Original Article

Assessment of pulmonary functions in obese adolescent boys

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ABSTRACT

Background: Obesity is rapidly escalating in India in all age groups. School-based data indicate a prevalence rate between 5.6% and 24% in children and adolescents. Adolescent obesity is associated with a greater long-term risk of hypertension and type 2 diabetes mellitus in adulthood. However, studies investigating pulmonary functions in obese adolescents are few. The present study assesses pulmonary functions in obese adolescent boys from a school in Baroda city, Gujarat. **Aims:** (i) To assess the dynamic lung functions in obese adolescent boys. (ii) To determine the predominant lung function impairment associated with obesity in adolescence. **Materials and Methods:** Dynamic lung functions were measured in 30 obese adolescent boys and an equal number of age-matched controls using MEDI:SPIRO software (Maestros Mediline Systems Ltd., Navi Mumbai, India). **Results:** Forced expiratory volume in the 1st second (FEV_1)/forced vital capacity (FVC) and maximum voluntary ventilation (MVV) were significantly decreased in the obese group ($P < 0.001$). Pulmonary functions in the study population correlated negatively with various indices of obesity, viz. weight, body mass index (BMI), waist circumference, hip circumference, and waist-to-hip ratio. The strongest negative correlation was between BMI and FEV_1/FVC ($P < 0.001$) and between BMI, MVV, and Forced Expiratory Flow ($FEF_{25-75\%}$) ($P < 0.001$). Waist-to-hip ratio in the study population correlated negatively with MVV ($P < 0.01$), but not with FEV_1/FVC. **Conclusions:** Lung function impairment, particularly decreased MVV and reduced FEV_1/FVC ratio, is associated with obesity in adolescence. In addition, pulmonary functions deteriorate with increasing obesity in adolescence and correlate negatively with various indices of obesity, viz. weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio. This study reveals another health hazard associated with obesity and highlights the need to aggressively reduce weight at a younger age.

KEY WORDS: Adolescent obesity, body mass index, pulmonary function tests, waist-to-hip ratio

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INTRODUCTION

Obesity is rapidly escalating globally in all age groups. In the United States, approximately 60% of adults and one in four children and adolescents can be classified as overweight or obese.[1,2] Though more studies are needed to ascertain the prevalence of overweight and obesity in India, school-based data indicate a prevalence of between 5.6% and 24% in children and adolescents.[3-5]

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The causes of childhood and adolescent obesity are manifold that include lack of regular exercise, sedentary habits, overconsumption of high-calorie foods, and genetic, perinatal, and early life factors.[6] Co-morbidities of adolescent obesity encompass both short- and long-term health concerns. Because 80% of adolescent obese become obese adults, adolescent obesity is associated with a greater long-term risk of cardiovascular disease and type 2 diabetes mellitus in adulthood. In addition, orthopedic issues such as slipped capital femoral epiphysis and gastrointestinal complications like cholelithiasis are far more common in the obese child. Obesity complicates the common adolescent problem of low self-esteem.[7]

Impairment of pulmonary function is associated with both adolescent and adult obesity. Studies have revealed a significant reduction in forced vital capacity (FVC), forced expiratory volume in the 1st second (FEV_1), flow rates [peak expiratory flow rate (PEFR) and forced expiratory flow ($FEF_{25-75\%}$)], maximum voluntary ventilation (MVV), expiratory reserve volume (ERV), and functional residual capacity (FRC) in the morbidly obese.[8] Reductions in pulmonary function in relation to the waist-to-hip ratio have been observed in the adult obese.[9] Significant decrease in FRC, ERV, flow rates, and MVV has been found in obese children and adolescents.[10,11] However, studies investigating pulmonary functions in obese children in India are few.[12] Hence, the present study was aimed to investigate pulmonary function variables in the adolescent obese in Baroda city, Gujarat.

