Obesity is a risk for asthma and wheeze but not airway hyperresponsiveness

L M Schachter, C M Salome, J K Peat, A J Woolcock

Abstract

Background—A study was undertaken to assess whether the recent increases in prevalence of both asthma and obesity are linked and to determine if obesity is a risk factor for diagnosed asthma, symptoms, use of asthma medication, or airway hyperresponsiveness.

Methods—Data from 1971 white adults aged 17–73 years from three large epidemiological studies performed in NSW were pooled. Doctor diagnosis of asthma ever, history of wheeze, and medication use in the previous 12 months were obtained by questionnaire. Body mass index (BMI) in kg/m² was used as a measure of obesity. Airway hyperresponsiveness (AHR) was defined as dose of <3.9 µmol histamine required to provoke a fall in forced expiratory volume in one second (FEV₁) of 20% or more (PD₂₀FEV₁). Adjusted odds ratios (OR) were obtained by logistic regression.

Results—After adjusting for atopy, age, sex, smoking history, and family history, severe obesity was a significant risk factor for recent asthma (OR 2.04, p=0.048), wheeze in the previous 12 months (OR 2.6, p=0.001), and medication use in the previous 12 months (OR 2.83, p=0.005), but not for AHR (OR 0.87, p=0.78). FEV₁ and forced vital capacity (FVC) were significantly reduced in the group with severe obesity, but FEV₁/FVC ratio, peak expiratory flow (PEF), and mid forced expiratory flow (FEF₂₅₋₇₅) were not different from the group with normal BMI. The underweight group (BMI <18.5 kg/m²) had increased symptoms of shortness of breath, increased airway responsiveness, and reduced FEV₁, FVC, PEF, and FEF₂₅₋₇₅ with similar use of asthma medication as subjects in the normal weight range.

Conclusions—Although subjects with severe obesity reported more wheeze and shortness of breath which may suggest a diagnosis of asthma, their levels of atopy, airway hyperresponsiveness, and airway obstruction did not support the suggestion of a higher prevalence of asthma in this group. The underweight group appears to have more significant respiratory problems with a higher prevalence of symptoms, reduced lung function, and increased airway responsiveness without an increase in medication usage. This group needs further investigation.

Keywords: obesity; asthma; airway hyperresponsiveness; wheeze

In the past two decades there has been a significant increase in the prevalence of both asthma' and obesity' worldwide. Previous cross sectional studies have shown an association between obesity and both wheezing and diagnosed asthma. However, the nature of the relationship has not been established and, furthermore, if the association is causal, the direction of causation remains unknown.

There are several mechanisms by which obesity could cause either respiratory symptoms or more fundamental changes in the airways leading to asthma. In obese people symptoms of breathlessness and wheeze may be due to increased work of breathing. Alternatively, obesity may have a direct effect on the mechanical behaviour of the respiratory system by altering lung volume, airway calibre, or respiratory muscle strength. In obese subjects functional residual capacity (FRC) is reduced by approximately 500 ml. Changes in lung volume of this magnitude induced by voluntarily breathing below FRC and changes in posture have been shown to increase airway responsiveness in normal subjects.

In the other hand, factors associated with asthma could lead to an increase in obesity. Inactivity or inability to exercise in asthmatic subjects or those with atopy could cause weight gain. Medication required for treatment of severe asthma such as oral steroids may cause weight gain, which may cause asthmatic patients to become obese or to worsen pre-existing obesity.

In this paper we report an analysis of cross sectional data in a large population of white Australian adults. The aim of this analysis was to determine if obesity, as measured by body mass index (BMI), is associated firstly with an increase in the prevalence of wheeze, diagnosed asthma, or medication use for asthma and, secondly, with a reduction in lung function or an increase in the prevalence of atopy or airway responsiveness to histamine.
Obesity and asthma

