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The Effect of Obesity Degree on Childhood Pulmonary Function Tests

Emel Torun[1], Erkan Cakir[2], Fatma Özgüç[1], İlker Tolga Özgen[3]

[1]Department of Pediatrics, Bezmialem Vakif University Faculty of Medicine, İstanbul, Turkey
[2]Department of Pediatric Pulmonology, Bezmialem Vakif University Faculty of Medicine, İstanbul, Turkey
[3]Department of Pediatric Endocrinology and Metabolism, Bezmialem Vakif University Faculty of Medicine, İstanbul, Turkey

Background: Childhood obesity has become a global epidemic. It is related to several chronic diseases such as essential hypertension, type 2 diabetes mellitus, and renal disease. The relationship between the degree of obesity and lung functions is well defined in adults, but limited information is available about the childhood period.
Aims: This study aims to determine the impact of the degree of obesity on the pulmonary functions of school children and adolescents.
Study Design: Cross sectional study.
Methods: Included in the study were a total of 170 school children and adolescents (9-17 years old) referred to our paediatric outpatient clinic. Of these subjects, 42 were lean and non-obese (BMI % <85), 30 subjects were overweight (BMI % >85, <95), 34 subjects were obese (BMI % >95, <97), and 64 subjects were morbidly obese (BMI % >97). Anthropometric measurements were taken and spirometry was performed on all subjects. Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), forced vital capacity 25-75 (FEV_{25-75}) and peak expiratory flow (PEF) were used to measure the ventilatory functions for all the subjects.
Results: The groups showed no significant differences in age or gender. Despite no statistically significant differences in FEV_1, FVC, or FEV_1/FVC, there were significant reductions in PEF ($p<0.001$) and FEV_{25-75} ($p<0.001$) in the overweight, obese and morbidly obese subjects, when compared with those who were non-obese.
Conclusion: Overweight, obese and morbidly obese children have no obstructive abnormalities compared with healthy lean subjects.
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Key Words: Adolescent, obesity, respiratory function tests, school children

The prevalence of obesity is increasing in adults and in children worldwide (1). Being overweight or obese is associated with a reduced quality of life and an increased risk of several chronic diseases (2-4). Pulmonary function abnormalities are one of the well-defined complications of obesity in adults (5). Obesity may lead to reduced lung volume in non-asthmatic adults (1, 6). Several mechanisms may be related to obesity and reduce thoracic wall compliance. One of these is the restriction of diaphragm movement and thoracic cage expansion (5). Another mechanism that leads to reduced lung compliance is the combination of an alveolar collapse together with an airway closing in the base of the lung, with increasing blood volume (7). Obesity may lead to a reduced capacity for functional exercise and to symptoms suggestive of lung disease (8). Although studies in different study populations have yielded different results, generally obesity has little effect on vital capacity or total lung capacity. It does, however, cause a reduction in the functional residual capacity and the expiratory reserve volume as a result of altered chest wall mechanisms in adults (9, 10).

Studies on the effect of childhood obesity on pulmonary function test parameters have revealed inconsistent results (11-14). Limited information is available about the effects of changes in obesity status and decline of lung function in children. We aimed to compare the lung functions of non-obese children to those of overweight, obese and morbidly obese children and to detect the effect of the degree of obesity on pulmonary function tests.

MATERIAL AND METHODS

Thirty overweight, 34 obese and 64 morbidly obese children and adolescents who had been admitted to our paediatric endocrinology department were enrolled in this cross-sectional study. The control group was composed of 42 non-obese

Address for Correspondence: Dr. Emel Torun, Department of Pediatrics, Bezmialem Vakif University Faculty of Medicine, İstanbul, Turkey
Phone: +90 212 453 17 00 e-mail: dr.emeltorun@gmail.com
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TABLE 1. Demographic features and mean anthropometric data of the groups

	Group 1 (n=42) mean±SD	Group 2 (n=30) mean±SD	Group 3 (n=34) mean±SD	Group 4 (n=64) mean±SD	f	p[+]
Age (years) (mean±SD)	11.6±2.1	12.6±1.7	12.6±2.3	12.5±2.5	1.9	0.128
Gender (female %)	23 (54.8)	14 (45.2)	15 (45.4)	31 (48.4)	-	0.239
Height (cm) (mean±SD)	147.8±12.1	149.9±15.4	151.8±13.4	145.9±14	1.069	0.365
BMI (kg/m^2) (mean±SD)	17.8±2.2	24.2±1.9	26.9±2.3	30.3±3.5	163.3	<0.001*
BMI % (mean±SD)	49.1±20.9	91.1±3.4	96.1±0.5	98.3±0.72	215.2	<0.001*
BMI SDS (mean±SD)	-0.18±0.92	1.37±0.2	1.77±0.1	2.18±0.19	216	<0.001*

