

# Obesity and pulmonary function tests in children and adolescents: a systematic review

*Obesidade e testes de função pulmonar em crianças e adolescentes: uma revisão sistemática*

*Obesidad y pruebas de función pulmonar en niños: una revisión sistemática*

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## ABSTRACT

**Objective:** To perform a systematic review of observational studies that analyzed the relation between spirometric parameters and the presence of obesity in children and adolescents.

**Data source:** Data were selected without language restriction, using the following databases: PubMed/Medline, Scopus, Lilacs, and SciELO, with no restriction as to initial date until December 2010. The descriptors were extracted from Medical Subject Headings: “respiratory function tests” and “childhood obesity”.

**Synthesis of data:** 89 papers were initially found, but only five were selected. Observational studies reporting spirometric parameters and body mass index of the patients were included, and those that assessed pulmonary function by other methods and whose subjects were not exclusively children or enrolled patients with associated comorbidities were excluded. In order to assess the quality of these studies, the scale for observational studies of the Agency for Healthcare Research and Quality was applied. All studies evaluated the forced vital capacity and the forced expiratory volume on the first second. Four papers also assessed the forced expiratory flow between 25 and 75%, forced expiratory flow at 50%, expiratory peak flow, and the relation between forced expiratory volume on the first second and forced vital capacity.

**Conclusions:** The studies show consistent data and evidence of association between decreased spirometric values of forced vital and capacity and forced expiratory volume on the first second with obesity in children and adolescents.

**Key-words:** obesity; children; adolescents; spirometry.

## RESUMO

**Objetivo:** Realizar uma revisão sistemática sobre os estudos observacionais que analisaram a relação entre os parâmetros espirométricos e a obesidade em crianças e adolescentes.

**Fontes de dados:** Os dados foram selecionados sem restrição de idioma, utilizando-se as bases de dados PubMed/Medline, Scopus, Lilacs e SciELO, sem data inicial até dezembro de 2010. Os descritores foram extraídos do *Medical Subject Headings* e incluíram “*respiratory function tests*” e “*childhood obesity*”.

**Síntese dos dados:** Por meio da estratégia de busca, 89 artigos foram encontrados, dos quais apenas cinco foram selecionados. Foram incluídos estudos observacionais com descrição dos parâmetros espirométricos e do índice de massa corpórea, sendo excluídos estudos com outros métodos de avaliação da função pulmonar, população não exclusiva de crianças/adolescentes e presença de comorbidades associadas à obesidade. Para avaliação da qualidade dos estudos

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utilizou-se a escala para estudos observacionais da *Agency for Healthcare Research and Quality*. Os estudos avaliaram a capacidade vital forçada e o volume expiratório forçado no primeiro segundo. Quatro artigos avaliaram também o fluxo expiratório forçado entre 25 e 75%, aquele em 50%, o pico de fluxo expiratório e a relação entre o volume expiratório forçado no primeiro segundo e a capacidade vital forçada.

**Conclusões:** Os artigos mostram evidências significativas de associação entre a diminuição dos valores de capacidade vital forçada e volume expiratório forçado no primeiro segundo com a obesidade em crianças e adolescentes.

**Palavras-chave:** obesidade; crianças; adolescentes; espirometria.

## RESUMEN

**Objetivo:** Realizar una revisión sistemática sobre los estudios observacionales que analizaron la relación entre los parámetros espirométricos y la obesidad en niños y adolescentes.

**Fuentes de datos:** Los datos fueron seleccionados sin restricción de idioma, utilizándose las bases de datos PubMed/Medline, Scopus, Lilacs y Scielo, sin fecha inicial hasta diciembre de 2010. Los descriptores fueron extraídos del *Medical Subject Headings* e incluyeron «*respiratory function tests*» y «*childhood obesity*».

**Síntesis de los datos:** Por medio de la estrategia de búsqueda, se encontraron 89 artículos, de los que solamente cinco fueron seleccionados. Se incluyeron estudios observacionales con descripción de los parámetros espirométricos y del índice de masa corporal, siendo excluidos estudios con otros métodos de evaluación de la función pulmonar, población no exclusiva de niños/adolescentes y presencia de comorbidades asociadas a la obesidad. Para evaluación de la calidad de los estudios, se utilizó la escala para estudios observacionales de la *Agency for Healthcare Research and Quality*. Los estudios evaluaron la capacidad vital forzada y el volumen espiratorio forzado en el primer segundo. Cuatro artículos evaluaron también el flujo espiratorio forzado entre 25 y 75%, aquél en 50%, el ápice de flujo espiratorio y la relación entre el volumen espiratorio forzado en el primer segundo y la capacidad vital forzada.