### Table 1  Anthropometric and questionnaire data for subjects classified according to body mass index (BMI)

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Underweight (BMI &lt;18.5)</th>
<th>Normal (BMI 18.5–24.9)</th>
<th>Overweight (BMI 25.0–29.9)</th>
<th>Moderate obesity (BMI 25.0–34.9)</th>
<th>Severe obesity (BMI ≥35.0)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of subjects</td>
<td>52</td>
<td>1127</td>
<td>592</td>
<td>141</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>% male</td>
<td>17.3%</td>
<td>37.9%</td>
<td>60.1%</td>
<td>48.9%</td>
<td>30.5%</td>
<td>0.000</td>
</tr>
<tr>
<td>Age (years)</td>
<td>26.7 (24.4 to 29.0)</td>
<td>32.3 (31.7 to 32.9)</td>
<td>39.9 (35.2 to 36.6)</td>
<td>47.2 (39.0 to 54.9)</td>
<td>41.4 (38.7 to 54.1)</td>
<td>0.27</td>
</tr>
<tr>
<td>% with family history of asthma</td>
<td>52.8 (39.4 to 66.2)</td>
<td>42.1 (39.2 to 45.0)</td>
<td>45.3 (41.4 to 49.3)</td>
<td>47.2 (39.0 to 54.9)</td>
<td>41.4 (38.7 to 54.1)</td>
<td>0.27</td>
</tr>
<tr>
<td>% wheeze in last 12 months</td>
<td>33.3 (20.5 to 46.1)</td>
<td>20.4 (18.0 to 22.8)</td>
<td>19.8 (16.6 to 23.0)</td>
<td>25.9 (18.7 to 33.1)</td>
<td>37.9 (25.5 to 50.3)</td>
<td>0.002</td>
</tr>
<tr>
<td>% SOBOE in last 12 months</td>
<td>40 (20.8 to 59.2)</td>
<td>17.7 (15.0 to 20.4)</td>
<td>21.2 (17.6 to 24.8)</td>
<td>29.2 (21.1 to 37.3)</td>
<td>49.0 (35.3 to 62.7)</td>
<td>0.000</td>
</tr>
<tr>
<td>% recent asthma</td>
<td>17.0 (6.8 to 27.2)</td>
<td>12.3 (10.4 to 14.2)</td>
<td>10.4 (7.9 to 12.9)</td>
<td>14.6 (8.8 to 20.4)</td>
<td>21.7 (11.2 to 32.2)</td>
<td>0.06</td>
</tr>
<tr>
<td>% used medication in last 12 months</td>
<td>11.4 (2.8 to 20.0)</td>
<td>14.3 (12.3 to 16.3)</td>
<td>13.4 (10.7 to 16.1)</td>
<td>15.5 (9.5 to 21.5)</td>
<td>35.3 (23.1 to 47.5)</td>
<td>0.028</td>
</tr>
<tr>
<td>% current smoker</td>
<td>25 (13.2 to 36.8)</td>
<td>15.4 (13.3 to 17.5)</td>
<td>17.4 (14.3 to 20.5)</td>
<td>18.4 (12.0 to 24.8)</td>
<td>10.2 (2.5 to 17.9)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

SOBOE = shortness of breath on exertion.

Values are means and 95% confidence intervals or prevalence and 95% confidence intervals.

*Atopy was defined as a positive reaction of ≥ 3 mm to any of a panel of eight common aeroallergens.

### Definition

DEFINITIONS

Recent wheeze was defined as a positive reply to questions on the presence of wheeze in the previous 12 months. Recent asthma was defined as recent wheeze plus a doctor diagnosis of asthma ever.

### Methods

SAMPLES AND SELECTION CRITERIA

Data from three large epidemiological studies conducted in three rural regions of NSW, Australia (Belmont, Lismore, and Wagga Wagga) between 1991–7 were pooled. Details of the population, response rates, and information about non-responders have been published previously. The same two senior researchers were present at all studies and trained and supervised all other staff involved. A large random group of adults aged 17–73 years was studied. Less than 5% of the sample were non-white and their data were excluded from the analysis. Subjects were included in the current analyses if data available included height, weight, age, and a measure of airway responsiveness. Diagnosis of asthma ever, history of wheeze, smoking history, and family history of asthma had been obtained by a self-administered questionnaire which all subjects completed. The questionnaire was a modified version of the International Union against Tuberculosis (IUATLD) questionnaire.

All of our raw data (questionnaires, lung function tests, and allergy testing) were taken from these three studies and no new interventions were made. The methodology for collecting all of the questionnaire data, lung function, and allergy testing were identical in all three studies.

