



Original/*Obesidad*

Anthropometric indicators of general and central obesity in the prediction of asthma in adolescents; central obesity in asthma

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Abstract

Objective: to determine the prevalence of asthma risk associated with anthropometric indicators of excess weight and body fat distribution.

Methodology: cross-sectional study including adolescents between 10 and 19 years of age. The anthropometric indicator used to classify excess weight was the body mass index (BMI-Z); those used for abdominal adiposity were waist circumference (WC), waist-to-height ratio (WHtR) and the conicity index (CI). Asthma characteristics were evaluated using the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire. The significance level was 5%, and the analyses were performed using *Statistical Package for the Social Sciences (SPSS)* Version 18.0.

Results: adolescent students (n=1362; 788 [57.9%] female) with a mean age of 15.65±1.24 years were evaluated. A high prevalence of asthma, excess weight (BMI-Z) and excess abdominal adiposity (WC and WHtR) was observed in the females. Only CI values for excess abdominal adiposity were higher for males than for females.

Adolescents with excess abdominal adiposity, as shown by the WHtR, had a 1.24 times higher risk of having asthma compared with non-obese adolescents. Boys with excess abdominal adiposity, as classified by CI, presented a 1.8 times greater risk of asthma. The risk of severe asthma was 3 times higher among adolescents who were classified as severely obese via the BMI-Z.

INDICADORES ANTROPOMÉTRICOS DE LA OBESIDAD GENERAL Y CENTRAL EN LA PREDICCIÓN DE ASMA EN ADOLESCENTES; OBESIDAD CENTRAL EN ASMA

Resumen

Objetivo: determinar la prevalencia de riesgo de asma asociado con indicadores antropométricos de exceso de peso y la distribución de la grasa corporal.

Metodología: estudio transversal que incluye adolescentes entre 10 y 19 años de edad. El indicador antropométrico utilizado para clasificar el exceso de peso fue el índice de masa corporal (IMC-Z); los utilizados para la adiposidad abdominal fueron la circunferencia de la cintura (CC), la relación cintura-estatura (RCE) y el índice de conicidad (IC). Las características del asma se evaluaron utilizando el cuestionario *International Study of Asthma and Allergies in Childhood (ISAAC)*. El nivel de significación fue del 5%, y los análisis se realizaron con el *Statistical Package for the Social Sciences (SPSS)* versión 18.0.

Resultados: fueron evaluados estudiantes adolescentes (n=1362; 788 [57,9%] mujeres) con una edad media de 15,65±1,24 años. Se observó en las mujeres una alta prevalencia de asma, exceso de peso (IMC-Z) y exceso de adiposidad abdominal (WC y RCE). Solo los valores de IC para el exceso de adiposidad abdominal fueron mayores para los hombres que para las mujeres.

Los adolescentes con exceso de adiposidad abdominal, como lo demuestra la RCE, tenían 1,24 veces más riesgo de tener asma en comparación con los adolescentes no obesos. Los niños con exceso de adiposidad abdominal, según la clasificación de IC, presentaron 1,8 veces mayor riesgo de asma. El riesgo de asma grave era 3 veces mayor entre las adolescentes que fueron clasificados como severamente obesos a través del IMC-Z.

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Conclusion: this study showed that excess body weight and abdominal obesity are associated with an increased risk of asthma and asthma severity in adolescents. Thus, additional BMI measurements are suggested for asthmatics.

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Key words: *Adolescent. Asthma. Body mass index. Abdominal obesity.*

Abbreviations

BMI: Body Mass Index.

WHO: World Health Organization.

WC: Waist Circumference.

WHtR: Waist-to-height Ratio.

CI: Conicity Index.

ISAAC: International Study of Asthma and Allergies in Childhood.

PR: Prevalence Ratio.

BMI-Z: Body Mass Index for age.

OR: Odds Ratio.

Introduction

Asthma, wheezing and hyperreactivity of the airways associated with high body mass index (BMI) in children and adolescents are subjects of continuous research, but the physiopathological bases and cause and effect factors are not completely understood. Studies suggest that in obese individuals, increased mass of the abdomen and chest wall reduces functional residual capacity, leading to a decrease in the length of the smooth muscle of the airway. Moreover, obese individuals assume a respiratory pattern characterised by high frequency and decreased flow volume, which predisposes them to increased airway responsiveness¹.

