Percent body fat, skinfold thickness or body mass index for defining obesity or overweight, as a risk factor for asthma in schoolchildren: which one to use in epidemiological studies?

Luis Garcia-Marcos*†, Jose Valverde-Molina‡, Maria L. Castaños Ortega‡, Manuel Sanchez-Solis*, Antonia E. Martinez-Torres* and Jose A. Castro-Rodríguez§

*Pediatric Allergy and Pulmonology Units, Department of Pediatrics, Virgen Arrixaca University Children's Hospital, 30120 El Palmar, Murcia, Spain, †Centre for Public Health Biomedical Network Research (CIBERSP), Pabellon Docente Universitario, Campus Ciencias de la Salud, 30120 El Palmar, Murcia, Spain, ‡Department of Pediatrics, Los Arcos Hospital, Paseo de Colón 54, Santiago de la Ribera, 30720 San Javier, Murcia, Spain, and §School of Medicine, Pontificia Universidad Catolica de Chile, Lira 44 1er piso, Santiago, Chile

Abstract

None of the epidemiological studies indicating that obesity is a risk factor for asthma in schoolchildren have used the percent body fat (PBF) to define obesity. The present study compares the definition of obesity using body mass index (BMI), PBF and the raw sum of the thickness of four skinfolds (SFT) to evaluate this condition as a risk factor for asthma. All classes of children of the target ages of 6–8 years of all schools in four municipalities of Murcia (Spain) were surveyed. Participation rate was 70.2% and the number of children included in the study was 931. Height, weight and SFT (biceps, triceps, subscapular and suprailiac) were measured according to standard procedures. Current active asthma was defined from several questions of the International Study of Asthma and Allergies in Childhood questionnaire. Obesity was defined using two standard cut-off points for BMI and PBF, and the 85th percentile for BMI, PBF and SFT. The highest quartile of each type of measurement was also compared with the lowest. A multiple logistic regression analysis was made for the various obesity definitions, adjusting for age, asthma in the mother and father and gender. The adjusted odds ratios of having asthma among obese children were different for boys and girls and varied across the different obesity definitions. For the standard cut-off points of BMI they were 1.19 [95% confidence interval (CI) 0.41–3.43] for girls and 2.00 (95% CI 0.97–4.10) for boys; however, for PBF (boys 25%, girls 30%) the corresponding figures were 1.54 (95% CI 0.63–3.73) and 1.20 (95% CI 0.66–2.21). BMI, PBF and SFT showed more consistency between each other when using the other cut-off points. BMI, PBF (except standard cut-off points) and SFT produce relatively comparable results when analysing the interaction between obesity and asthma.

Keywords: asthma, body mass index, body fat, children, obesity.

Correspondence: Luis Garcia-Marcos, Pediatric Pulmonology Unit, Department of Pediatrics, Virgen Arrixaca University Children's Hospital, 30120 El Palmar, Murcia, Spain. E-mail: lgmarcos@um.es

Introduction

Numerous epidemiological studies in children have found that obesity is a risk factor for asthma (Luder *et al.* 1998; Figueroa-Munoz *et al.* 2001; von Kries *et al.* 2001; Gilliland *et al.* 2003; Bibi *et al.* 2004; Wickens *et al.* 2005; Mannino *et al.* 2006), although others have been unable to find any association between these two conditions (Huang *et al.* 1999; Schachter *et al.* 2003; To *et al.* 2004). Other studies have found that the risk is limited to prepubertal girls (Castro-Rodriguez *et al.* 2001; Herrera-Trujillo *et al.* 2005; Cassol *et al.* 2006). Furthermore, according to a recent meta-analysis (Flaherman & Rutherford 2006), the risk values of obesity or high birthweight for suffering future asthma found in several cohorts are higher as the study is more recent in time (statistically significant from year 2001).

Most studies in children have used body mass index (BMI) as the parameter for defining obesity, establishing cut-off points according to percentiles, usually the 85th and/or the 95th. However, there is no clear agreement about which cut-off points should be used to define obesity. A recent report (Wickens *et al.* 2005) uses the international cut-off points described by Cole *et al.* (2000) in six large nationally representative populations of children where overweight and obesity were defined according to the childhood centile lines (2–18 years of age) that reached the adult limits of 25 kg m^{-2} (overweight) and 30 kg m^{-2} (obesity) at 18 years.