**Conclusiones:** Los artículos muestran evidencias significativas entre la reducción de los valores de capacidad vital forzada, volumen espiratorio forzado en el primer segundo y viceversa, con la obesidad en niños y adolescentes.

**Palabras clave:** obesidad; niños; adolescentes; espirometría.

## Introduction

Obesity, defined as excessive fat tissue, contributes to the development of several systemic diseases and higher mortality<sup>(1-3)</sup>. Some clinical conditions, such as type II diabetes, strokes, dyslipidemia, hypertension, cardiovascular and respiratory diseases, depression and some types of cancer, as associated with metabolic syndrome, whose causes are complex and not well defined yet<sup>(3,4)</sup>. Another object of concern is the fact that obesity has become pandemic and its prevalence has increased at an accelerated rate among children and adults in several countries<sup>(5-7)</sup>.

Obesity may affect several body systems and, therefore, lead to higher morbidity and mortality rates in the population<sup>(8-10)</sup>. Of all those affected, the respiratory system deserves special attention because obesity promotes important changes in its mechanics, in tolerance to exercise, gas exchanges, control of the respiratory pattern and the strength and endurance of respiratory muscles<sup>(11-14)</sup>.

According to ventilatory mechanics and pulmonary function, this accumulation of fat may lead to dysfunctions of the several structures that make up the respiratory system, particularly the muscles that take part in breathing. This may lead to changes in pulmonary functions due to the increase in respiratory effort and the compromise of gas transport<sup>(15,16)</sup>. The negative impact on pulmonary function in obese adults is directly proportional to the degree of obesity, which reductions of expiratory reserve volume (ERV); increase in small airway resistance; increase in the residual volume to total lung capacity ratio (RV/TLC); reduction of lung and thorax compliance; reduction of oxygen arterial pressure and increase of the oxygen arterial-alveolar difference and alveolar hypoventilation<sup>(17-19)</sup>. In contrast, studies found that obesity at a low level has little effect on pulmonary function<sup>(20-22)</sup>.

In childhood, it is difficult to evaluate obesity because of the intense rate of change of body structures during growth, and there is not universally accepted system to classify childhood obesity. However, the World Health Organization (WHO) takes into consideration the distribution of the weight/height Z score, which is the ratio of weight measured and ideal weight for height, that is, the body mass index (BMI) is used<sup>(4,23,24)</sup>. The number of obese children has increased significantly, which predisposes them to the same changes in respiratory mechanics as adults<sup>(25,26)</sup>. Although

the correlation between overweight/obesity with respiratory pressures was described in some studies, their association is not clear in children and adolescents<sup>(15,27,28)</sup>.

This study conducted a systematic review of observational studies to evaluate current scientific evidence of the association between childhood obesity and pulmonary function.

## Method

Studies conducted any time until December 2010 were retrieved from the PubMed/Medline, Scopus, Lilacs and Scielo databases. The following keywords were selected in the Medical Subject Heading (MeSH) and the Descritores em Ciência da Saúde (DeCS): “respiratory function tests” and “childhood obesity”.

The searches were conducted independently in the electronic databases by two experienced authors. The following criteria were used to select studies: complete studies with human beings written in any language. Inclusion criteria were: observational studies with spirometric parameters and BMI. The studies that used a different type of pulmonary function evaluation, whose participants were not only children, or which included comorbidities were excluded.

To evaluate the level of study quality, we used a scale of the Agency for Healthcare Research and Quality (AHRQ) for observational studies, modified and validated by West *et al*<sup>(29)</sup>. These criteria have been used in several systematic reviews with and without a final assessment score<sup>(30-32)</sup>. The AHRQ scale, modified by West *et al*<sup>(29)</sup>, includes the