### Table 2  Adjusted odds ratio for symptoms and airway hyperresponsiveness (AHR) in atopic and non-atopic subjects compared with a group of normal weight

<table>
<thead>
<tr>
<th>BMI Classification</th>
<th>Underweight (BMI &lt;18.5)</th>
<th>Overweight (BMI 25–29.9)</th>
<th>Moderate obesity (BMI 30–34.9)</th>
<th>Severe obesity (BMI ≥35.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheeze in last 12 months</td>
<td>1.75 (0.80 to 3.82)</td>
<td>0.97 (0.68 to 1.38)</td>
<td>1.24 (0.70 to 2.20)</td>
<td>1.71 (0.73 to 4.02)</td>
</tr>
<tr>
<td>Atopics Non-atopics</td>
<td>0.57 (0.16 to 2.05)</td>
<td>1.31 (0.86 to 2.00)</td>
<td>2.37 (1.23 to 4.56)</td>
<td>5.10 (2.27 to 11.45)</td>
</tr>
<tr>
<td>Recent asthma</td>
<td>1.42 (0.59 to 3.45)</td>
<td>0.99 (0.65 to 1.51)</td>
<td>1.21 (0.62 to 2.35)</td>
<td>1.43 (0.54 to 3.79)</td>
</tr>
<tr>
<td>Atopics Non-atopics</td>
<td>0.38 (0.05 to 3.02)</td>
<td>0.90 (0.47 to 1.72)</td>
<td>2.21 (0.92 to 5.33)</td>
<td>4.08 (1.52 to 10.98)</td>
</tr>
<tr>
<td>SOBOE</td>
<td>2.34 (0.71 to 7.76)</td>
<td>1.18 (0.76 to 1.84)</td>
<td>1.89 (0.98 to 3.64)</td>
<td>2.96 (1.15 to 7.62)</td>
</tr>
<tr>
<td>Atopics Non-atopics</td>
<td>2.99 (0.86 to 10.31)</td>
<td>1.92 (1.23 to 2.97)</td>
<td>2.87 (1.51 to 5.49)</td>
<td>8.83 (3.79 to 20.58)</td>
</tr>
</tbody>
</table>

BMI = body mass index; SOBOE = shortness of breath on exertion; AHR = airway hyperresponsiveness; DRR = dose response ratio.

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Table 3  Lung function and airway responsiveness as classified by body mass index (BMI)

<table>
<thead>
<tr>
<th>BMI</th>
<th>Underweight (BMI &lt;18.5)</th>
<th>Normal (BMI 18.5–24.9)</th>
<th>Overweight (BMI 25.0–29.9)</th>
<th>Moderate obesity (BMI 30.0–34.9)</th>
<th>Severe obesity (BMI 35.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 (% pred)</td>
<td>95.0 (91.9 to 98.1)*</td>
<td>102.0 (101.3 to 102.7)</td>
<td>100.5 (99.3 to 101.5)</td>
<td>99.2 (97.3 to 101.1)</td>
<td>98.1 (95.2 to 101.0)*</td>
</tr>
<tr>
<td>FVC (% pred)</td>
<td>94.2 (91.5 to 96.9)*</td>
<td>99.4 (98.7 to 101.1)</td>
<td>97.4 (96.4 to 98.4)</td>
<td>95 (93.1 to 96.9)*</td>
<td>93.6 (90.7 to 96.5)*</td>
</tr>
<tr>
<td>FEV1/FVC (%)</td>
<td>86.4 (84.3 to 88.5)</td>
<td>86.3 (85.9 to 86.7)</td>
<td>85.9 (85.9 to 86.2)</td>
<td>86.9 (85.9 to 87.2)</td>
<td>87.6 (86.1 to 89.1)</td>
</tr>
<tr>
<td>DR (measure of AR)</td>
<td>89.9 (85.7 to 94.1)*</td>
<td>102.2 (101.1 to 103.3)</td>
<td>105.5 (104.1 to 106.9)</td>
<td>106.2 (103.2 to 109.2)</td>
<td>106.2 (101.8 to 110.6)</td>
</tr>
<tr>
<td>DRR (% pred)</td>
<td>85.8 (79.7 to 91.9)*</td>
<td>97.1 (95.7 to 98.5)</td>
<td>98.5 (96.5 to 100.5)</td>
<td>101.4 (97.4 to 105.4)</td>
<td>101.2 (94.3 to 108.1)</td>
</tr>
<tr>
<td>DRR (measure of AR)</td>
<td>6.32 (4.88 to 8.18)*</td>
<td>7.41 (4.52 to 4.92)</td>
<td>4.42 (3.43 to 4.62)</td>
<td>4.72 (4.28 to 5.21)</td>
<td>4.66 (4.08 to 5.33)</td>
</tr>
</tbody>
</table>