MATERIALS AND METHODS

Subjects were randomly selected from Rosary High School, Pratapgunj, Baroda. Boys in the age group of 12–17 years were screened to identify the obese by recording their weight (in kilograms) and height (in centimeters). The protocol of the study was approved by the Institutional Ethics Committee. Body mass index (BMI) was calculated as per the following formula:

body mass index = weight (kilograms)/height^2 (meter^2)

Boys having BMI greater than the 95th percentile for age were classified as obese.[13] A total of 30 such obese boys were identified. An identical number of age-matched non-obese boys were taken as controls. Boys with symptoms of illness like fever, cough, abdominal pain, etc., and anxious, apprehensive, and uncooperative ones were excluded from the study. All subjects were explained about the procedures to be undertaken and written informed consent was obtained as per Helsinki Declaration, modified according to the test protocol. Informed consent forms were signed by parents/guardians as the children were minors. The following measurements/tests were performed.

Clinical Assessment

A detailed personal history was elicited. A brief questionnaire was administered regarding the subjects' perception of obesity, any influence of obesity on their self-esteem, parental history of obesity, any complication in the perinatal period, weight at 5–7 years, habits like hours of watching television, daily physical activity, diet, etc. A complete physical examination was performed. Pulse and blood pressure were recorded observing the standard procedure. Systemic examination was carried out.

Anthropometric Measurements

Weight (in kilograms) and height (in centimeters) were recorded on a beam balance. Waist circumference was measured as the smallest circumference between the ribs and the iliac crest to the nearest 0.1 cm, while the participant was standing with the abdomen relaxed, at the end of normal expiration. Hip circumference was recorded as the maximum circumference between the iliac crest and the pubic symphysis. Skinfold thicknesses were measured at four sites by vernier calipers – triceps, chest, subscapular, and superior iliac crest thickness.

Pulmonary Function Testing

The subjects were demonstrated the maneuvers of the pulmonary function tests. Computerized spirometry was carried out using MEDI:SPIRO (Maestros Mediline Systems Ltd., Navi Mumbai, India) observing the guidelines laid down by the American Thoracic Society and European Respiratory Society,[14] with the subject seated. Calibration of the spirometer was carried out daily using a 3-L calibration syringe as recommended by the American Thoracic Society. For the FVC maneuver, the subjects were asked to take a deep inspiration and breathe out as rapidly as and as long as possible into the mouth of the spirometer. Flow volume curve was plotted with the best of three acceptable maneuvers being taken as the final reading. In addition, maximum voluntary ventilation was recorded by asking the subject to breathe as rapidly and as deeply as possible for a period of 12 s. Possible chronic obstructive pulmonary disease was defined on the basis of "GOLD" criteria.[15] The following pulmonary functions were recorded: FEV_1, FVC, FEV_1/FVC (ratio of FEV_1 and FVC), PEFR, $FEF_{25-75\%}$ or maximum mid-expiratory flow rate (MMEFR), and MVV.

STATISTICAL ANALYSIS

The data of the obese and control groups were compared using Student's *t*-test. The following comparisons were made:

- Age, BMI, waist/hip ratio, skinfold thicknesses
- Pulmonary function parameters of the obese and control groups

Correlation co-efficient was calculated to determine the relationship between various measures of adiposity (weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio) and pulmonary function parameters.

RESULTS

Table 1 compares the age and anthropometric variables of the obese and control groups. The average BMI of the obese group was 29.4 ± 4.12 kg/m^2 compared to the control group's 19.51 ± 1.23 kg/m^2. The average age of the obese and control groups were 15.8 ± 1.37 and 15.9 ± 1.4 years, respectively.

