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Obesity, waist size and prevalence of current asthma in the California Teachers Study cohort

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ABSTRACT

Background: Obesity is a risk factor for asthma, particularly in women, but few cohort studies have evaluated abdominal obesity which reflects metabolic differences in visceral fat known to influence systemic inflammation. A study was undertaken to examine the relationship between the prevalence of asthma and measures of abdominal obesity and adult weight gain in addition to body mass index (BMI) in a large cohort of female teachers.

Methods: Prevalence odds ratios (ORs) for current asthma were calculated using multivariable linear modelling, adjusting for age, smoking and race/ethnicity.

Results: Of the 88 304 women in the analyses, 13% (n = 11 500) were obese (BMI ⩾30 kg/m^2) at baseline; 1334 were extremely obese (BMI ⩾40 kg/m^2). Compared with those of normal weight, the adjusted OR for adult-onset asthma increased from 1.40 (95% confidence interval (CI) 1.31 to 1.49) for overweight women to 3.30 (95% CI 2.85 to 3.82) for extremely obese women. Large waist circumference (>88 cm) was associated with increased asthma prevalence, even among women with a normal BMI (OR 1.37, 95% CI 1.18 to 1.59). Among obese women the OR for asthma was greater in those who were also abdominally obese than in women whose waist was ⩽88 cm (2.36 vs 1.57). Obese and overweight women were at greater risk of severe asthma episodes, measured by urgent medical visits and hospital admissions.

Conclusions: This study confirms the association between excess weight and asthma severity and prevalence, and showed that a large waist was associated with increased asthma prevalence even among women considered to have normal body weight.

Obesity has recently been identified as a risk factor for adult asthma, particularly in women.[1–4] Excess abdominal fat may be an important risk factor for asthma, but measures of central obesity have been examined in only a few studies.[4–8] Waist circumference and the waist-to-height ratio closely reflect the amount of visceral fat deposits, which are metabolically different from other body fat.[9] In addition, obesity may increase the severity of asthma.[10 11] In this analysis we examined the relationships between several aspects of excess weight and fat distribution—including overall adiposity, abdominal adiposity and adult weight gain—in relation to the prevalence and severity of asthma in a large cohort of women.

METHODS

Study population

The California Teachers Study (CTS) is an ongoing well-described cohort of 133 479 female teachers and school administrators who were employed in the California public school system or retired and receiving retirement benefits at the inception of the cohort in 1995 (40% of the women contacted joined the cohort).[12] All cohort members completed an extensive baseline questionnaire in 1995–6. Follow-up questionnaires were administered in 1997, 2000 and 2005. Data of primary relevance to this analysis were height and weight at baseline and at age 18 (all obtained in 1995 in the first questionnaire); waist circumference (collected in 1997); and several asthma-related measures from the 2000 questionnaire, including self-report of physician-diagnosed current asthma, associated symptoms, healthcare utilisation for asthma symptoms and age at first asthma diagnosis. Waist circumferences were self-measured based on standardised validated instructions[13] using a tape measure provided by the researchers. Data on asthma risk factors—including age, race, ethnicity and smoking exposures—were collected at baseline.

The present analysis included 88 304 women. From the original cohort of 133 479 we excluded women (in a hierarchical manner) as follows: 18 who requested that their survey data only be used for breast cancer research (the original purpose of the study), 3886 women who died before mailing of the 2000 follow-up questionnaire, 40 530 who did not complete the 2000 questionnaire and 741 who had missing information on asthma.

Asthma outcomes

A woman was considered to have current asthma if she answered yes to the question: "Has a doctor ever said that you have asthma?" and reported asthma symptoms that required medication, an urgent visit to a physician's office or emergency department, or a hospital admission within the 12-month period prior to completing the questionnaire in 2000. The prevalence of current asthma was examined in three groups: (1) all women; (2) those with adult-onset asthma; and (3) those with adult-onset asthma who were not overweight at age 18. Age of asthma onset was reported in four categories: 0–4 years, 5–18 years, 19–34 years and ⩾35 years. We defined adult-onset asthma as that for which a first diagnosis occurred at age 19 or later. Severity of disease was measured by comparing women with current asthma who reported an urgent physician or emergency department visit or hospital admission during the 12 months preceding administration of the 2000 questionnaire with those who only used medication during that period.