FEV1 = forced expiratory volume in one second; FVC = forced vital capacity; PEF = peak expiratory flow; FEF25–75 = mid forced expiratory flow; DRR = dose response ratio for current asthma, wheeze, and AHR in the presence of obesity and adjusted for family history of asthma, age, sex, atopy status, and smoking history. Pearson's correlation coefficient was used to assess correlation between BMI and airway responsiveness.

A one way ANOVA was used to analyse means of grouped data. Duncan’s post hoc analysis using the pooled variance was also performed to correct for multiple comparisons when comparing specific groups. We did not perform trend tests as the data did not suggest that there was a dose response trend. We also chose not to do multiple comparisons in order to reduce the type 1 error rate.

Results

Data from 1971 white adults were analysed. The response rate for Belmont was 57%, for Lismore was 66%, and for Wagga Wagga was 62%. All non-responders were telephoned and asked about their medication use for asthma. The rates of medication use between responders and non-responders were not significantly different in any region, although they suggest that current asthmatics were slightly less likely to attend so that the prevalence rates reported may be an underestimate of the true disease rate. The BMI distribution in our sample (table 1) was similar to the distribution in the general population in Australia.13

The prevalence of symptoms and medication use differed significantly between groups classified by BMI (table 1). Further analysis showed that, compared with normal weight subjects, subjects with severe obesity had a significantly higher prevalence of wheeze ($\chi^2 = 16.65$, p<0.01, fig 1), shortness of breath on exertion ($\chi^2 = 39.40$, p<0.001), and medication use for asthma in the previous 12 months in subjects grouped according to BMI classification.
Obesity and asthma comparison showed a reduction in flow rates, and wheeze (table 1). In this group post hoc increase in symptoms of shortness of breath underweight group there was a significant differences between atopic and non-atopic ses showed that there were no significant in FEV1/FVC% between the groups. In the weight, moderate, and severely obese groups reduced in the underweight and severely obese months (χ² = 12.33, p<0.05, fig 2). There was no difference between the groups in the prevalence of atopy (χ² = 4.42, NS). Separate analyses showed that there were no significant differences between atopic and non-atopic subjects (table 2) or between men and women in the strength of the associations between BMI and recent asthma, wheeze in the previous 12 months, medication use, or AHR. There did, however, appear to be a trend in the increase in symptoms in non-atopic subjects compared with atopic subjects but this was not significant and may be due to the small numbers in the severe obesity group (table 2).

There were significant differences between groups in lung function parameters including FEV1, FVC, PEF, FEF25–75, and DRR, although the mean values of the groups remained within the predicted normal range (table 3). Post hoc comparison showed that FEV1 was significantly reduced in the underweight and severely obese group and FVC was reduced in the underweight, moderate, and severely obese groups (p<0.05). There was no significant difference in FEV1/FVC% between the groups. In the underweight group there was a significant increase in symptoms of shortness of breath and wheeze (table 1). In this group post hoc comparison showed a reduction in flow rates, measured by PEF and FEF25–75, and a higher prevalence of AHR (table 3). In the group with severe obesity flow rates and airway responsiveness were not different from the normal group.

After adjusting for atopy, sex, age, smoking history, and family history, severe obesity was a significant risk factor for recent asthma, defined as recent wheeze plus a previous diagnosis of asthma (OR 2.04, p=0.048), wheeze in the previous 12 months (OR 2.6, p=0.001), and medication use in the previous 12 months (OR 2.83, p=0.005) but not for AHR (OR 0.87, p=0.78). Furthermore, obesity was a significant risk for wheeze without AHR (OR 3.33, p=0.0001) but not for wheeze in the presence of AHR (OR 0.72, p=0.73). There was no significant correlation between BMI and airway responsiveness (r=−0.041, p=0.07).