Body mass index is only a moderate predictor of body fat, especially of central fat: BMI may underestimate the level of fat in children with central fat distribution. Furthermore, boys and girls differ considerably in body fat at a given BMI: for an equivalent BMI, girls have greater amounts of body fat than boys (Daniels *et al.* 1997). Only two studies in children have used BMI and skinfold thickness to assess the association between obesity and asthma: one of them included BMI together with the triceps and subscapular skinfolds (Figueroa-Munoz *et al.* 2001) and the other measured also BMI and the triceps skinfold (Cassol *et al.* 2006).

The measurement of percent body fat (PBF) from four skinfolds (biceps, triceps, subscapular and suprailiac) is subject to debate: while some authors argue in favour of its validity (Moreno *et al.* 2001), others consider the method to be unreliable (Reilly *et al.* 1995; Tennefors & Forsum 2004). Both BMI and PBF calculated from skinfolds are poor predictors of body fat calculated by the hydro-densitometry method. However, skinfolds predict body fat better than BMI (Sarria *et al.* 1998).

The measurement of both BMI and skinfold thickness can be performed in the school setting; however, skinfold measurement is more challenging and time consuming than BMI. The impact of PBF, as measured from skinfold thickness, on asthma prevalence has not yet been studied in the epidemiological field. The aim of the present study is to evaluate how different ways of measuring and defining obesity or overweight, based either on BMI, PBF or SKT values, can modify their importance as a risk factors for asthma.

Methods

The target population was all children in every class of 1st and 2nd year of all primary schools ($n = 21$) in four municipalities of the province of Murcia, Spain (San Javier, San Pedro del Pinatar, Los Alcázares and Torre Pacheco). All schools agreed to participate in the study which had been previously approved by the local ethics committee. A total of 1672 children (6–8 years old) were in those classes and 1174 returned the questionnaire (participation rate 70.2%). After discarding those whose family origins were not in Spain ($n = 212$), in order to have the most uniform population as possible of a similar predisposition to suffer from asthma and/or from obesity and those with missing data ($n = 31$) in the two main outcome variables (asthma and body measurements), 931 children with a comparable ethnic background were included in the analysis (51.1% boys).

A questionnaire including the core questions of the International Study of Asthma and Allergies in Childhood (ISAAC) survey (Ellwood *et al.* 2005) was given to the children by their teachers. Children took the questionnaire home to be answered by their parents. Current active asthma (CAA) was defined as a combination of four questions: 'Has your child had wheezing or whistling in the chest during the last

12 months?'; 'How many attacks of wheeze has your child had during the last 12 months? (none, 1–3, 4–12, more than 12)'; 'In the last 12 months, how often, on average, has your child's sleep been disturbed because of wheezing (Never, less than one night per week, one or more nights per week); and 'In the last 12 months, has wheezing been severe enough to limit your child's speech to only one or two words at a time between breaths?' It was considered CAA when there were four or more asthma attacks, or when sleep was disturbed at least once, or when there was an episode of speech limitation, in the previous 12 months. Those children with no sleep disturbance at any time in the previous year, with three or less wheezing attacks or without any severe episode were considered occasional symptoms sufferers and were excluded from the analyses. Consequently, the non-asthmatic group was composed by children who had no asthma symptoms at all.

Children were weighed and measured (in their shorts) by a team of fieldworkers that included the school nurse. Height was measured to the nearest 0.1 cm without shoes by means of a rigid stadiometer (Seca 220, Hamburg Germany) and weight was recorded using a scale (Seca 714, Hamburg Germany) to the nearest 0.1 kg. The stadiometer was checked for accuracy and the scale calibrated each morning before examinations. The measurements were made twice by a nurse and a family doctor, and their means were used for the analysis. Skinfold thickness was measured using a Holtain caliper (Holtain Ltd., Pembrokeshire, UK) to the nearest 0.1 mm at the biceps, triceps, subscapular and suprailiac sites (Sarria *et al.* 1998). The mean of a triplicate measurement in each site was included in the dataset. BMI was calculated from weight and height as kg m^{-2}, and PBF was estimated using Siri's formula (Siri 1956) from body density (Brook 1971) as follows:

