



Determining respiratory system resistance and reactance by impulse oscillometry in obese individuals

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ABSTRACT

Objective: To evaluate peripheral respiratory system resistance and reactance (Rrs and Xrs, respectively) in obese individuals. **Methods:** We recruited 99 individuals, dividing them into four groups by body mass index (BMI): < 30.0 kg/m² (control, n = 31); 30.0-39.9 kg/m² (obesity, n = 13); 40.0-49.9 kg/m² (severe obesity, n = 28); and ≥ 50.0 kg/m² (morbid obesity, n = 13). Using impulse oscillometry, we measured total Rrs, central Rrs, and Xrs. Peripheral Rrs was calculated as the difference between total Rrs and central Rrs. All subjects also underwent spirometry. **Results:** Of the 99 individuals recruited, 14 were excluded because they failed to perform forced expiratory maneuvers correctly during spirometry. The individuals in the severe obesity and morbid obesity groups showed higher peripheral Rrs and lower Xrs in comparison with those in the two other groups. **Conclusions:** Having a BMI ≥ 40 kg/m² was associated with a significant increase in peripheral Rrs and with a decrease in Xrs.

Keywords: Obesity; Airway obstruction; Oscillometry; Respiratory function tests.

INTRODUCTION

Obesity currently poses a major risk to human health, affecting more than 600 million people worldwide⁽¹⁾ and constituting a predisposing factor for other health problems, including respiratory diseases, cardiovascular diseases, osteoarticular diseases, diabetes, and hyperlipidemia.⁽²⁾

Thoracic and abdominal adipose tissue accumulation results in reduced respiratory system compliance and, consequently, increased respiratory effort. In addition, reduced expiratory reserve volume (ERV) and functional residual capacity result in a decrease in lung elastic recoil pressure. The aforementioned factors can play a role in reducing peripheral airway caliber and increasing respiratory system resistance (Rrs) in obese individuals.⁽³⁻⁶⁾ In addition, increased circulating leptin levels are associated with reduced airway caliber and predispose to increased bronchial hyperresponsiveness.^(7,8)

A variant of the forced oscillation technique, impulse oscillometry (IO) is a noninvasive, effort-independent method for assessing respiratory mechanics.⁽⁹⁾ Previously studied in clinical practice, IO involves the application of pressure pulses of single or multiple frequencies to the airways, allowing measurement of Rrs, respiratory system impedance, and respiratory system reactance (Xrs).^(4,10,11)

One of the advantages of IO over other methods is that it allows differentiation between central Rrs and peripheral Rrs.⁽¹¹⁾ In addition, the fact that IO requires no patient

effort and minimal patient cooperation makes it easier to perform than spirometry or plethysmography.^(12,13)

The objective of the present study was to evaluate peripheral Rrs and Xrs by IO in individuals with varying degrees of obesity.

METHODS

This was an exploratory, comparative observational study conducted between June of 2007 and March of 2010 in the *Laboratório de Função Pulmonar* of the *Hospital das Clínicas* of the *Universidade Federal de Pernambuco*, in the city of Recife, Brazil. The study was approved by the local research ethics committee (Protocol no. 0316.0.172.000-07). All participants gave written informed consent.

We recruited 99 individuals between 18 and 60 years of age, dividing them into four groups by body mass index (BMI): < 30.0 kg/m² (control, n = 31); 30.0-39.9 kg/m² (obesity, n = 13); 40.0-49.9 kg/m² (severe obesity, n = 28); and ≥ 50.0 kg/m² (morbid obesity, n = 13). Only 12 participants had FVC or FEV₁/FVC values below 80% of predicted, 3 of whom were in the control group and 9 of whom were in the severe obesity group.

Individuals with a history of pulmonary disease were excluded, as were those with signs and symptoms of recent pulmonary disease (wheezing on auscultation, cough, or dyspnea), those with a history of smoking, those with chest X-ray changes, those with neurological

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disease, those with musculoskeletal disease, and those who failed to perform forced expiratory maneuvers correctly during spirometry.

Anthropometric data (weight and height) were obtained with the use of an electronic scale (Metalúrgica Arja, São Paulo, Brazil), whereas IO and spirometric parameters were obtained with the MasterScreen IO system (Jäeger, Würzburg, Germany). All tests were performed with the individuals sitting comfortably with both feet flat on the floor, breathing through a plastic mouthpiece, and using a nose clip. The IO system was calibrated daily before data collection, by the variable flow method with a 3-liter syringe (Jäeger).