Measures of body mass and weight gain

Weight and height were reported in pounds, and feet and inches, respectively, and converted to kilograms and metres. Body mass index (BMI) was calculated by dividing weight by height squared. We used BMI categories adopted by the World Health Organization and the National Institutes of Health: <18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (overweight), 30.0–34.9 (obesity, class I), 35.0–39.9 (obesity, class II) and ≥40 kg/m^2 (extreme obesity, class III).[14 15] BMI at age 18 years and the weight change between age 18 and completion of the baseline questionnaire were measured. Women with BMI values <16 kg/m^2 or >54.9 kg/m^2 were excluded as highly unlikely. A validation study conducted within a subgroup of the CTS showed excellent correlations between self-reported measurements and those obtained by trained interviewers: r = 0.93 for height; r = 0.87 for weight; r = 0.87 for BMI; and r = 0.85 for waist circumference (N = 317 participants).

Statistical methods

We examined prevalence odds ratios (ORs) for current asthma by the various measures of body size using logistic modelling (PROC LOGISTIC of SAS Version 9).[16] We included in our models covariates based on prior knowledge of asthma and obesity-related risk factors including smoking status (current, former, never), age (<40, 40–49, 50–59, 60–69, ≥70 years) and race/ethnicity (white, black/African American, Latina, Asian/Pacific Islander, other). As a sensitivity analysis we repeated the analysis including the women with mild symptoms classified as having current asthma. We also stratified our main analyses by menopausal status (assessed at the same time as the asthma symptoms).

RESULTS

Of the 88 304 women eligible for inclusion in the asthma analyses, 13% were obese (BMI ≥30 kg/m^2 at baseline). The overall prevalence of current asthma was 7.6%, with 10.9% among women in obese class I (BMI 30–34.9 kg/m^2), 13.4% among women in obese class II and 18.3% among extremely obese women (BMI ≥40 kg/m^2) (table 1).

In the multivariable models, obesity was strongly associated with an increased prevalence of current asthma (table 2). Compared with those of normal weight, the OR increased from 1.40 (95% confidence interval (CI) 1.31 to 1.49) for overweight women to 3.30 (95% CI 2.85 to 3.82) for women with class III obesity. We also found statistically significant positive associations between current asthma prevalence and weight gain since age 18 years, waist circumference and waist-to-height ratio (table 2). ORs for the obesity measures were somewhat higher when the analyses were restricted to women with adult-onset asthma as well as those with adult-onset asthma who had not been overweight at age 18 (table 2). When stratified by menopausal status, the OR for BMI and asthma prevalence were somewhat higher among premenopausal women than postmenopausal women (for the highest category of BMI, OR = 3.73 vs 3.33 for adult-onset current asthma).

When BMI was included simultaneously in multivariable models with waist-to-height ratio, both factors remained strongly associated with increased prevalence of current asthma. For example, when modelled together, the OR for extreme obesity was 2.19 (95% CI 1.79 to 2.66) and the OR for the highest quartile of waist-to-height ratio was 1.75 (95% CI 1.56 to 1.96).

A waist circumference of >88 cm for women has been classified by the National Institutes of Health[15] as conferring an increased disease risk for diabetes, hypertension and cardiovascular disease. As shown in table 3, when we stratified BMI by this waist circumference cut-off, we observed an increased asthma prevalence for abdominally obese women even among those of normal weight based on BMI (OR 1.37, 95% CI 1.18 to 1.59). Among women who were overweight based on BMI, those whose waist size was <88 cm had an adjusted OR of 1.33 (95% CI 1.20 to 1.47), but those who also had a large waist (>88 cm) had an OR of 1.67 (95% CI 1.51 to 1.85). Among women defined as obese, the OR for asthma was greater among those who were also abdominally obese than in women whose waist was ≤88 cm (2.36 vs 1.57).

To test the sensitivity of the results to the definition of current asthma used, we repeated the analyses including women with any reported symptoms in the last 12 months, not just symptoms that required medication or medical visits. The overall prevalence of asthma increased from 7.6% to 10.9%. The adjusted ORs for BMI and the other body size measures were similar to those reported in table 2. The OR for current adult-onset asthma was 3.69 (95% CI 3.21 to 4.25) for BMI ≥40 kg/m^2, 2.62 (95% CI 2.34 to 2.93) for BMI 35–39 kg/m^2, 2.02 (95% CI 1.87 to 2.19) for BMI 30–34.9 kg/m^2 and 1.41 (95% CI 1.33 to 1.49) for BMI 25–29.9 kg/m^2.