The distribution of body fat may play an important role in the association between obesity and asthma, but little research has considered the role of abdominal adiposity. In adults, this measure is significantly associated with an increased risk of asthma^{2,3}. In the child population, central obesity has been associated with asthma, increased asthma severity, reduced lung function and atopy.

Thus, excess weight can increase the risk of developing asthma in predisposed individuals. However, the results are still controversial because of the limitations inherent in the methodology used in this research⁴. Prominent among these limitations is the fact that most studies use BMI as the main anthropometric measure to determine excess weight and obesity. This index is used as an epidemiological and clinical indicator and is an inexpensive and easy measurement, but it does not allow the distribution of body composition to be examined. Anthropometric evaluation should therefore

Conclusión: este estudio mostró que el exceso de peso y la obesidad abdominal se asocian con un mayor riesgo de asma y asma severa en adolescentes. Por lo tanto, se sugieren mediciones de IMC adicionales para los asmáticos.

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Palabras clave: *Adolescente. Asma. Índice de masa corporal. Obesidad abdominal.*

re use other indicators, such as waist circumference, waist-height ratio and conicity index, which are also inexpensive tools that are easy to standardise⁵.

Given the above, the present study aims to determine the prevalence of asthma risk associated with anthropometric indicators of excess weight and body fat distribution.

Methodology

This study had a cross-observational design and was conducted with adolescents aged 10 to 19 years of both genders from public high schools located in the urban area of the municipality of Santa Maria-RS, Brazil, from May to November 2012.

These individuals agreed to participate, and their parents signed a consent form. Adolescents with neurological damage or any type of physical disability, birth defect or other factor that would prevent evaluation were excluded.

Sampling was performed by randomly drawing classes. The calculation of sample size was performed to provide a difference of RR = 2.0 in the prevalence of excess weight (15%) among adolescents with and without asthma (21%), considering a significance level of 0.05 and a power of 80%. This required at least 395 individuals. Sampling was increased by 10% to allow for possible losses and refusals, making a total of 435 students.

The research project designed for this study was approved by the Ethics Committee of the Universidade Federal do Rio Grande do Sul - UFRGS under Protocol No. 20009. It is noteworthy that the evaluations were returned to all participants and the school received the overall results of the screening in which the students participated.

Data relating to the sample characterisation, anthropometric evaluations and asthma characteristics were collected in the schools by the author and by previously trained undergraduate nutrition students. The questionnaires were administered in the classroom to all students that were present, and anthropometric measurements were taken individually in a private room.

Anthropometric measurements were taken using standardised techniques with calibrated equipment and in duplicate, assuming a maximum difference of

1.0 cm or 100 g between measures. The mean value of each measure was used for the evaluations⁶.

Body mass (weight) in kg was obtained with the participant wearing minimal clothing and barefoot. *Plenna*[®] platform scales with a maximum load of 150 kg and 100 g variation were used for this purpose. Height was measured using a *Sanny*[®] brand extensible stadiometer affixed to a smooth wall without a footer. The participants were barefoot during height measurement⁶.

The anthropometric indicator used to classify nutritional status was the BMI for age (BMI-Z), analysed using the program *Anthro Plus* Version 1.04 (WHO, 2009). The results were obtained as a z-score and classified according to WHO criteria⁶.

The anthropometric indicators used to classify abdominal adiposity were waist circumference (WC), waist-to-height ratio (WHtR) and the conicity index (CI).

WC was measured using a *Secca*[®] brand inelastic tape positioned at the minimum circumference between the iliac crest and the last rib. Excess abdominal fat was defined as a WC greater than the 80th percentile for age and gender⁷.

WHtR was determined by dividing the waist circumference (cm) by the height (cm). The cut-off point used as a threshold for the diagnosis of excess abdominal fat was 0.43^{8,9}.

CI was calculated using the mathematical equation described by Valdez¹⁰. The cut-off point for abdominal obesity used in this study was ≤ 1.1 ¹¹.

The characteristics of asthma were evaluated in writing using the *International Study of Asthma and Allergies in Childhood* (ISAAC) self-administered questionnaire, which was validated after translation to Portuguese/Brazil¹².

Asthma was evaluated using the overall ISAAC score, an indicator recommended by Wandalsen *et al.*¹³. The ISAAC score cut-off used to identify adolescents with asthma was ≥ 6 ¹². Asthma was considered more severe when, in addition to wheezing in the past 12 months, there was one or more positive responses to the following questions: inability to speak at least two complete words during a wheezing attack, more than 12 crises in the last year and awakenings as a result of asthma (> 1 night per week)¹⁴.