$$\text{Body density (boys)} = 1.1690 - 0.0788 \log \Sigma (\text{four skinfolds})$$

$$\text{Body density (girls)} = 1.2063 - 0.0999 \log \Sigma (\text{four skinfolds})$$

$$\text{PBF} = (4.95/\text{body density} - 4.5) \times 100$$

Obesity was defined according to the cut-off points of body BMI reported by Cole (Cole *et al.* 2000) for each age and sex, and also as a PBF greater than 30% in girls or 25% in boys (Malina & Katzmarzyk 1999). Those cut-off points were considered the 'standard' ones. An additional cut-off point for both BMI and PBF was established in the 85th percentile (the 95th percentile could not be chosen as an additional cut-off point because of the limited number of children who were in that category). Additionally, the sum of the thickness of the four skinfolds was used as a marker of obesity. As there are no standard cut-off points for this measurement, only the 85th percentile was used here.

Those indexes of obesity or overweight with their different cut-off points were separately tested as a risk factor for CAA in a logistic regression in which gender, age and asthma in the mother or in the father were included as potential confounders [factors found significantly ($P < 0.05$) or very near significantly related to CAA in the univariate analysis]. Using the same potential confounding factors, the prevalence of asthma in the highest quartile (for age and sex) of BMI, PBF and thickness of four skinfolds (SFT) was compared with that in the lowest one.

Results

Among the 931 children, 85 (9.1%) suffered from CAA, 44 (4.7%) had occasional mild asthma and 802 (86.1%) had no symptoms at all. According to the international cut-off points for obesity, the prevalence of this condition was 13.7%. The demographic characteristics of the population, together with the prevalence of the risk factors included in the questionnaire are given in Table 1. Except for birthweight (a significant number of boys weighed 3500 g or more as compared with girls) and for height (greater in boys) the rest of the factors were comparable between genders. The *post hoc* power of the study to detect significant differences of BMI between children with CAA and children with no symptoms was 62%.

The associations between those risk factors and suffering from CAA are shown in Table 2: only gender, and having an asthmatic mother were significant factors; asthma in the father and age were very near significance ($P = 0.06$ and $P = 0.07$ respectively) and were included in the multivariate analysis.

Table 1. Demographic characteristics of the 931 children included in the analysis [mean ± standard deviationor *n* (%)]

	Boys *n* = 476	Girls *n* = 455	*P*
Age	6.92 ± 0.74	6.95 ± 0.74	0.56
Height (cm)	129.8 ± 5.8	128.8 ± 6.3	0.02
Weight (kg)	28.9 ± 6.9	28.2 ± 6.7	0.06
Body mass index	17.04 ± 3.17	16.86 ± 3.21	0.22
Percent body fat	22.53 ± 7.52	23.14 ± 8.77	0.54
Asthma in the mother	23 (4.8)	31 (6.8)	0.20
Asthma in the father	16 (3.4)	11 (2.4)	0.39
Smoking mother	185 (38.8)	177 (38.9)	0.99
Older siblings			
None	196 (41.2)	187 (41.1)	0.98
One	183 (38.4)	182 (40.0)	0.62
More than one	84 (17.6)	77 (16.9)	0.77
Not available	13 (2.7)	9 (2.0)	0.45
Younger siblings			
None	256 (53.8)	251 (55.2)	0.67
One	178 (37.4)	157 (34.5)	0.35
More than one	20 (4.2)	24 (5.3)	0.44
Not available	22 (4.6)	23 (5.0)	0.75
Birthweight			
Less than 2000 g	19 (4.0)	20 (4.4)	0.75
2000–3499 g	265 (55.7)	292 (64.1)	0.008
3500 g or more	176 (37.0)	127 (27.9)	0.002
Not available	16 (3.4)	16 (3.5)	0.89

Table 2. Association between the factors included in the questionnaire and suffering from clinical active asthma