Among the 6713 women with current asthma requiring medication, 704 (10.5%) reported an urgent care or emergency department visit and 148 (2.2%) reported a hospital admission for asthma in the past 12 months. We categorised women with an urgent care visit, emergency department visit or hospital admission as having severe asthma. The ORs for severe asthma (adjusted for age, race/ethnicity and smoking) for overweight, obesity (class I and II combined) and extreme obesity were 1.31 (95% CI 1.10 to 1.56), 1.32 (95% CI 1.08 to 1.62) and 2.00 (95% CI 1.42 to 2.83), respectively (reference group was women of normal weight). Waist circumference and waist-to-height ratio were also related to severity (for example, the OR for the highest quartile of waist circumference was 1.59; 95% CI 1.23 to 2.06). When both BMI and waist circumference were in the same model, the OR for highest BMI was 1.91 (95% CI 1.17 to 3.13) and the OR for highest waist quartile was 1.28 (95% CI 0.91 to 1.79).

DISCUSSION

All measures of obesity were strongly associated with increased asthma prevalence. Even being modestly overweight was associated with higher asthma prevalence in this population. In addition, a large waist circumference was associated with modestly increased asthma prevalence among women who were of normal weight based on BMI. These findings are particularly troubling because a majority of American adults are now overweight or obese. The current prevalence of obesity in US adults is estimated at 32% and the prevalence of overweight and obesity combined is 66%.[17] Abdominal obesity is increasing faster than overall obesity: according to an analysis of data from the 2003–4 National Health and Nutrition Examination Survey, 61% of US women were abdominally obese based on waist circumference.[18]

BMI has been widely used as the standard measure of obesity in a variety of health studies, but some researchers have also advocated the use of waist circumference and the waist-to-height ratio because they more closely reflect visceral fat deposits which are metabolically different from other body fat.[9] Peripheral fat, deep abdominal subcutaneous fat and

Table 1 Characteristics of the California Teachers Study population and prevalence of current asthma

	No	Percentage of total study subjects	Percentage with current asthma
Race/ethnicity			
White	77719	88.0	7.5
Black or African American	1990	2.3	7.6
Hispanic or Latina	3231	3.7	8.8
Asian or Pacific Islander	3036	3.4	6.8
Other	2328	2.6	8.9
Age in 2000–2001 (years)			
<40	8551	9.7	8.0
40–49	15029	17.0	9.0
50–59	25632	29.0	8.1
60–69	18039	20.4	7.2
⩾70	21053	23.8	6.2
Cigarette smoking			
Never	56999	64.5	7.5
Former	24681	28.0	8.1
Current	3842	4.4	7.2
Unknown	2782	3.2	6.4
BMI at baseline (kg/m^2)			
16–18.5 (underweight)	2156	2.4	6.6
18.5–24.9 (normal weight)	49533	56.1	6.3
25–29.9 (overweight)	21657	24.5	8.2
30–34.9 (obese, class I)	7588	8.6	10.9
35–39.9 (obese, class II)	2578	2.9	13.4
⩾40 (obese, class III)	1334	1.5	18.3
Unknown or out of range	3458	3.9	7.3
BMI at age 18 (kg/m^2)			
<25 (not overweight)	75362	85.3	7.4
25–29.9 (overweight)	6290	7.1	8.8
⩾30 (obese)	2220	2.5	12.5
Unknown or out of range	4432	5.0	7.4
Weight gain since age 18			
Lost weight	15044	17.0	6.7
⩽25th percentile (<5 kg)	17392	19.7	5.8
25–49th percentile (5–10 kg)	17416	19.7	6.7
50–74th percentile (10.1–18 kg)	16146	18.3	7.5
⩾75th percentile (⩾18.1 kg)	18349	20.8	11.0
Unknown	3957	4.5	7.2
Percentile* of waist circumference			
⩽25th percentile (<72.4 cm)	18461	20.9	5.9
25–49th percentile (72.4–80 cm)	18597	21.1	6.5
50–74th percentile (80.1–90 cm)	16329	18.5	7.5
⩾75th percentile (⩾90.1 cm)	17959	20.3	10.0
Unknown or ineligible	16958	19.2	8.4
Percentile* of waist-to-height ratio			
⩽25th percentile (⩽0.441)	17458	19.8	5.7
25–49th percentile (0.442–0.484)	17310	19.6	6.6
50–74th percentile (0.485–0.546)	18253	20.7	7.2
⩾75th percentile (⩾0.547)	17605	19.9	10.1
Unknown or ineligible	17678	20.0	8.3
Total	88304	100.0	7.6