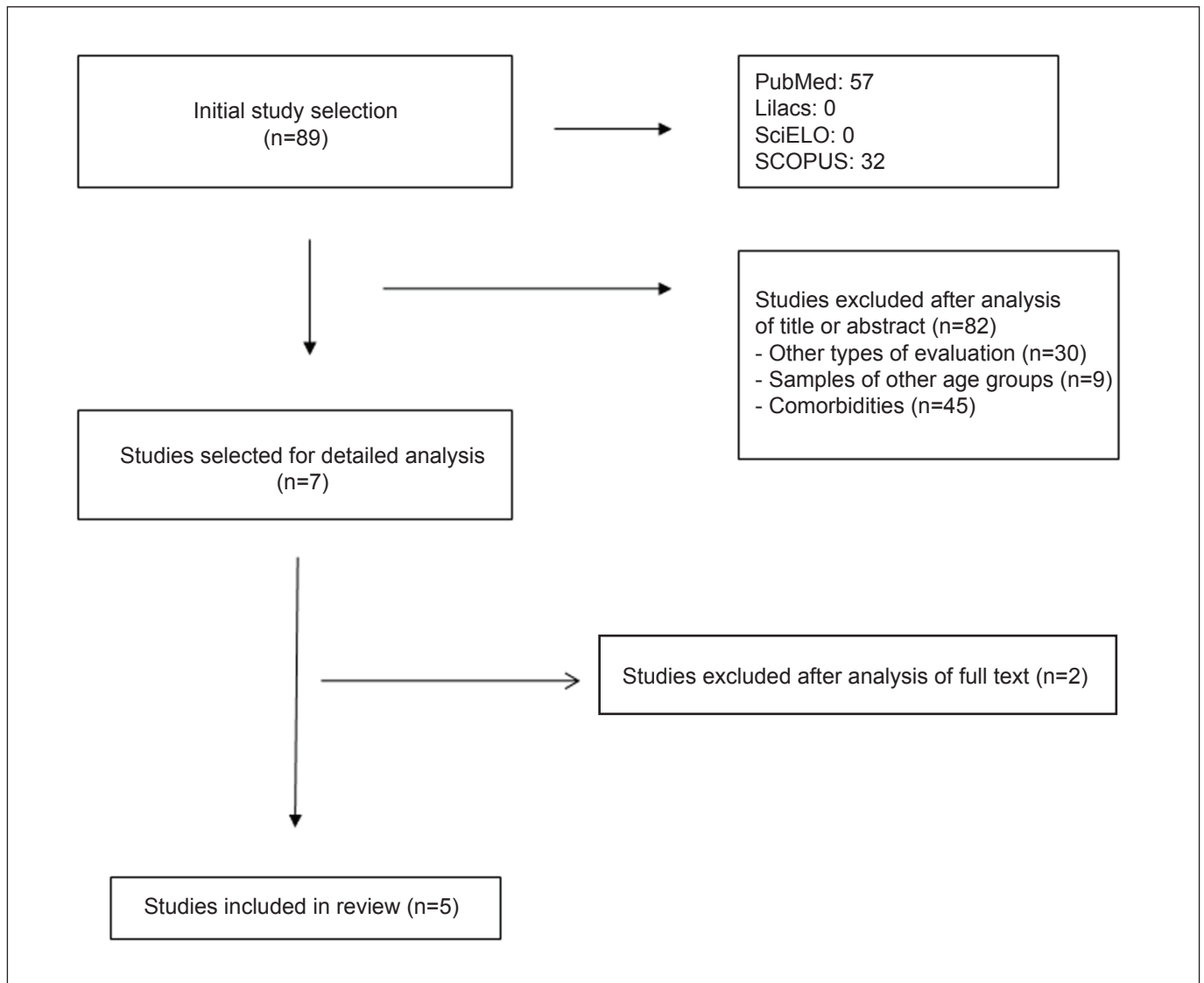


Figure 1 - Flowchart of literature reviewed

following criteria for evaluations (points): study question (2), population under study (8), participant comparability (22), exposure or intervention (11), result measures (20, statistical analysis (19), results (8), discussion (5) and support or sponsorship (5), at a total of 100 points.

Titles and abstracts were identified by two experienced independent investigators familiar with the selection of potentially relevant studies. Disagreements were discussed with a third evaluator. After selection, the studies were evaluated according to quality criteria.

## Results

The search yielded 89 studies, and seven (8%) were selected for data analysis according to the inclusion criterion previously established. One (1%) was excluded due to incompatibility of the inclusion and exclusion criteria because

the authors did not evaluate pulmonary function, and one (1%) due to the fact that the study population had asthma.