Group 1: Non-obese control group; Group 2: Overweight group; Group 3: Obese group; Group 4: Morbidly obese group
SD: standard deviation; BMI: body mass index; BMI SDS: body mass index standard deviation score; BMI %: body mass index percentage; vs: versus
Statistical tests: One-Way ANOVA.
[+]Tukey post-hoc test
*1 vs. 2, 3, 4; 2 vs. 1, 3, 4; 3 vs. 1, 2, 4 and 4 vs. 1, 2, 3

healthy lean children and adolescents who were brought to our general paediatric clinic for routine visits. After a detailed history and physical examination, including an evaluation of asthma or other atopic diseases and endocrine diseases, children who had atopic or chronic respiratory diseases, asthma, or a family history of asthma, or who had atopic dermatitis, or any food intolerance or a syndromal problem (Prader Willi, Laurence-Moon Biedel syndrome, etc.), were not included in the study. None of the participants were using any medication or had any history or evidence of current metabolic, cardiovascular, respiratory or hepatic disease.

Body mass index (BMI) was calculated by dividing weight by height in meters squared (kg/m²). Standing height was measured to the nearest 0.1 cm with a Harpenden fixed stadiometer. Body weight (kg) was measured on a SECA balance scale to the nearest 0.1 kg, with each subject dressed off. The children were divided into 4 groups according to BMI percentile (BMI %), i.e., Group 1: normal weight (BMI % <85th), Group 2: overweight (BMI % >85th, <95th), Group 3: obese (BMI % >95th, <97th) and Group 4: morbidly obese (BMI % >97th) (15, 16). Obesity was defined according to the International Task Force of Obesity in Childhood and Population-Specific Data (17, 18).

All the subjects were analysed by spirometry (MIR, Spirolab III colour, Roma, Italy). The best of at least three technically acceptable values for forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC), forced vital capacity 25-75 (FEF_{25-75}) and peak expiratory flow (PEF) were used as measures of ventilatory function (19). Obstructive airway disease was identified as a decrease in the FEV_1/FVC ratio to <80% (19).

Version 19 of the Statistical Package for the Social Sciences (SPSS) statistical program for Windows (SPSS Inc., Chicago, IL, USA) was used to perform the data analysis. Normally distributed continuous data is presented as a mean±standard deviation (SD). Means and standard deviations were calculated and data were tested by one-way ANOVA test. Post-hoc tests were calculated using the Tukey's multiple comparison test. A p value of <0.05 was considered statistically significant.

The study was approved by the local ethics committee. Informed written consent was obtained from the subjects themselves (if they were older than 12) and from their parents.

RESULTS

A total of 170 children aged between the ages of 9 to 17 years old were enrolled in the study. Age and gender distribution were not statistically different between the four groups (Table 1). Body mass index, BMI SDS and BMI % were significantly different between the 3 groups (p<0.001).

Comparing the non-obese lean group with the overweight, obese and morbidly obese subjects, the mean FVC and FEV_1/FVC and FEV_1 values were found to decrease, but not to a statistically significant level (p=0.232, 0.089 and 0.054, respectively). There were significant differences between the non-obese group and the overweight, obese and morbidly obese groups in terms of PEF and FEV_{25-75} (p<0.001) (Table 2).

DISCUSSION

Overweight, obese, and morbidly obese people may have variables which differ from those people with normal weight, and which could have an effect on the pulmonary capacity and respiratory function. In adults, obesity leads to the reduction of the pulmonary function because the reserve volume is reduced and so is the functional vital capacity, which is, in turn, caused by a reduced chest wall and lung compliance (20-22). However, studies on children have found conflicting results. Lung compliance, vital capacity, and residual volume in obese children are similar to those of non-obese children in the majority of the studies (23-26). On the other hand, some studies

TABLE 2. Pulmonary function tests of non-obese, obese and morbid obese children

	Group 1 (n=42) mean±SD	Group 2 (n=30) mean±SD	Group 3 (n=34) mean±SD	Group 4 (n=64) mean±SD	f	p
FVC %	92.1±13.4	87.9±11.4	93.4±10.5	91.9±12.4	1.443	0.232
FEV_1 %	100.2±10.8	92.9±12.5	96.7±9.8	95.6±11.3	2.750	0.054
FEV_1/FVC	101.8±10.9	101.5±6.7	96.4±10.2	99.7±9.5	2.211	0.089
PEF	84.1±12	69.9±14.2	72.9±12.6	74.8±10.5	9.678	<0.001*
FEV_{25-75}	119.1±22.3	101.4±23.9	97.4±21.8	99.9±20.6	8.295	<0.001*