The results were expressed as the mean and standard deviation, and the Kolmogorov-Smirnov test was applied to evaluate the distribution of variables. The chi-square test was applied to analyse the association between qualitative variables. Raw and adjusted prevalence ratio (PR) estimates with a confidence interval of 95% (95% CI) were calculated using the Poisson regression method with robust adjustment of variance in bivariate analyses.

The significance level adopted was 5%, and the analyses were performed using *Statistical Package for the Social Sciences* (SPSS) version 18.0.

Results

A total of 1362 students were evaluated from 57 classes in 16 high schools in the city of Santa Maria, RS. The mean age of the adolescents was 15.65 ± 1.24 years; 788 (57.9%) were female, and 574 (42.1%) were male.

Table I summarises the frequency of affirmative answers to questions on the ISAAC questionnaire and the asthma score and severity. A statistically significant higher prevalence rate of signs and symptoms was observed among females.

Table I
Prevalence of signs and symptoms related to asthma according to the ISAAC questionnaire, in overweight and non-overweight adolescents

Questionnaire	Adolescentes			P
	Total* (n = 1362)	Male* (n = 574)	Female* (n = 788)	
Wheezing or whistling, any time	588 (43.2)	226 (16.6)	362 (26.6)	0.016**
Wheezing or whistling in the chest	282 (20.7)	92 (6.8)	190 (14)	<0.05**
Attacks of wheezing	38 (2.8)	12 (0.9)	26 (1.9)	0.181
Sleep been disturbed due to wheezing	179 (13.1)	58 (4.3)	121 (8.9)	0.005**
Wheezing to limit your speech	46 (3.4)	11 (0.8)	35 (2.6)	0.011**
Ever asthma	219 (16.1)	84 (6.2)	135 (9.9)	0.220
Wheezy during or after exercise	217 (16)	70 (5.2)	147 (10.8)	0.002**
Dry cough at night	491 (36.2)	167 (12.3)	324 (23.9)	<0.05**
Score and cut-off point(≥ 6)	279 (20.5)	85 (14.8)	194 (24.6)	<0.05**
Severeasthma	78 (5.7)	23 (1.7)	55 (4)	0.020

ISAAC, *International study of asthma and allergies in childhood*; *of subjects (percentage), n (%); Value obtained by Pearson's chi-square test, **p<0.05.

The classification of nutritional status by anthropometry is shown in table II. There was a higher prevalence of excess weight according to BMI-Z and excess

Table II
Prevalence of nutritional state according to indicators of excess adiposity in adolescents according to gender

Nutritional status	Adolescentes			P
	Total* (n = 1362)	Male* (n = 574)	Female* (n = 788)	
BMI-Z				
Eutrophic	995 (73.1)	419 (30.8)	576 (42.3)	0.979
Overweight	255 (18.7)	109 (8.0)	146 (10.7)	
Obesity	94 (6.9)	38 (2.8)	56 (4.1)	
Severeobesity	18 (1.3)	08 (0.6)	10 (0.7)	
WC				
Withoutexcess	862 (63.3)	356 (26.1)	506 (37.2)	0.407
Withexcess	500 (36.7)	218 (16)	282 (20.7)	
WHR				
Withoutexcess	776 (57)	337 (24.7)	439 (32.2)	0.269
Withexcess	586 (43)	237 (17.4)	349 (25.6)	
CI				
Eutrophic	699 (51.3)	208 (15.3)	491 (36.0)	0.001**
Obesity	663 (48.7)	366 (26.9)	297 (21.8)	

BMI-Z, Body mass index (score-z); WC, Waist Circumference; WHR, Waist/Height Ratio; CI, Conicity Index. *Number of subjects (percentage), n (%); Value obtained by Pearson's chi-square test. **p<0.05.

abdominal adiposity according to the WC and WHtR indicators for females and according to CI for males, with statistical significance.

As demonstrated in figure 1, adolescents with a score ≥ 6 and severe asthma had a higher prevalence of excess weight (in the case of females) and obesity (in the case of males). The boys with asthma had a higher prevalence of excess abdominal fat (according to CI) than the girls with asthma. Those with severe asthma showed the same trend, but prevalence of obesity (according to WC) was higher among females. There were statistically significant associations between asthma and CI, only in males, and between asthma and WHtR.