Male gender	Odds ratio	95% CI	*P*
	2.07	1.29–3.33	0.002
Age			
6	1		
7	0.82	0.50–1.34	0.43
8	0.54	0.27–1.06	0.07
Asthmatic mother	3.48	1.74–6.97	<0.001
Asthmatic father	2.61	0.95–7.17	0.06
Smoking mother	1.12	0.70–1.78	0.62
Mould stains in the household wall	1.68	0.87–3.24	0.12
Older siblings			
None	1		
One	0.87	0.53–1.43	0.59
More than one	0.91	0.48–1.71	0.77
Younger siblings			
None	1		
One	1.00	0.62–1.62	0.99
More than one	1.22	0.46–3.25	0.69
Birthweight			
2000–3499 g	1		
Less than 2000 g	0.52	0.12–2.22	0.38
3500 g or more	1.04	0.64–1.68	0.86

CI, confidence interval.

Table 3 shows the different adjusted odds ratios (aOR) of suffering from CAA among children according to different definitions using BMI, PBF or SFT and cut-off points for obesity or overweight. There was no full significant association between high BMI and PBF defined by the standard cut-off points and CAA neither in girls nor in boys. However, for BMI the association was very near significance in boys. This same trend was found for BMI, PBF and SFT when the cut-off point was established in the 85th percentile. When comparing the two extreme quartiles a significant relationship between CAA and the highest quartile of BMI and PBF was found in boys, but not in girls. With respect to SFT, the association was near statistical significance for the highest quartile only in boys.

Discussion

It is generally recognized that BMI and PBF do not measure exactly the same thing. For example, Daniels *et al.* (1997) conclude that boys and girls differ substantially in PBF given a similar BMI (for an equivalent BMI, girls have greater amounts of body fat than boys), and those differences probably are present throughout life.

According to this lack of agreement between BMI and PBF, discordant results might be expected when using those two parameters to evaluate obesity as a risk factor for asthma. However, the logistic regression analysis shows a consistent (although not statistically significant) trend for an association between being obese (any definition except the standard cut-off points for PBF) and suffering from asthma in boys, but not in girls.

There are several epidemiological studies in schoolchildren relating obesity to asthma prevalence or incidence. Most of them conclude that obesity is a risk factor for asthma; however, they do not agree on which gender is affected most. von Kries *et al.* (2001), in a very large sample of schoolchildren 5–6 years of age, found that girls were more at risk than boys. They

Table 3. Odds ratios of suffering from clinical active asthma in children according to different definitions of obesity or overweight, either using body mass index, percent body fat or the raw sum of the thickness of four skinfolds

	Girls		Boys		Total	
	n	aOR (95% CI)	N	aOR (95% CI)	*n*	aOR (95% CI)
Body mass index						
International	426	1.19 (0.41–3.43)	448	2.00 (0.97–4.10)	865	1.68 (0.95–3.00)
85th percentile	426	1.44 (0.53–3.87)	448	1.85 (0.90–3.78)	874	1.69 (0.95–2.99)
Highest quartile	211	1.20 (0.38–3.75)	220	2.81 (1.21–6.49)	431	2.03 (1.05–3.91)
Percent body fat						
25% boys, 30% girls	426	1.54 (0.63–3.73)	448	1.20 (0.66–2.21)	874	1.28 (0.77–2.11)
85th percentile	426	0.67 (0.19–2.31)	448	1.83 (0.90–3.74)	874	1.33 (0.73–2.44)
Highest quartile	209	1.71 (0.47–6.17)	218	2.70 (1.11–6.55)	427	2.28 (1.11–4.68)
Sum of four skinfolds						
85th percentile	426	0.70 (0.20–2.47)	448	1.83 (0.90–3.73)	874	1.36 (0.74–2.50)
Highest quartile	214	2.97 (0.88–10.01)	220	2.22 (0.94–5.20)	434	2.33 (1.16–4.64)

Values are adjusted for age, asthma in the mother and in the father; additionally the total sample was adjusted for sex. The international cut-off points were established according to age and sex. The highest quartile is compared with the lowest. aOR, adjusted odds ratio; CI, confidence interval.