Spirometry was performed in accordance with the American Thoracic Society guidelines.⁽¹⁴⁾ We evaluated slow vital capacity (SVC), ERV, inspiratory capacity, FVC, FEV₁, FEV₁/FVC, and FEF_{25-75%}. For SVC, inspiratory capacity, and FEV₁, the highest values obtained from three acceptable maneuvers were selected, whereas FEF_{25-75%} was obtained from the maneuver with the highest sum of FVC and FEV₁. The data obtained were compared with the predicted values for the Brazilian population.⁽¹⁵⁾

During IO, patients were instructed to keep their lips around the mouthpiece and breathe normally for 40 s while pressing their cheeks together in order to prevent movement and reduce the upper airway shunt effect. The harmonic frequencies of the sound waves ranged from 5 Hz to 35 Hz, and pressure never exceeded 5.98 cmH₂O (0.5 kPa). We measured total Rrs (5 Hz), central Rrs (20 Hz), Xrs (5 Hz), and resonant frequency (Fres). Peripheral Rrs (also known as frequency dependence of resistance) was calculated as the difference between total Rrs and central Rrs. Low-frequency Xrs is associated with the peripheral airways, which is why Xrs was measured at a frequency of 5 Hz.⁽¹⁶⁾

To ensure reliability, measurements were repeated until consistency was > 0.7 for a frequency of 5 Hz and > 0.9 for a frequency of 20 Hz, a maximum of five maneuvers being performed.⁽¹⁰⁾

The Kolmogorov-Smirnov test was used in order to assess the distribution of variables. Fisher's exact test was used in order to compare categorical variables. One-way ANOVA and the Kruskal-Wallis test were used

in order to compare variables between groups. The chi-square test was used in order to evaluate nominal variables, and Tukey's post hoc test was used in order to determine the pairs of groups that differed from one another. GraphPad Prism, version 4 (GraphPad Software Inc., San Diego, CA, USA), and Microsoft Office Excel 2007 were used.

RESULTS

A total of 99 individuals participated in the present study. Although all individuals were able to perform IO maneuvers correctly, 14 failed to perform forced expiratory maneuvers correctly during spirometry and were therefore excluded. Of those 14 individuals, 2 were in the control group, 2 were in the obesity group, 5 were in the severe obesity group, and 5 were in the morbid obesity group.

Table 1 presents the general characteristics of the 85 individuals who remained in the study, by group. There were no differences among the groups regarding age. With regard to gender, females predominated in the control, severe obesity, and morbid obesity groups.

Table 2 shows an intergroup comparison of mean spirometric values (in % of predicted) in the study population. Both FVC and FEV₁ were significantly lower in the morbid obesity group than in the control and obesity groups; SVC was significantly lower in the morbid obesity group than in the obesity group; and ERV was significantly lower in the severe obesity and morbid obesity groups than in the control and obesity groups.

Table 3 shows an intergroup comparison of mean IO values in the study population. Total Rrs and peripheral Rrs were highest in the severe obesity and morbid obesity groups. This shows that peripheral Rrs is the major factor responsible for an overall increase in Rrs. In addition, Xrs was lowest in the severe obesity and morbid obesity groups. There was a slight negative association between peripheral Rrs and ERV (R = -0.32; p < 0.01).

DISCUSSION

Obesity is a major risk factor for pulmonary complications arising from changes in lung volumes

Table 1. General characteristics of the study population (N = 85), by group.^a

Characteristic	Group ^b				p
	Control (n = 31)	Obesity (n = 13)	SO (n = 28)	MO (n = 13)	
Gender [*]					
Male	9 (29.1)	8 (61.5)	4 (14.2)	5 (38.4)	0.1825
Female	22 (70.9)	5 (38.5)	24 (85.8)	8 (61.6)	0.5826
Age, years ^{**}	31.8 ± 11.3	39.6 ± 9.2	34.8 ± 12.4	34.1 ± 6.9	0.1924
BMI, kg/m ^{2**}	24.2 ± 3.0	32.6 ± 2.7	45.5 ± 2.7	56.7 ± 5.2	< 0.0001

SO: severe obesity; MO: morbid obesity; and BMI: body mass index. ^aValues expressed as n (%) or mean ± SD. ^bControl group: BMI < 30.0 kg/m²; obesity group: BMI = 30.0-39.9 kg/m²; SO group: BMI = 40.0-49.9 kg/m²; and MO group: BMI ≥ 50.0 kg/m². ^{*}Chi-square test. ^{**}One-way ANOVA and Tukey's post hoc test.