Discussion
We have found that severe obesity, defined as a BMI of >35 kg/m², was associated with a higher prevalence of wheeze, diagnosed asthma, and medication use. Despite the fact that FEV1 and FVC were significantly reduced in severely obese subjects, these subjects did not have evidence of airflow obstruction or reduced flow rates, nor was there any increase in airway responsiveness to histamine.

In this study we used data from a large number of randomly selected white adults in three rural towns in NSW. The distribution of BMI in these samples was representative of the general population in Australia. The methods and the IUATLD questionnaire were similar to those used in other large epidemiology studies and are well validated.

Obesity could increase the risk of asthma if the functional consequences of changes to the respiratory system were sufficient to modify airway behaviour and increase airway responsiveness in susceptible individuals. Reductions in lung volume induced by voluntarily breathing below FRC and changes in posture have been shown to increase airway responsiveness in normal subjects. The response to methacholine is altered when the FRC is reduced by approximately 500 ml, a level of reduction which is commonly found in obese or severely obese subjects. Changes in compliance or elastic recoil resulting from low lung volume could decrease the tidal fluctuations of airway smooth muscle and enhance contractility, and thus shift the dose response curve or increase the level of the maximal response. We found no evidence of any reduction in flow rates or any increase in airway responsiveness in obese subjects.

Alternatively, the anatomical changes could cause increased symptoms of wheeze and shortness of breath without altering airway behaviour. It has been reported that obese subjects are more likely to report asthma-like symptoms without an increase in AHR or prevalence of atopy. Breathlessness and wheeze might be attributable to other causes in obese subjects such as increased work of breathing or deconditioning.

Severe obesity may cause changes in the upper airway and wheeze may result from extrathoracic obstruction caused by fat deposition. Obstructive sleep apnoea is also increased in severe obesity and the combination of asthma-like symptoms plus waking at night with shortness of breath or choking may be misinterpreted as asthma. Finally, the high level of reported wheeze in the obese group may be related to the lack of specificity of the question regarding the presence of wheeze.

Although the prevalence of wheeze and shortness of breath was increased in the severely obese group, there was no airway narrowing on spirometric testing, no reduction in flow rates, and no increase in airway responsiveness. While the increased rate of diagnosis of asthma in this group probably reflects the increase in prevalence of symptoms, there is little objective evidence to support the diagnosis. If the definition of asthma includes airway inflammation, then it is unlikely that this group genuinely have asthma since there is no evidence that obesity is associated with increased airway inflammation. It is also unlikely.
that the asthmatic group selectively became obese, either as a result of increased medication use or reduced activity levels, since the prevalence of atopy was not increased in the obese group.

Medication use, particularly inhaled corticosteroids, may have affected the outcome of the study if the severely obese group were receiving sufficient treatment to normalise airway responsiveness. Although we do not have detailed information of the type or dose of medication taken, this seems an unlikely explanation. Despite the fact that a greater proportion of severely obese subjects had taken anti-asthma medication, as a group they continued to have symptoms, suggesting that the medication was inadequate or inappropriate to control their symptoms.

If symptoms in this group are due to causes unrelated to asthma, then asthma medication would be unlikely to affect their symptoms. The high level of medication use in the severely obese subjects probably reflects a high level of presentation for medical intervention. Symptoms alone do not appear to be a good guide for asthma treatment in this group.

The underweight group appeared to have more respiratory problems. Their increased prevalence of symptoms was associated with poorer lung function, indicated by a reduction both in FVC and in flow rates, and an increase in airway responsiveness. There are several possible causes for this. The high levels of airway responsiveness and low levels of medication use suggest that they may have under-treated asthma. Reduction in respiratory muscle strength and function may also be a potential cause. The causes for these abnormalities are unknown and deserve further investigation.

This study has significant clinical implications. We found that obese people with symptoms of dyspnoea and wheeze are frequently diagnosed with asthma even though there is no evidence of airway obstruction, reduced flow rates, or airway hyperresponsiveness. It is likely that the prevalence of asthma in this group is similar to that in the rest of the population. It is important that obese patients are fully assessed with measurement of lung function, reversibility or airway responsiveness if they present for health care with symptoms consistent with asthma. If treatment for asthma is commenced, clinical and adverse effects should be closely monitored as treatment with either oral or high dose inhaled steroids may cause further weight gain and may be an inappropriate mode of treatment for this group.

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