Group 1: Non-obese control group; Group 2: Overweight group; Group 3: Obese group; Group 4: Morbidly obese group
FVC: forced vital capacity; FEV_1 %: forced expiratory volume in 1 second; PEF: peak expiratory flow; FEV_{25-75}: forced expiratory volume
Statistical tests: One-Way ANOVA, Tukey post-hoc test
*1 vs. 2, 3, 4

have confirmed reduced functional residual capacity and static lung volumes (12-14). The impact of obesity on respiratory functions in overweight, obese and morbidly obese children has not yet been fully determined. We aim to understand the effect of the degree of obesity on pulmonary function tests in children.

FEV_1, FVC and FEV_1/FVC are the most important indicators of obstructive diseases in a pulmonary function test. Although in the present study, FEV_1, FVC, and FEV_1/FVC values were lower in overweight, obese and morbidly obese subjects, the difference was not statistically significant. It was also found that the overweight, obese and morbidly obese children and adolescents had no obstructive impairment compared to healthy ones.

In our study, the FEV_{25-75} and PEF values were found to be reduced in overweight, obese and morbidly obese children and adolescents compared with their healthy lean peers. This could be explained by airflow limitation related to lower inspiratory pressure and flow as well as reduced respiratory muscle strength. The extrinsic mechanical compression on the lung together with the thorax might also be the leading mechanism of a decreased FEV_{25-75} in our study. Because the PEF is limited by force-velocity characteristics of expiratory muscles instead of mechanical properties of the lung and airways, insufficient force would lead to flow limitation (27).

In the adult studies that investigated the effect of changes in obesity status, the spirometric parameters revealed a variable reduction as the degree of obesity increased. Weight loss appeared to be capable of reducing the decline of lung functions linked to obesity (28). Data about the impact of the degree of obesity in children and adolescents showed conflicting results. The studies about lung functions in obese children most frequently reported abnormalities in lung volumes and expiratory flow rates. Inselman et al. (13) found a reduced diffusion capacity and ventilatory muscle endurance among obese children. Marcus et al. (26) found both restrictive and obstructive abnormalities on pulmonary function tests in obese children. Mallory et al. (12) reported that obstructive abnormalities were the main problem in obese children. Li et al. (14) found that reduction in the functional residual capacity and a diffusion impairment in obese adolescents correlated to the degree of obesity. Paralikar et al. (29) reported a strongly negative correlation between the FEV_1/FVC, maximum voluntary ventilation, and $FEF_{25-75\%}$ with body weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio in obese and non-obese boys. A similar negative correlation between the BMI and pulmonary functions was observed in India by Sri Nageswari et al. (30) in a group of obese children of mixed socioeconomic backgrounds. They hypothesised that obesity is characterised by a decrease in chest wall compliance due to an increased amount of adipose tissue around the chest and abdomen, which decreases the pulmonary functions in these children. In our study, the baseline pulmonary function test parameters were not different between the children and adolescent subjects, who were overweight, obese, and morbidly obese, compared to those who were lean and healthy.

Reports about lung functions after weight loss showed obese asthmatic adolescents to report significant improvements in asthma outcomes (31), static lung functions (including expiratory reserve volume), and quality of life scores (32). The effect of weight loss in obese non-asthmatic children was not evaluated. It would be ideal to assess the changes in lung function in healthy obese children after they have lost weight.

Our study has certain limitations. The waist-to-hip ratio has been suggested to explain a large part of the variance in pulmonary functions rather than the BMI (33, 34); in order to decrease the lung volume in obese patients, fat distribution and tissue composition are needed (35). However, body proportions normally change during pubertal development and can vary according to the individual, therefore, measuring waist circumference and fat distribution makes it difficult to interpret in children. BMI was used according to the previously defined criteria as a measure of obesity (36). We also recognise that the integration of covariates related with the obesity (such as physical activity, socioeconomic status) and co-morbidites (such as diabetes, hypertension, and hyperlipidaemia) could have effects on pulmonary function tests.

Finally the sample size of the present study was not calculated *a priori*, but the power of the study with the current sample size was calculated (by NCSS-PASS program) *a posteriori* using the observed results. The study had a power of 80% to observe significant differences between three groups with α=0.05.

Our study results did not support obstructive abnormality in obese and morbidly obese children compared with healthy lean subjects. Longitudinal studies investigating both the effect of the degree of obesity and weight loss are further needed to explore the variations of pulmonary function tests in childhood obesity.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of the Bezmialem Vakif University Medical Faculty.

Informed Consent: Written inform consent was obtained from patients and parents who participated in this study.

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