol* 2005;95:247–253.
- 31 Celedón JC, Litonjua AA, Ryan L, Weiss ST, Gold DR: Day care attendance, respiratory tract illnesses, wheezing, asthma, and total serum IgE level in early childhood. *Arch Pediatr Adolesc Med* 2002;156:241–245.
- 32 McKune AJ, Smith LL, Semple SJ, Mokethwa B, Wade AA: Immunoglobulin responses to a repeated bout of downhill running. *Br J Sports Med* 2006;40:844–849.
- 33 Brooker S, Clements AC, Bundy DA: Global epidemiology, ecology and control of soil-transmitted helminth infections. *Adv Parasitol* 2006;62:221–261.
- 34 Leung TF, Wong GW, Ko FW, Lam CW, Fok TF: Clinical and atopic parameters and airway inflammatory markers in childhood asthma: a factor analysis. *Thorax* 2005;60: 822–826.