An analysis of each of the ISAAC questionnaire questions found significant associations, adjusted for age and gender, for wheezing after exercise PR: 1.35 (95% CI 1.06 to 1.73) (p=0.014) and PR: 1.42 (95% CI 1.11 to 1.82; p=0.005) for the WC and CI excess adiposity indicators, respectively. Among the males with severe obesity, there was a risk of impaired speech during crises; for those with excess adiposity according to CI, there was a risk of sleep disturbed by wheezing.

The prevalence asthma ratios according to the pre-established model are shown in tables III and IV. It is noteworthy that adolescents had a 1.24 times higher risk of asthma scores ≥ 6 when classified with excess abdominal adiposity by the WHtR, and males had a 1.8 times greater risk according to the CI indicator.

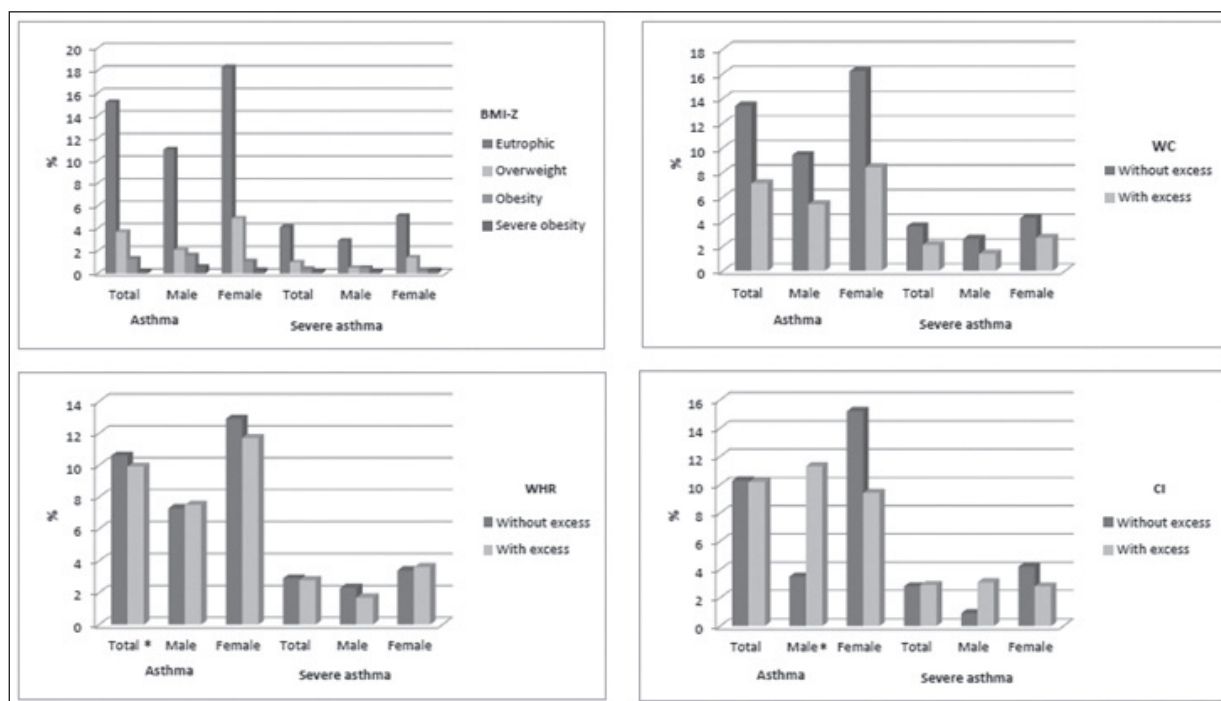


Fig. 1.—Association between the classification of anthropometric indicators, overall score and asthma severity among adolescents according to gender.

BMI-Z, z-score of body mass index; WC, waist circumference; WHtR, waist-height ratio; CI, conicity index; chi-square test, *p<0.005.