Table 2 compares the pulmonary function parameters of the obese and control groups [Figures 1 and 2]. FEV_1 (% predicted) was significantly decreased in the obese group ($P < 0.01$)[Figure 1] FEV_1/FVC (both observed and percent predicted) was also significantly less in the obese group [Figure 3]. However, no obstructive impairment was detected in any subject of the obese group. In addition, MVV (both observed and percent predicted) was significantly decreased in the obese group ($P < 0.001$) [Figure 3] The other parameters, viz. FVC and flow rates (PEFR and $FEF_{25-75\%}$), were not significantly different in the obese and control groups.

Table 3 presents the correlation matrix between various anthropometric variables and pulmonary function parameters. Weight, BMI, waist circumference, and hip circumference were strongly negatively correlated with FEV_1/FVC, MVV, and $FEF_{25-75\%}$ ($P < 0.01$). Waist-to-hip ratio was strongly negatively correlated with MVV ($P < 0.01$) and $FEF_{25-75\%}$ ($P < 0.05$), but not with FEV_1/FVC [Figures 4-6].

DISCUSSION

The predominant pulmonary function abnormality detected in the obese subjects was a reduction in the FEV_1/FVC ratio and MVV. FEV_1 and FEV_1/FVC were significantly decreased in the obese subjects. A decrease in the FEV_1/FVC was also observed by Inselman *et al.*[16] and Mallory *et al.*[17] However, no significant reduction was detected by Bossisio *et al.*[18] and Chaussain *et al.*[19] A reduction in the FEV_1/FVC ratio indicates airway narrowing, the severity of which is indicated by the absolute value of FEV_1.[20] Because no obstructive impairment was detected in any of the obese, results are indicative of airflow limitation without significant obstruction.

A significant finding of the study is a decrease in the MVV in the obese group. MVV depends on the movement of air into and out of the lungs during continued maximal effort throughout a preset interval. The MVV is a simple, informative test that provides an overall assessment of the effort, co-ordination, and flow-resistive properties of the respiratory system. A similar decrease in MVV was observed by Ho *et al.*[11] and Inselman *et al.*[15] in children, and Sahebjami *et al.*[21] in adults. They hypothesized that some obese subjects manifest peripheral airway abnormalities, suggested by reduced maximum expiratory flow rates at low lung volumes and air trapping. As a result of air trapping, inspiratory muscles are placed at a mechanical disadvantage leading to lower inspiratory pressure and flow, and reduced respiratory muscle strength, causing low MVV. Alternatively, in some obese subjects, diaphragmatic muscle weakness due to a variety of causes could lead to a decreased MVV.[17] In addition, a decreased MVV may reflect extrinsic mechanical compression on the lung and the thorax.

In our study, across the spectrum of normal weight and obese boys, FEV_1/FVC, MVV, and $FEF_{25-75\%}$ were strongly negatively correlated with body weight, BMI, waist circumference, hip circumference, and waist-to-hip ratio. This suggests that pulmonary function may be impaired, though not sufficiently to cause clinical abnormality with increasing adiposity as suggested by these indices. The strongest negative correlation was with BMI ($P < 0.001$). Similar negative correlation between BMI and pulmonary function was observed by Sri Nageswari *et al.*[12] in a group of obese children of mixed socioeconomic status from Punjab, India. They hypothesized that obesity is characterized by decrease in chest wall compliance due to increased amount of adipose tissue around the chest and abdomen, which decreases pulmonary functions in these children.

With increasing waist circumference and hip circumference, values of pulmonary function have decreased. Waist-to-hip ratio was negatively correlated with MVV ($P < 0.01$) and $FEF_{25-75\%}$ ($P < 0.05$). A number of studies have revealed a negative correlation between measures of abdominal adiposity and pulmonary function parameters. Ochs-