Figure 1 describes the five (6%) studies included in this review: Lazarus *et al*<sup>(27)</sup>, Ulger *et al*<sup>(33)</sup>, Eisenmann *et al*<sup>(34)</sup>, He *et al*<sup>(35)</sup> and Chow *et al*<sup>(36)</sup>. The characteristics of the studies selected are presented according to date of publication (Table 1). In the five studies included in the study, 5,579 boys and girls were studies, and 2,742 (49%) were girls. There was a wide variation in the sample size included in the quantitative studies. Four studies were conducted in the Asian continent<sup>(33-36)</sup> and one, in Oceania<sup>(37)</sup>. For the classification of obesity, only the studies conducted by Ulger *et al*<sup>(33)</sup> and Chow *et al*<sup>(36)</sup> described Z score for their samples.

For the analysis of pulmonary function, the studies selected<sup>(27,33-36)</sup> used spirometers, but only Ulger *et al*<sup>(33)</sup>, Eisenmann *et al*<sup>(34)</sup> and He *et al*<sup>(35)</sup> described calibration procedures. The following spirometric variables were included

**Table 1** - Characteristics of studies eligible for the review

Authors (country)	Subjects	Objectives	Spirometric variables	Results
Lazarus <i>et al</i> <sup>(27)</sup> (Australia)	2,464 (1,242 F/1,222 M)	To investigate the effect of total body fat on ventilatory function as TBF% among children	FVC (L), FEV <sub>1</sub> (L)	FVC and FEV <sub>1</sub> increased with weight ( $p < 0.0001$ ) and FVC and FEV <sub>1</sub> decreased with TBF% ( $p < 0.0001$ ). Ventilatory function decreases with the increase of body fat.
Ulger <i>et al</i> <sup>(33)</sup> (Turkey)	68 (OG – 38; 22 M/16 F; CG – 30; 16 M/14 F)	To evaluate the effect of childhood obesity on pulmonary function tests.	FVC (L), FEV <sub>1</sub> (L), PEF (L/s), FEF <sub>25-75%</sub> (L/s, FEV <sub>1</sub> /FVC (%))	FVC ( $p < 0.001$ ), FEV <sub>1</sub> ( $p < 0.001$ ) and FEF <sub>25-75%</sub> ( $p < 0.001$ ) were lower in OG.
Eisenman <i>et al</i> <sup>(34)</sup> (India)	813 (384 M/429 F)	To evaluated the effect of pulmonary function on obese children.	FVC (L), FEV <sub>1</sub> (L), FEV <sub>1</sub> % , FEF <sub>25-75%</sub> (L/s)	Pulmonary function is affected by childhood obesity, with a decrease of FVC ( $p < 0.05$ ), FEV <sub>1</sub> ( $p < 0.05$ ) and FEV <sub>1</sub> /FVC ( $p < 0.05$ ).
Chow <i>et al</i> <sup>(36)</sup> (China)	55 (M) NONA (13) ONA (16) NOA (15) OA (11)	To evaluate the association of spirometric parameters and childhood obesity.	FEV <sub>1</sub> predicted (%), FVC predicted (%), FEV <sub>1</sub> /FVC (%), FEF <sub>25</sub> predicted (%), FEF <sub>50</sub> predicted (%), FEF <sub>75</sub> predicted (%)	Decreases FVC ( $p = 0.041$ ) and FEV <sub>1</sub> ( $p = 0.049$ )
He <i>et al</i> <sup>(35)</sup> (China)	2.179 1138 (M/1.041 F)	Study the association between asthma, asthma symptoms and pulmonary function in children.	FVC (L), FEV <sub>1</sub> (L), FEF <sub>25-75</sub> (L/s), FEF <sub>75</sub> (L/s), FEF <sub>25</sub> (L/s)	FVC increased with BMI. Obese children had higher FEV <sub>1</sub> than children whose weight was normal**.