Table III
Raw and adjusted prevalence ratio, in bivariate analysis, for anthropometric indicators associated with overall asthma score in adolescents

Nutritional status	Asthma-score						Asthma-score											
	Total* (n = 1362)			Male* (n = 574)			Female* (n = 788)			Total ** (n = 1362)			Male*** (n = 574)			Female*** (n = 788)		
	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P		
BMI-Z																		
Eutrophic	Ref.	-	-	-	-	-	-	-	Ref.	-	-	-	-	-	-	-	-	
Overweight	0.91	0.778	0.73	0.292	1.07	0.669	0.96	0.786	0.71	0.229	1.07	0.71	0.229	1.07	0.79-1.45	0.669	0.669	
Obesity	0.73-1.26		0.41-1.31		0.79-1.45		0.74-1.26		0.41-1.24		0.79-1.45		0.41-1.24		0.79-1.45		0.669	
Severeobesity	0.92	0.707	1.57	0.147	0.64	0.159	0.91	0.690	1.54	0.168	0.64	0.91	0.168	0.64	0.35-1.18	0.153	0.153	
	0.59-1.42		0.85-2.91		0.35-1.19		0.58-1.42		0.83-2.85		0.35-1.18		0.83-2.85		0.35-1.18		0.153	
	0.80	0.676	0.83	0.845	0.80	0.726	0.80	0.675	0.79	0.807	0.82	0.80	0.807	0.82	0.23-2.89	0.763	0.763	
	0.28-2.26		0.13-5.27		0.23-2.78		0.29-2.25		0.13-5.00		0.23-2.89		0.13-5.00		0.23-2.89		0.763	
WC																		
Without excess	Ref.	-	-	-	-	-	-	-	Ref.	-	-	-	-	-	-	-	-	-
With excess	0.92	0.452	0.94	0.757	0.92	0.556	0.93	0.530	0.93	0.747	0.91	0.93	0.747	0.91	0.71-1.18	0.490	0.490	
	0.74-1.14		0.62-1.41		0.71-1.19		0.74-1.16		0.62-1.40		0.71-1.18		0.62-1.40		0.71-1.18		0.490	
WHR																		
Without excess	Ref.	-	-	-	-	-	-	-	Ref.	-	-	-	-	-	-	-	-	-
With excess	1.24	0.042 †	1.46	0.060	1.13	0.331	1.23	0.052	1.43	0.071	1.12	1.43	0.071	1.12	0.88-1.44	0.353	0.353	
	1.01-1.53		0.98-2.15		0.89-1.45		0.99-1.51		0.97-1.12		0.88-1.44		0.97-1.12		0.88-1.44		0.353	
CI																		
Eutrophic	Ref.	-	-	-	-	-	-	-	Ref.	-	-	-	-	-	-	-	-	-
Obesity	1.05	0.669	1.85	0.011 †	1.02	0.880	1.19	0.090	1.79	0.014 †	1.01	1.79	0.014 †	1.01	0.78-1.30	0.958	0.958	
	0.84-1.29		1.15-2.96		0.79-1.31		0.97-1.47		1.12-2.88		0.78-1.30		1.12-2.88		0.78-1.30		0.958	

BMI-Z, Body mass index (score-z); WC, Waist Circumference; WHR, Waist/Height Ratio; CI, Conicity Index; CI95%, confidence interval of 95%; PR, prevalence ratio; Ref., reference; Poisson regression: *crude analysis, **adjusted for age and sex, ***adjusted for age, **p < 0.05.

Table IV
Raw and adjusted prevalence ratios in bivariate analysis for anthropometric indicators associated with asthma severity in adolescents

Nutritional status	Severe asthma						Severe asthma					
	Total* (n = 1362)		Male* (n = 574)		Female* (n = 788)		Total** (n = 1362)		Male*** (n = 574)		Female*** (n = 788)	
	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P	PR CI95%	P
BMI-Z												
Eutrophic	Ref.	-	-	-	-	-	Ref.	-	Ref.	-	-	-
Overweight	0.97	0.932	0.72	0.597	1.08	0.803	0.98	0.944	0.73	0.614	1.08	0.803
Obesity	0.55-1.72		0.21-2.43		0.57-2.06		0.56-1.72		0.21-22.5		0.57-2.06	
Severeobesity	0.94	0.901	2.07	0.231	0.51	0.350	0.93	0.883	2.08	0.227	0.51	0.351
	0.38-2.30		0.63-6.78		0.13-2.07		0.38-2.29		0.63-6.83		0.13-2.08	
	2.96	0.045 [†]	3.27	0.220	2.88	0.104	3.04	0.039 [†]	3.29	0.227	2.86	0.104
	1.02-8.58		0.49-21.78		0.80-10.30		1.05-8.76		0.48-2.46		0.80-10.2	
WC												
Without excess	Ref.	-	-	-	-	-	Ref.	-	-	-	-	-
With excess	0.93	0.093	0.87	0.748	1.11	0.701	1.03	0.902	0.87	0.741	1.12	0.681
	0.65-1.59		0.37-2.02		0.66-1.87		0.66-1.59		0.37-2.03		0.66-1.87	
WHR												
Without excess	Ref.	-	-	-	-	-	Ref.	-	-	-	-	-
With excess	1.26	0.296	1.09	0.828	1.30	0.307	1.23	0.340	1.09	0.821	1.31	0.312
	0.82-1.94		0.49-2.45		0.78-2.17		0.80-1.90		0.49-2.45		0.77-2.23	
CI												
Eutrophic	Ref.	-	-	-	-	-	Ref.	-	-	-	-	-
Obesity	1.11	0.636	2.05	0.151	1.10	0.714	1.28	0.260	2.08	0.143	1.10	0.708
	0.72-1.71		0.77-5.43		0.65-1.85		0.83-1.97		0.785.55		0.65-1.88	