Table 2. Spirometric variables (in % of predicted) in the study population (N = 85).^a

Variable	Group ^b			
	Control (n = 31)	Obesity (n = 13)	SO (n = 28)	MO (n = 13)
FVC	97.6 ± 15.5	100.6 ± 12.5	90.6 ± 12.2	81.9 ± 14.3*†
FEV ₁	97.4 ± 12.1	99.5 ± 14.9	90.6 ± 12.6	82.4 ± 16.6*†
FEV ₁ /FVC	84.6 ± 7.4	81.4 ± 7.9	83.4 ± 6.2	84.3 ± 6.7
FEF _{25-75%}	98.3 ± 19.1	106.2 ± 29.0	95.3 ± 27.4	83.1 ± 29.0
ERV	121.6 ± 35.7	111.8 ± 53.0	73.3 ± 27.6*†	52.3 ± 26.2*†
IC	96.7 ± 26.4	114.7 ± 16.2	110.9 ± 19.6	106.7 ± 29.3
SVC	100.7 ± 15.8	104.9 ± 17.2	97.9 ± 10.8	88.4 ± 16.2†

SO: severe obesity; MO: morbid obesity; ERV: expiratory reserve volume; IC: inspiratory capacity; and SVC: slow vital capacity. ^aValues expressed as mean ± SD. ^bControl group: BMI < 30.0 kg/m²; obesity group: BMI = 30.0-39.9 kg/m²; SO group: BMI = 40.0-49.9 kg/m²; and MO group: BMI ≥ 50.0 kg/m². *p < 0.01 vs. control group. †p < 0.01 vs. obesity group. ‡p < 0.05 vs. obesity group. One-way ANOVA and Tukey's post hoc test.

Table 3. Impulse oscillometry variables in the study population (N = 85).^a

Variable	Group ^b			
	Control (n = 31)	Obesity (n = 13)	SO (n = 28)	MO (n = 13)
Total Rrs, cmH ₂ O/L/s	4.3 ± 1.1	4.5 ± 1.5	5.6 ± 1.7*	6.0 ± 1.2†
Total Rrs, % of predicted ^c	130.2 ± 36.6	136.5 ± 39.7	163.0 ± 54.0 [‡]	185.6 ± 46.0***
Central Rrs, cmH ₂ O/L/s	3.7 ± 1.0	3.7 ± 1.2	4.2 ± 1.4	4.4 ± 1.1
Central Rrs, % of predicted ^c	135.1 ± 38.2	133.9 ± 39.7	146.3 ± 51.7	161.9 ± 48.0
Peripheral Rrs, cmH ₂ O/L/s	0.5 ± 0.4	0.7 ± 0.4	1.4 ± 0.6*†	1.6 ± 0.4*†
Fres, Hz	13.5 ± 3.6	16.2 ± 2.6	19.2 ± 3.1***	20.4 ± 3.9***
Xrs, cmH ₂ O/L/s	-1.3 ± 0.4	-1.6 ± 0.9	-2.0 ± 0.8 [‡]	-2.1 ± 0.9 [‡]

SO: severe obesity; MO: morbid obesity; Rrs: respiratory system resistance; Fres: resonant frequency; and Xrs: respiratory system reactance. ^aValues expressed as mean ± SD. ^bControl group: BMI < 30.0 kg/m²; obesity group: BMI = 30.0-39.9 kg/m²; SO group: BMI = 40.0-49.9 kg/m²; and MO group: BMI ≥ 50.0 kg/m². ^cCalculated on the basis of Pelosi et al.⁽²⁰⁾ *p < 0.01 vs. control group. †p < 0.01 vs. obesity group. ‡p < 0.05 vs. control group. ***p < 0.05 vs. obesity group. One-way ANOVA and Tukey's post hoc test.

and peripheral Rrs and can lead to increased work of breathing and reduced gas exchange.⁽¹⁷⁻¹⁹⁾

The results of the present study show reduced SVC and FEV₁ in severely obese or morbidly obese individuals (Table 2), as reported elsewhere.⁽²⁰⁻²³⁾ In addition, analysis of IO parameters revealed a strong association of the degree of obesity with increased peripheral Rrs and reduced Xrs (Table 3).