$p<0.01$ for all variables (χ^2 test).
*Percentiles based only on women with non-missing values.
BMI, body mass index.

visceral intra-abdominal fat have different effects on the body, with the visceral abdominal fat contributing to a high-risk phenotype that is proinflammatory and prothrombotic.[19] This phenotype has also been linked to insulin resistance and raised triglyceride levels.[19] Waist circumference and waist-to-height ratio may be better predictors of diabetes and cardiovascular disease risk and are more robust than BMI across ethnic groups, age groups and between men and women.[20–22]

The potential role of central obesity in asthma has been examined in only a few studies. A recent report from Australia indicated that central obesity, measured by both waist circumference and waist-to-hip ratio, was significantly associated with current non-atopic but not atopic asthma.[7] A community-based study in Sweden found that both BMI and waist circumference were associated with increased risks for asthma incidence and symptoms, especially in non-atopic

Table 2 Adjusted* prevalence ratios for body composition and current asthma and adult-onset asthma among California Teachers Study cohort members

	Current asthma	Adult-onset asthma	Adult-onset asthma among women not overweight at age 18
	OR* (95% CI)	OR* (95% CI)	OR* (95% CI)
BMI at baseline (kg/m^2)			
<18.5 (underweight)	1.05 (0.88 to 1.26)	1.00 (0.81 to 1.24)	1.03 (0.82 to 1.28)
18.5–24.9 (normal weight)	1.00	1.00	1.00
25–29.9 (overweight)	1.40 (1.31 to 1.49)	1.45 (1.36 to 1.56)	1.52 (1.41 to 1.64)
30–34.9 (obese, class I)	1.89 (1.73 to 2.05)	1.97 (1.79 to 2.16)	2.10 (1.89 to 2.32)
35–39.9 (obese, class II)	2.30 (2.03 to 2.59)	2.52 (2.21 to 2.88)	2.70 (2.30 to 3.18)
≥40 (obese, class III)	3.30 (2.85 to 3.82)	3.66 (3.12 to 4.30)	4.17 (3.33 to 5.22)
Weight gain since age 18			
Lost weight			
≤25th percentile (5 kg)	1.00	1.00	1.00
25–49th percentile (5–10 kg)	1.20 (1.10 to 1.31)	1.20 (1.08 to 1.33)	1.19 (1.07 to 1.33)
50–74th percentile (10.1–18 kg)	1.34 (1.27 to 1.52)	1.39 (1.26 to 1.54)	1.39 (1.25 to 1.55)
≥75th percentile (≥18.1 kg)	2.12 (1.96 to 2.30)	2.22 (2.02 to 2.44)	2.21 (2.00 to 2.43)
Percentile of waist circumference			
≤25th percentile (<72.4 cm)	1.00	1.00	1.00
25–49th percentile (72.4–80 cm)	1.17 (1.07 to 1.28)	1.21 (1.09 to 1.34)	1.16 (1.05 to 1.29)
50–74th percentile (80.1–90 cm)	1.46 (1.34 to 1.59)	1.54 (1.39 to 1.70)	1.49 (1.34 to 1.66)
≥75th percentile (≥90.1 cm)	2.01 (1.85 to 2.18)	2.19 (1.99 to 2.41)	2.13 (1.92 to 2.37)
Percentile of waist-to-height ratio			
≤25th percentile (≤0.441)	1.00	1.00	1.00
25–49th percentile (0.442–0.484)	1.28 (1.17 to 1.40)	1.38 (1.24 to 1.53)	1.37 (1.23 to 1.53)
50–74th percentile (0.485–0.546)	1.49 (1.36 to 1.62)	1.61 (1.45 to 1.79)	1.59 (1.43 to 1.77)
≥75th percentile (≥0.547)	2.22 (2.04 to 2.41)	2.51 (2.27 to 2.77)	2.50 (2.25 to 2.79)

*Adjusted for race/ethnicity, age group and cigarette smoking.
BMI, body mass index.

patients.[6] However, in the Nurses' Health Study, when both BMI and waist-to-hip ratio were included in the same multivariable model, only the point estimates for the BMI categories remained relatively unchanged and statistically significantly associated with increased risk of incident asthma.[4] In a recent cross-sectional study of 1232 adults in Chile, neither BMI nor waist circumference was associated with asthma symptoms.[23] A prospective cohort of French women examined BMI and changes in body silhouettes since menarche.[24] Both high BMI and increases in self-reported body silhouette (a measure of overall size and shape) were strong risk factors for developing asthma as an adult. That study did not report specific measures of abdominal obesity. We also observed weight gain since age 18 years to be statistically significantly associated with increased prevalence of adult asthma symptoms. Overall, the available data seem to suggest that central body fat and weight gain may represent important risk factors for asthma.