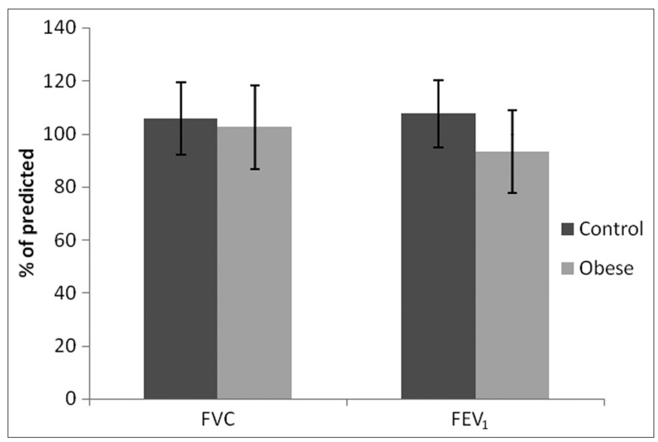

Figure 1: Comparison of FVC and FEV_1 (% of predicted values) of the control and obese groups

Table 1: Standard anthropometric measurements of the control and obese groups

Parameters	Control ($n = 30$) Mean ± SD	Obese ($n = 30$) Mean ± SD
Age (years)	15.9 ± 1.4	15.8 ± 1.37
Height (cm)	164.6 ± 6.43	166.77 ± 9.49
Weight (kg)	51.92 ± 4.53	81.3 ± 13.9***
Waist (cm)	65.6 ± 7.51	89.5 ± 13.35**
Hip (cm)	72.23 ± 5.68	96.63 ± 11.48**
Waist/hip	0.91 ± 0.05	0.96 ± 0.09
Body surface area (m^2)	1.53 ± 0.09	1.99 ± 0.18 ***
Body mass index (kg/m^2)	19.51 ± 1.23	29.4 ± 4.12***
Skinfold thicknesses		
Triceps (cm)	2.34 ± 0.96	4.34 ± 0.85***
Subscapular (cm)	2.7 ± 0.79	5.48 ± 1.55***
Chest (cm)	2.02 ± 0.63	4.43 ± 1.47***
Sup. iliac (cm)	4.95 ± 1.37	9.15 ± 1.92***

**$P < 0.01$; ***$P < 0.001$

Table 2: Measurements of pulmonary function tests in control and obese adolescents

Parameters		Control ($n = 30$) Mean ± SD	Obese ($n = 30$) Mean ± SD
FVC	(O)	3.43 ± 0.52	3.66 ± 0.65
(L)	(%)	105.7 ± 13.73	102.4 ± 15.88
FEV_1	(O)	3.2 ± 0.42	3.01 ± 0.57
(L)	(%)	107.5 ± 12.51	93.27 ± 15.74**
FEV_1/FVC	(O)	93.6 ± 5.96	81.74 ± 10.92***
(%)	(%)	102.77 ± 7.5	92.03 ± 12.25***
PEFR	(O)	6.82 ± 1.53	6.87 ± 1.56
(L/s)	(%)	89 ± 24.92	83.77 ± 16.36
$FEF_{25-75\%}$	(O)	4.76 ± 1.35	3.56 ± 1.02
(%)	(%)	124.9 ± 41.55	90 ± 23.58
MVV	(O)	148.96 ± 29.04	108.45 ± 22.6***
(Lts.)	(%)	131.53	95.07***

O = observed values, P = predicted values, **$P < 0.01$; ***$P < 0.001$

Table 3: Correlation of various anthropometric variables and pulmonary function parameters in adolescent boys (values are correlation co-efficient *r*)

	FEV_1	FVC	FEV_1/FVC	MVV	PEFR	$FEF_{25-75\%}$
Wt (kg)	0.05	0.29*	−0.48***	−0.38**	0.24	−0.31*
Ht (cm)	0.54***	0.60***	−0.09	0.09	0.45***	0.14
BMI (kg/m^2)	−0.19	0.88***	−0.52***	−0.50***	0.06	−0.43***
Waist circumference (cm)	0.00	0.19	−0.37**	−0.38**	0.14	−0.37**
Hip circumference (cm)	−0.04	0.20	−0.45***	−0.41***	0.08	−0.37**
Waist/hip ratio	−0.01	0.13	−0.24	−0.33**	0.04	−0.31*