M: male; F: female; OG: obese group; CG: control group; BMI: body mass index; NONA: group of non obese children without asthma; ONA: group of obese children without asthma; NOA: group of nonobese children with asthma; AO: group of obese children with asthma; TLC: total lung capacity; RV: residual volume; RV/TLV: residual volume to total lung capacity ratio; FVC: forced vital capacity; FEF<sub>25-75%</sub>: forced expiratory flow at 25 and 75%; FEV<sub>1</sub>: forced expiratory flow in 1 second; FEV<sub>1</sub>/FVC: ration of forced expiratory flow in 1 second to forced vital capacity; PEF: peak expiratory flow; \* data not available; value of p not available

**Table 2** - Quantitative analysis of studies selected in this systematic review (modified AHRQ scale<sup>1</sup>)

Criteria	Weighed score	Lazarus et al <sup>(27)</sup>	Eisenmann et al <sup>(34)</sup>	Ulger et al <sup>(33)</sup>	Chow et al <sup>(36)</sup>	He et al <sup>(35)</sup>
1. Study objective	2	2	2	2	2	2
• Clearly focused and appropriate						
2. Study population	8	8	8	5	5	8
• Description of study population						
• Sample size calculation						
3. Comparability of participants in observational studies	22	19	0	13	13	8
• Specific inclusion and exclusion criteria for all groups;						
• Criteria equally applied to all groups;						
• Comparability of groups at beginning of study according to disease and prognostic factors						
• Study groups comparable to groups of individuals not included according to confounding factors;						
• Use of control group;						
• Comparability of follow-up between groups in each evaluation						
4. Exposure or intervention	11	11	9	11	11	11
• Clear definition of exposure;						
• Standard, valid and reliable measurement method;						
• Exposure equally measured in all study groups.						
5. Measurement of results	20	13	15	13	13	15
• Clearly defined primary and secondary outcomes;						
• Blinded measurements of exposure or intervention outcome;						
• Standard, valid and reliable method to evaluate results;						
• Length of follow-up adequate to study objective.						
6. Statistical analysis	19	10	12	8	10	10
• Appropriate statistical tests						
• Multiple comparisons included in considerations;						
• Appropriate techniques and models for multivariate analysis;						
• Information provided about power calculation ;						
• Analysis of confounding factors;						
• Dose-response evaluation, if appropriate.						
7. Results	8	8	6	5	8	8
• Effect size for results and adequate precision measurements.						
• Adequate follow-up for each study group						
8. Discussion	5	5	4	5	3	5
• Conclusions supported by results and discussion of possible biases and limitations.						
9. Funding and support	5	5	5	0	5	0
• Type and source of funding for the study						
Total score	100	81	57	57	70	67



in the studies:<sup>(27,33-36)</sup> TLC, RV, VR/TLC, forced vital capacity (FVC), forced expiratory flow at 25A and 75% ( $FEF_{25-75\%}$ ), forced expiratory volume in 1 second ( $FEV_1$ ),  $FEV_1/FVC$  and peak expiratory flow (PEF). In the analysis of spirometric variables and body weight gains, Lazarus *et al*<sup>(27)</sup>, Ulger *et al*<sup>(33)</sup>, Eisenmann *et al*<sup>(34)</sup>, He *et al*<sup>(35)</sup> and Chow *et al*<sup>(36)</sup> unanimously found an inverse association between BMI, FRC and  $FEV_1$ . Table 1 also shows the limitations of the studies according to those authors.

No study reached the total score in the AHRQ scale, but the publication with the best score reached 81 points<sup>(27)</sup>. The quantitative analysis is described in Table 2.

## Discussion

Respiratory function is affected in obese children, may be due to changes in the mechanics of respiratory muscles that expand the thorax and in lung compliance and resistance, which may lead to rapid, shallow breathing, increased work of breathing and reduced maximal ventilatory capacity<sup>(37-39)</sup>.

Several studies found an association between ventilatory abnormalities and obesity in adults<sup>(40-44)</sup>, but according to others, further studies should be conducted to elucidate the effect of childhood obesity in ventilatory patterns<sup>(27,33-36)</sup>. The difficulty in analyzing this association in children results from respiratory changes found in childhood. However, among adults, other behavioral or environmental factors may be involved, such as smoking<sup>(45,46)</sup>.

The increase of obesity in childhood directly contributes to obesity in adulthood and the consequence is the increase in the incidence of diseases associated with mortality, such as cardiovascular diseases, metabolic syndrome, dyslipidemia, diabetes, hypertension and even respiratory disorders, among others<sup>(47-49)</sup>.