BMI-Z, Body mass index (score-z); WC, Waist Circumference; WHR, Waist/Height Ratio; CI, Conicity Index; CI95%, confidence interval of 95%; PR, prevalence ratio; Ref., reference; Poisson regression: *crude analysis, **adjusted for age and sex, ***adjusted for age, *p < 0.05.

The risk of having severe asthma was 3 times higher among individuals who were classified as severely obese using the BMI-Z.

Discussion

The Brazil has a high prevalence of asthma in individuals aged 13-14 years, ranging from 11.8 to 30%. The prevalence of asthma among adolescents in Santa Maria, RS was higher compared to the total for all cities in southern Brazil that participated in Phase III of the ISAAC study. Considering wheezing over the past 12 months and asthma throughout life, the prevalence rates were 19%-20.7% and 13.6%-16.1% for ISAAC and the present study, respectively. For impaired speech, the prevalence in this study was lower (4.7% and 3.4%)¹⁵.

Furthermore, the prevalence of asthma evaluated by overall score (≥ 6) was approximately 5% and 7% higher than in studies of adolescents from public and private schools in Paraná state cities¹⁶ and in Rio de Janeiro¹⁷.

In this study, asthma was predominant among adolescent females, corroborating other studies of this age group^{13,18,19}. Although an association between female gender and asthma in adolescence has been recognised, the cause of this association has not yet been identified, and factors such as hormonal and psychosocial influences and environmental exposures for each gender have been indicated²⁰.

Regarding nutritional status measured by BMI among all adolescents, the prevalence rates were 6% and 3% higher for excess weight and obesity compared with the Brazilian population. When classified by gender, the rates were higher for women in this study and for men according to IBGE²¹.

This study showed a higher prevalence of excess abdominal adiposity for the whole sample than that obtained in the study by Wu *et al.*²². However, both studies showed higher percentages of excess abdominal fat in females according to the WC and WHtR indicators. In contrast, Sant'Anna *et al.*⁹ reported that there were no significant differences between genders regarding WC and WHtR indicators.

It is noteworthy that among the adolescents studied, those with asthma had higher rates of excess adiposity according to the BMI-Z and WC indicators for females and according to the WHtR and CI indicators for males. These results are similar to those found in a study of adults where females were significantly more likely to present obesity according to BMI and WC². In contrast, Kronander *et al.*³ and del Río Navarro²³ found no link between asthma and WC, but they did observe that men with abdominal obesity had an increased risk of developing asthma.

Asthma severity in most studies has included a medical diagnosis, and the odds ratio (OR) has ranged from 1.12 to 2.6^{24,25}. These results are similar to those

of this study, in which individuals with severe asthma showed a 3 times higher risk when classified with severe obesity via BMI-Z.

Most studies that have evaluated the correlations between adiposity and asthma have used self-reported height and weight to calculate BMI and have used various cut-off points. Most studies have considered the 95th percentile corresponding to obesity according to the growth curves of the *Center for Disease Control and Prevention* (CDC)²⁶. Currently, the WHO charts⁶ provide a set of standards that allow comparisons of data from different populations. These standards are considered the most sensitive available reference for the diagnosis of excess weight and appropriate for classifying nutritional disorders in Brazilian adolescents. It is noteworthy that this is one of the first studies to compare excess adiposity according to BMI-Z using the WHO⁶ standard for asthma.