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

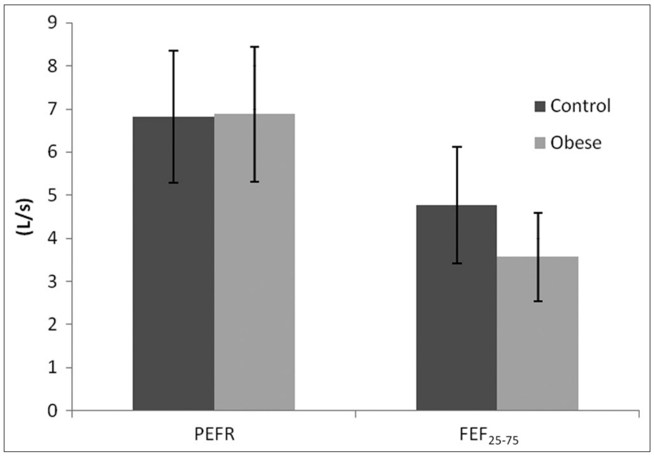

Figure 2: Comparison of PEFR and $FEF_{25-75\%}$ (observed values) of the control and obese groups

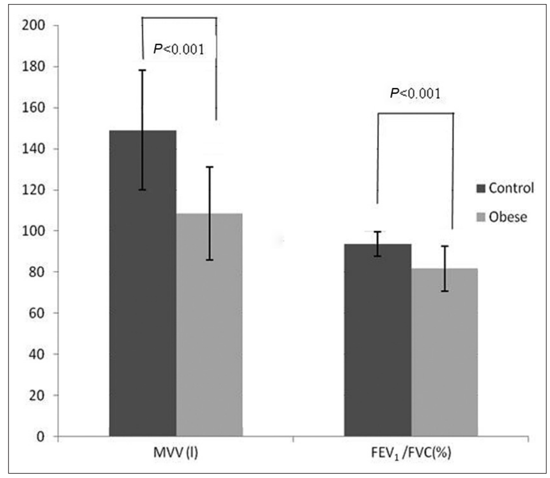

Figure 3: Comparison of the pulmonary function parameters (observed values) of the control and obese groups

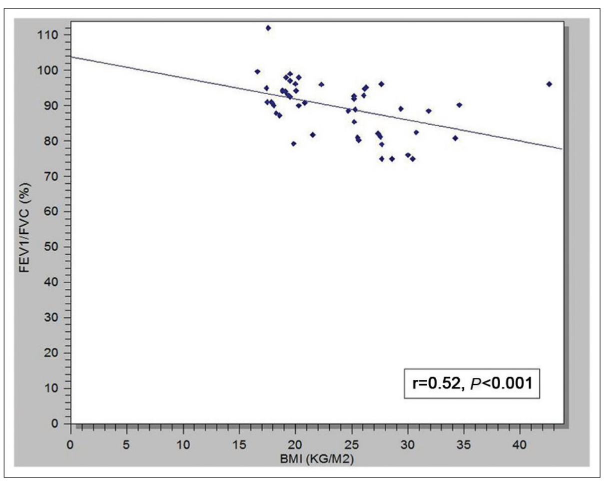

Figure 4: Correlation between BMI and FEV_1/FVC in the entire study population ($N = 60$)