Among women with asthma in the CTS cohort, obese and overweight women reported more severe asthma episodes than women of normal weight, as measured by higher proportions of urgent medical visits or hospital admissions. The relationship between severity of asthma and obesity has not been well defined.[25] A recent French study reported that BMI was related to asthma severity in women but not men.[11] Obese subjects with asthma who lose large amounts of weight have been shown to experience a reduction in the severity of their asthma symptoms.[2 26] In the Nurses' Health Study, women with a BMI of <22.5 kg/m^2 were less likely than obese women to report a hospital admission for asthma, but the prevalence of asthma medication usage was almost the same in both groups.[4]

Asthma may be overdiagnosed in overweight and obese patients because of respiratory symptoms such as shortness of breath on exertion that are not actually due to asthma.[27] Data from the Third National Health and Nutrition Examination Survey showed that asthma and bronchodilator use were more commonly reported by obese individuals who, however, did not exhibit reduced airflow.[27] There are also several possible mechanisms by which obesity could cause or exacerbate asthma. Obesity is a risk factor for airway hyper-responsiveness[28] and can promote systemic inflammation.[25] Although specific mechanisms linking systemic inflammation with asthma have not yet been convincingly elucidated, it has been hypothesised that obesity can affect the airways via effects on atopy, Th1:Th2 lymphocyte ratio, immune responsiveness, lung development and airway smooth muscle.[25] Obesity is also linked to gastro-oesophageal reflux disease, which may be an independent risk factor for adult-onset asthma.[25 29]

Several cross-sectional studies have shown stronger associations between asthma and obesity in women than in men.[5 8 30–32] This sex difference suggests that oestrogen and other female hormones may be important in the aetiology of asthma,

Table 3 Adjusted odds ratios* for adult-onset current asthma by body mass index, stratified by abdominal obesity, among California Teachers Study cohort members

Body mass index (kg/m^2)	Not abdominally obese (waist circumference ≤88 cm)	Abdominally obese (waist circumference >88 cm)
	OR (95% CI)	OR (95% CI)
Normal (18.5–24.9)	1.00 (reference)	1.37 (1.18 to 1.59)
Overweight (25–29.9)	1.33 (1.20 to 1.47)	1.67 (1.51 to 1.85)
Obese (≥30)	1.57 (1.21 to 2.03)	2.36 (2.15 to 2.59)

*Adjusted for race/ethnicity, age group and smoking.

possibly through modulation of Th2 cytokine production.[25] Obesity may lead to increased levels of oestrogen because androgens are converted to oestrogens in fatty tissue via increased levels of aromatase and 17-β hydroxysteroid dehydrogenase.[33 34] In turn, oestrogen may affect airway responsiveness, immune cells or inflammatory processes; however, biological mechanisms have not been elucidated.[34]

Our analyses were conducted in a large cohort with the ability to examine and detect a clear monotonic association with fine categories of BMI, including the category of extreme obesity. We also had several other measures of body size including waist circumference that allowed us to assess abdominal obesity, which was associated with an increased prevalence of asthma even among women of normal weight. However, we did not have information on several recognised risk factors for asthma, including family history of asthma and allergy, exposures to allergens and early-life respiratory infections; thus, we cannot rule out the possibility of confounding in our results. In addition, because our data were mostly cross-sectional, the temporal relationship between weight gain, obesity onset and asthma onset is not clear, although we did find that retrospective data on weight gain since age 18 years was associated with adult-onset asthma. In addition, a physician diagnosis of asthma was self-reported and not confirmed by an examination of medical records. While self-reported measures of body composition are also subject to error,[35] a validation study of these measures (excluding weight gain and waist-to-height ratio) conducted in the CTS showed strong correlations between self-report and interviewer-measured assessments. The effects of selection bias or participation bias cannot be ruled out since 30% of the original cohort did not complete the subsequent questionnaire that contained the asthma questions.

In summary, we found statistically significant associations between the prevalence of current asthma and multiple measures of body size and weight gain. Abdominal adiposity appeared to have independent effects on prevalence, separate from BMI. In the next phase of this study we will prospectively ascertain new asthma cases and will be able to evaluate BMI, waist size and weight change as risk factors for incident asthma in women.

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