Fat deposition in the neck, thorax, and abdomen can lead to reduced lung volumes, resulting in reduced elastic recoil pressure of the lung and of the walls of the smaller bronchi, as well as in reduced airway caliber. In addition, the mechanical disadvantage imposed on the diaphragm by an increase in abdominal pressure leads to reduced ERV. The aforementioned factors, together with extrinsic airway compression, result in expiratory airflow limitation in obese individuals.⁽³⁾

In obese individuals, functional residual capacity is more markedly reduced than is residual volume; consequently, there is a marked reduction in ERV. Therefore, in obese individuals, tidal breathing occurs at low lung volumes. Under such conditions, some airways tend to narrow or even close during exhalation.⁽²⁴⁾ The association between IO variables and plethysmography variables should be evaluated

in order to confirm the relationship between reduced lung volume and airway narrowing.

One advantage of IO over other methods for evaluating respiratory mechanics, such as spirometry and whole-body plethysmography, is that IO does not require forced expiratory maneuvers (which can affect bronchial tone), therefore requiring minimal patient cooperation.⁽⁴³⁾ In this regard, we were able to measure IO parameters correctly in 14 obese patients who failed to perform forced expiratory maneuvers correctly during spirometry.

Zerah et al.⁽⁵⁾ used plethysmography in order to study lung volumes and respiratory mechanics in 46 individuals with no history of lung disease and found increased airway resistance and reduced lung volumes in those whose BMI was ≥ 30 kg/m². Oliveira et al.⁽⁴⁾ used IO and found increased airway resistance in 25 obese individuals who were compared with 25 non-obese individuals. However, neither group of authors stratified patients by BMI. This was done in the present study, which showed that the aforementioned changes occur predominantly in severely obese or morbidly obese individuals, i.e., those whose BMI is ≥ 40 kg/m². In addition, we differentiated between central Rrs and peripheral Rrs, which clearly showed the role that the small airways play in airflow limitation in such patients, as demonstrated by increased Fres and peripheral Rrs.

Both Fes and peripheral Rrs as measured by IO, which are considered to be small airway markers,⁽²⁵⁻²⁷⁾ can detect increased peripheral Rrs.⁽¹⁶⁾ Friedman et al.⁽²⁸⁾ evaluated IO data from residents and area workers who inhaled dust and fumes from the World Trade Center disaster and found increased total Rrs and increased peripheral Rrs, which were associated with increased exposure to dust and fumes, as well as with lower respiratory symptoms.

In patients with mild to moderate asthma, Yamaguchi et al.⁽²⁹⁾ found reduced peripheral Rrs after 12 weeks of treatment with inhaled hydrofluoroalkane-134a beclomethasone dipropionate, which has ultrafine particles; however, no changes were observed in FEF_{25-75%}. These findings suggest that IO is more sensitive to measure the response to asthma and COPD treatment than are other methods.⁽³⁰⁾

A complex concept, Xrs incorporates lung elastic recoil properties. Low-frequency Xrs has been correlated with peripheral airway obstruction. At low frequencies, there is passive lung distension, increased lung compliance, reduced elastic recoil pressure, and reduced Xrs.⁽¹³⁾ Xrs at 5 Hz expresses Xrs as a whole, being reduced in patients with restrictive lung disease and in those with chest wall disease.^(13,16) Our comparative analysis revealed a significant reduction in Xrs in severely obese

and morbidly obese individuals. This finding reflects the association between obesity and reduced Xrs, given that none of the study participants had abnormal chest X-ray findings or a history of collagen disease.

Our results show that individuals with a BMI \geq 40 kg/m² can have normal spirometry results despite significant changes in respiratory mechanics, which are detected by IO. Reduced lung volume resulting from the interdependence of tissue structures reduces small airway diameter, increasing small airway resistance. Future studies will soon be able to show real, volume-corrected obstruction, combining IO data with residual volume and functional residual capacity as determined by plethysmography.

In this context, the clinical relevance of IO is evident, given that it is an accurate, noninvasive method for evaluating changes in respiratory mechanics (Rrs and Xrs) in the early stages of disease. The findings of the present study show the importance of drawing treatment plans aimed at reducing airway resistance and, consequently, improving lung function in obese individuals, especially those with respiratory symptoms. In addition, IO is an alternative method for evaluating patients who are unable to perform the required respiratory maneuvers for spirometry and plethysmography.

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