Despite its strong correlation with measures of adiposity in adolescents, BMI may not be an accurate measure of the changes in body composition that occur in this age group and that are distinct between genders. Many authors employing nutritional indicators have shown significant correlations between WC and BMI and between WHtR and intra-abdominal adipose tissue^{7,27}.

An analysis of the abdominal adiposity indicators in this study showed that adolescents classified as having excess abdominal adiposity showed a 1.24 times greater risk of asthma according to the WHtR indicator and a 1.8 times greater risk for males according to the CI. Although the indicators associated with asthma and risk range differ, these results corroborate the findings of MUSAAD *et al.*⁴, who showed that asthma was significantly correlated with measures of central obesity, i.e., for every unit increase in WC, the OR for asthma was significantly increased by approximately 3 times (OR, 2.95). In boys, the CI was positively associated with asthma (OR, 2.43), and in girls, WC was negatively associated with asthma (OR, 0.43). It is noteworthy that the study evaluated American children and adolescents, and the indicators were analysed by percentiles and asthma diagnosed according to *American Thoracic Society* (ATS) standards.

Moreover, Leung *et al.*²⁸ evaluated WC, asthma and atopy, among other indicators, using the ISAAC questionnaire. The study indicated that in Chinese children, excess adiposity is associated with atopy, but not with asthma. This is an important observation because allergic sensitisation most likely contributes to the link between obesity and asthma.

In adults, the anthropometric variable evaluated in addition to BMI is WC, with measurement performed at the midpoint and asthma classified using a variety of methods, including self-reported, validated questionnaires and spirometry. Risks vary from 1.01 to 2.23, with differences between higher and lower risk populations and genders^{2,3,29}. Consistent with these outcomes, longitudinal studies indicate that regardless of

BMI, excess abdominal adiposity was associated with the late onset of asthma but not with early onset³⁰.

The mechanisms by which asthma is affected by abdominal adipose tissue are not clearly established, although several hypotheses have been proposed. Abdominal adiposity may mechanically affect the diaphragm and chest wall compliance with decreased lung volumes, especially in the supine position. Another hypothesis refers to the accumulation of visceral fat, which is positively correlated with pro-inflammatory markers, such as leptin, interleukin-6 and tumour necrosis factor- α , and negatively correlated with anti-inflammatory markers, such as adiponectin, that contribute to the hyper-responsiveness of the airways³¹.

The present study highlights that there is a positive prevalence ratio between WHtR and asthma. This association and the risks presented may in part be explained by the few studies that evaluated the relationship between WHtR and inflammatory markers. In non-asthmatics, WHtR is associated with the homeostasis model assessment of insulin resistance (HOMA-IR). The authors suggest that in this situation, lipolysis is intensified, producing atherogenic dyslipidemia; together with cytokine production by the visceral adipose tissue, this effect promotes inflammatory reactions and hepatic synthesis of C-reactive protein (CRP)^{27,32}.

Among the limitations of this study, the absence of uniform criteria for defining asthma in the studies may be cited. The ISAAC questionnaire is widely used for this purpose as its specificity has previously been demonstrated, but the information obtained can be subject to bias as the information is self-provided. Furthermore, it is known that obesity can induce respiratory symptoms that mimic asthma; however, obesity is not an independent predictor of asthma misdiagnosis³³.

The non-inclusion of pulmonary function in studies such as this does not seem to interfere specifically in the results. Pulmonary function tests are not decisive in the diagnosis of asthma because of their low sensitivity, and the authors observed that non-asthmatic obese children had responses that were very similar to those of the non-obese asthmatic group²³.

The classification of the students' sexual maturation could partially account for differences between the genders and body composition; however, the pubertal stage was not evaluated because the mean age of the adolescents was 15 years and, according to the literature, such children would be classified as post-pubescent³⁴. Additionally, Vink *et al.*³⁵ found no association between sexual maturation and the prevalence of asthma.

As with other studies, there was a high prevalence of excess weight, obesity and asthma. Adolescents with asthma have higher rates of excess adiposity according to BMI-Z and WC indicators in females and according to WHtR and CI in males. However, it is suggested that excess body weight and abdominal obesity are factors that increase the risk of asthma and its

severity in adolescents. Therefore, we recommend that additional measures of BMI and WHtR are included in the nutritional evaluation of asthmatic adolescents; in this regard, the only additional measurement that would need to be performed would be waist circumference, which is quick, simple and inexpensive.

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