Lazarus *et al*<sup>(27)</sup> investigated the effects of obesity on the ventilatory function of Australian children aged nine, 12 and 15 years. Their main hypothesis was that the percentage of body fat might affect ventilatory function regardless of height, weight and sex. Their study data were collected in the Australian Health and Fitness Survey (AHFS) of Schoolchildren in 1985 and included 8,484 children aged seven to 15 years. Data about ventilatory function were available for only 2,464 individuals (1,222 men). Their main results were a positive association between weight and increased FVC and  $FEV_1$ , regardless of height, age or sex. Those authors reported that large proportions of body fat are associated with decreased values of ventilatory

function, and also described two important limitations of their study: the lack of a prediction equation, according to ethnicity in their population and a direct method to evaluate body composition.

Conversely, Ulger *et al*<sup>(33)</sup> conducted an investigation based on previous studies to explain the effects of obesity on respiratory function tests in childhood and to define the association between the degree of obesity and respiratory function. Their sample comprised 68 children aged nine to 15 years, where 38 (55%) were obese and 30 (44%) whose weight was normal and formed the control group. Their inclusion and exclusion criteria, such as age, exposure to smoking and cardiopulmonary disease, aimed at reducing study biases. Pulmonary function tests were performed using a calibrated spirometer and following the guidelines of the European Respiratory Society (ERS). Those authors found heterogeneous results for weight and BMI in the groups. The respiratory function results, except  $FRV_1/FVC$ , were lower in the group of obese children than in the control group. In the same study, the authors mention that one of the limitations of the respiratory function test was the lack of reference parameters for the Turkish population.

Also to evaluate the effect of obesity on the pulmonary function of children, Eisenmann *et al*<sup>(34)</sup> examined 557 (68%) Navajo children and 256 (21%) Hopi children, at a total of 813 children aged five to 12 years in the state of Arizona. Of the Navajo children, 274 (49%) were boys, and of the Hopi children, 110 (43%) were boys. All children underwent tests to investigate allergies and preexisting pulmonary diseases. Spirometry was performed according to the standards defined by the American Thoracic Society (ATS) and the unit was properly calibrated. Their main result was a decrease in pulmonary function of obese children. Of the limitations of their study was the difficulty in defining body composition for the children because of the changes in lean mass and the presence of puberty in the age group under study.

The study conducted by Chow *et al*<sup>(36)</sup> evaluated airway inflammation in addition to investigating the association between obesity and spirometric parameters among children. Children and adolescents aged six to 18 years were recruited (n=55) and divided into four study groups: non obese and without asthma (n=13); obese and without asthma (16); non obese with asthma (n=15) and obese with asthma (n=11). The authors classified obesity according to the WHO criteria using

the Z score. As in the study conducted by Ulger *et al*<sup>(33)</sup>, they used rigorous inclusion and exclusion criteria to avoid biases in data collection, such as the exclusion of patients exposed to smoking and those with systemic diseases. They did not follow any specific guidelines to standardize collection of spirometric data and did not describe how the spirometer was calibrated. The main result for the spirometric variables was the positive correlation between Z score and FVC; however, the antropometric variable was inversely associated with FEV<sub>1</sub>. In the analysis of study limitations, the authors discuss sample size, which might be responsible for false positive results.

He *et al*<sup>(35)</sup> examined the association between obesity and asthma and the characteristic symptoms of asthma with pulmonary function. Their sample comprised 2,179 children divided into three groups: normal weight (n=1,845), overweight (n=183) and obese (n=151). Pulmonary function was evaluated using the ATS standards. The authors used the Pearson test to compare the basic characteristics between groups and linear regression to evaluate whether spirometric parameters and levels of obesity were

associated. Their main result in the analysis of obesity and pulmonary function was the positive correlation between FVC and BMI increases. The authors mentioned that one of the limitations of their study was the fact that pulmonary function should be analyzed longitudinally to investigate the effects of BMI along time. The diagnosis of asthma severity was not evaluated among children.

The main limitation of this systematic review was the small number of studies about childhood obesity and pulmonary function and the lack of standardization and uniform pulmonary function values for children and adolescents. Therefore, this systematic review could not generate a meta-analysis to provide quantitative evidence of pulmonary function in this age group.

This systematic review analyzed studies that demonstrated evidence of an association between lower FVC, FEV<sub>1</sub> and FEV<sub>1</sub>/FVC values in obese children and adolescents. Further studies should investigate pulmonary function in childhood obesity because studies so far are scarce and often have methodological flaws. Moreover, reference parameters should be established for BMI values among children and adolescents.

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