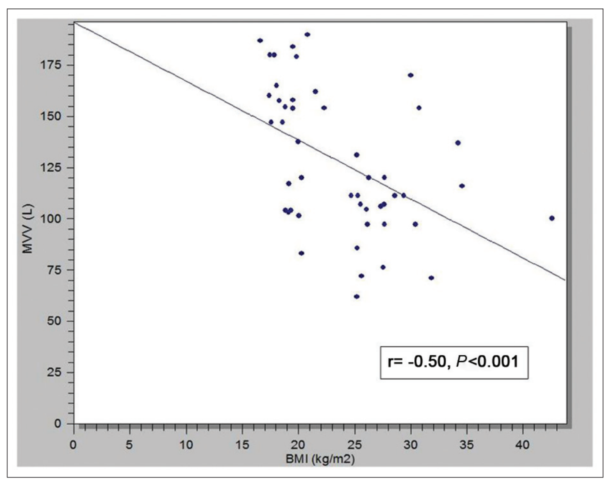

Figure 5: Correlation between BMI and MVV in the entire study population ($N = 60$)

Balcom *et al.*[22] found inverse associations of abdominal height and waist circumference with pulmonary function in men and women with BMI values of ≥25 kg/m^2. Canoy *et al.*[23] analyzed the association of waist-to-hip ratio and pulmonary function in the European Prospective Investigation into Cancer and Nutrition (EPIC-Norfolk) study and reported an inverse relation. Harik-Khan *et al.*[24] investigated the association of fat distribution and pulmonary function using waist/hip ratio. They reported an inverse association of FEV_1 and waist/hip ratio in men only. Lazarus *et al.*[25] reported an inverse association of abdominal girth/hip breadth ratio with pulmonary function after adjustment for BMI in men over a narrow range in the Normative Aging Study. Collins *et al.*[26] examined normal to mildly obese firefighters and found decreased pulmonary function in men with a waist/hip ratio of >0.95.

A number of hypotheses have been proposed to explain the negative correlation between pulmonary function parameters and measures of visceral adiposity. One possible mechanism is a mechanical limitation of chest expansion during the FVC maneuver. Increased abdominal mass may impede the descent of the diaphragm and increase the thoracic pressure. Also, abdominal adiposity is likely to reduce ERV via compressing the lungs and diaphragm.[22]

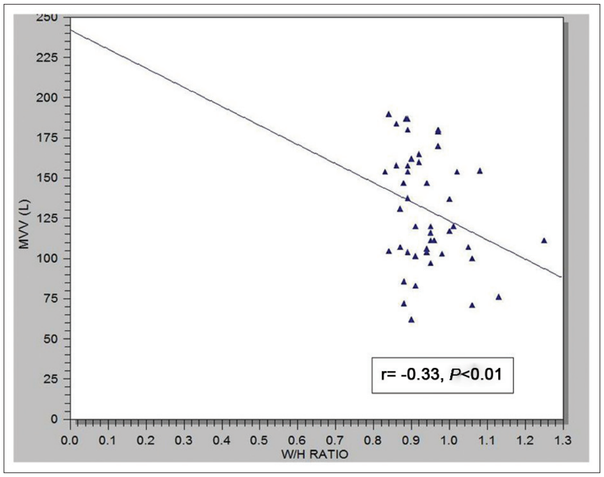

Figure 6: Correlation between waist/hip ratio and MVV in the entire study population (N = 60)

In addition, visceral adipose tissue influences circulating concentrations of interleukin-6, tumor necrosis factor-alpha, leptin, and adiponectin, which are cytokines that may act via systemic inflammation to negatively affect pulmonary function.[27-30] Investigators reported an inverse association of serum leptin concentrations with FEV_1, as well as higher levels of C-reactive protein, leukocytes, and fibrinogen, which are markers of systemic inflammation. Therefore, inflammation may be the link between visceral obesity and pulmonary function.[31]

To conclude, pulmonary functions are decreased (as compared to normal weight subjects) in our group of obese adolescent boys. This study unravels yet another health hazard associated with obesity and highlights the need to aggressively reduce weight at a younger age.

However, no clinical abnormality, viz. obstructive or restrictive deficit, has been detected in any of the obese children. Also, the small sample size makes it necessary to view the results with caution. In addition, it would be interesting to conduct longitudinal studies to better assess the relationship between increasing body weight and pulmonary functions in obese.

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