found that prevalence of wheeze during the previous year was 9% among those with a BMI lower than 90th percentile and about 11% among those with a BMI over that percentile. That study is, however, the only one that obtained this result clearly, apart from those including pubertal or adolescent children (Castro-Rodriguez *et al.* 2001; Herrera-Trujillo *et al.* 2005; Cassol *et al.* 2006). Figueroa-Munoz *et al.* (2001) comparing the 10th percentile of BMI with the 90th, found a slightly higher risk in girls and only in the inner city sample of their population, which showed a 17% prevalence of wheeze at any time in the life. Other studies, such as those by Bibi *et al.* (2004), Gilliland *et al.* (2003) and Mannino *et al.* (2006), concluded that the risk is higher for boys. The first of those studies used the 95th percentile to define obesity and the prevalence of wheeze was 14.5% (obese children) vs. 10.5% (non-obese children); the second one defined overweight as a BMI greater that the 85th percentile and obesity when BMI was higher than the 95th percentile and the overall prevalence of wheezing at any moment in the past was 21%; the last one used the 85th percentile as the cut-off point for BMI and doctor-diagnosed asthma developed in 5% of the children (recruited at birth and free of asthma symptoms during the two first years of life) over a follow-up period of 14 years: boys were affected more frequently than girls.

Still other studies, such as the ones by Chinn & Rona (2001), among children 5–11 years old with low prevalence of obesity (2.5%) as defined by a similar method as the one of the present study (Cole *et al.* 2000) and high prevalence of ever wheeze (15%–20% depending on the cohort year) and Gold *et al.* (2003) in a population of children 6–11 years old with active doctor-diagnosed asthma in 3.5% of them, and using quintiles of BMI as the risk factor, did not find a big difference between the two genders.

All the aforementioned studies used BMI as the way of defining obesity; however, the cut-off points

were not the same. This difference could explain in part those discrepancies. There are probably other more critical factors: for instance, in the whole population of the same age group of the ISAAC study in 11 centres in Spain, performed one year earlier than the present one, the risk was higher in girls. However, in the ISAAC centre of Murcia it was the boys who were at greater risk (data not shown), thus confirming the current results. When children approach puberty, the higher risk found in girls seems to be more consistent (Castro-Rodriguez *et al.* 2001; Herrera-Trujillo *et al.* 2005; Cassol *et al.* 2006). Interestingly, in the longitudinal study from Tucson, obese girls with early menarche – less than11 years of age had clearly more risk for developing new asthma than those non-obese ones (Castro-Rodriguez *et al.* 2001).

In summary, using several cut-off points of BMI, PBF and SKF, this study shows a trend for obese or overweight boys – aged 6–8 years to be at a greater risk for asthma than non-obese or non-overweight ones. Conversely, school girls have no such a risk. The three parameters produce relatively comparable results in terms of aOR when analysing the interaction between obesity and asthma, except when using the standard cut-off points for PBF. It would be desirable that studies on obesity and/or overweight as a risk factor for asthma use a standard definition: the international cut-off points are probably the soundest option because they allow international comparisons and offer good consistency with other cut-off points. Additionally height and weight are easier to measure than skinfold thickness. However, other parameters related to body fat such as fat distribution, especially in adolescent boys and girls, have not yet been studied and it would be very interesting to include them in future surveys.

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Conflicts of interest

None declared.

Key messages

- Although some studies have shown an association between obesity and asthma, others have not: to what extent this is due to the use of different cut-off points of BMI in the different studies, is not known.
- In spite of the known lack of agreement between BMI and PBF for defining obesity or overweight, either of the two parameters or the sum of four skinfolds produces relatively comparable results in terms of aOR when analysing the interaction between those conditions and asthma. However, because of the difficulty of measuring skinfolds as compared with height and weight and the fact that skinfold values have limitations to predict body adiposity, BMI seems the most reasonable measurement for epidemiological studies assessing obesity as a risk factor for asthma.
- It would be desirable that studies on obesity and/or overweight as a risk factor for asthma use a standard definition: the international cut-off points for BMI are probably the soundest option as they could make studies more comparable. Additionally, they offer consistent results with other cut-off points of BMI and with the same cut-off points of PBF and SKF.

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