Correlation of lung function and respiratory muscle strength with functional exercise capacity in obese individuals with obstructive sleep apnea syndrome

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ABSTRACT

Objective: To evaluate lung function and inspiratory muscle strength, correlating them with exercise tolerance, in obese individuals with obstructive sleep apnea syndrome (OSAS). **Methods:** The sample comprised 31 adult subjects with moderate-to-severe OSAS diagnosed by polysomnography. We used spirometry to measure FVC, FEV_1, and FVC/FEV_1 ratio, using pressure manometry to measure MIP and MEP. The incremental shuttle walk test (ISWT) and the six-minute walk test (6MWT) were used in order to determine functional exercise capacity. **Results:** In this sample, the mean values for FVC (% of predicted), FEV_1 (% of predicted): MIP, and MEP were 76.4 ± 12.3%, 80.1 ± 6.3%, 60.0 ± 21.9 cmH_2O, and 81.3 ± 22.2 cmH_2O, respectively. The mean distances covered on the ISWT and 6MWT were 221 ± 97 m and 480.8 ± 67.3 m, respectively. The ISWT distance showed moderate positive correlations with FVC (r = 0.658; p = 0.001) and FEV_1 (r = 0.522; p = 0.003). **Conclusions:** In this sample of obese subjects with untreated OSAS, lung function, inspiratory muscle strength, and exercise tolerance were all below normal. In addition, we found that a decline in lung function, but not in respiratory muscle strength, was associated with exercise tolerance in these patients.

Keywords: Sleep apnea syndromes; Exercise tolerance; Respiratory function tests; Respiratory muscles.

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is characterized by partial or total obstruction of the upper airways during sleep.[1-3] Obstructive events are associated with oxyhemoglobin desaturation, sleep fragmentation or deprivation, hypoxemia, hypercapnia, dyspnea, as well as diurnal symptoms such as excessive daytime sleepiness.[3,4] The etiology of OSAS is multifactorial, including craniofacial anatomical changes and obesity. Obese individuals present a higher risk of pharyngeal occlusion and altered respiratory mechanics.[5]

An increase in the volume of adipose tissue in the thoracic and abdominal regions impairs diaphragmatic function and reduces chest cavity compliance and lung volumes, leading to an increase in inspiratory muscle work.[6,7] Episodes of recurrent hypoxia in OSAS are usually accompanied by microarousals to reestablish normal ventilation after occlusion of the upper airways.[8] In addition, recurrent episodes of hypoxia and reoxygenation related to upper airway obstruction in OSAS are associated with abnormal partial pressure of oxygen and of carbon dioxide, reducing respiratory muscle activity and lung volumes. These factors generate new episodes of apnea-hypopnea throughout the night, limiting the ability to perform activities of daily living.[9-11]

Obesity and OSAS are factors that potentially alter aerobic capacity and exercise tolerance in different ways. The initial impairment of lung function and respiratory muscle function seen in obese individuals is related to reductions in functional exercise capacity and quality of life.[12,13] There is also evidence that the lower-than-normal exercise tolerance in OSAS patients is due to OSAS-related episodes of dyspnea, intermittent hypoxemia, respiratory muscle dysfunction, and pulmonary hypertension.[14,15] In obese patients with OSAS, cardiovascular diseases such as arterial hypertension, cardiac arrhythmia, and systolic dysfunction can also limit exercise tolerance, as can increased work of breathing, hypoventilation, and a sedentary lifestyle.[16,17]

The present study aimed to evaluate lung function and inspiratory muscle strength, correlating them with exercise tolerance, in obese individuals with OSAS.

METHODS

This was a cross-sectional, descriptive, observational study with quantitative analysis. We recruited individuals of either gender with a diagnosis of OSAS, confirmed through polysomnography, who were evaluated and treated at the Pulmonology Outpatient Clinic of the

Hospital Otávio de Freitas, located in the city of Recife (PE), Brazil. We applied the following inclusion criteria: having been diagnosed with moderate or severe OSAS; being between 50 and 70 years of age; being able to perform stress tests for functional capacity assessment; and having a body mass index (BMI) between 18 kg/m^2 and 40 kg/m^2. Patients with mild apnea—defined as a apnea-hypopnea index (AHI) between 5-15 events/h—were excluded, as were those with cardiopulmonary, neuromuscular, or orthopedic diseases that could influence or limit their ability to perform the tests, those with a BMI > 40 kg/m^2, and those being treated with continuous positive airway pressure. We initially evaluated 150 patients for eligibility, and 81 of those patients did not meet the inclusion criteria. Therefore, 69 patients were selected to perform the tests. However, 38 were excluded during the evaluation. Consequently, the final sample comprised 31 patients (Figure 1).

The sample size calculation was performed with MedCalc software, version 17.9.5 (MedCalc Software, Mariakerke, Belgium), considering as parameters a probabilistic error of 0.05 (5% alpha) and a statistical power of 80%. Thus, the minimum number of subjects required was calculated to be 24.

The research was approved by the human research ethics committee of the institution. All participants gave written informed consent.

All of the patients completed the Pittsburgh Sleep Quality Index questionnaire, which evaluates sleep quality in the last month.[18] The Epworth Sleepiness Scale was used for the evaluation of excessive daytime sleepiness.[19] The heart rate was measured with a heart monitor (model FT1; Polar, Kempele, Finland). Blood pressure was measured with an aneroid sphygmomanometer with an arm cuff (Premium model; Missouri Mikatos, Embu, Brazil) and a Rappaport premium stethoscope (Accumed, Rio de Janeiro, Brazil). The heart rate was measured at rest and immediately after the test. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured at rest, 1 min after the test, 3 min after the test, 5 min after the test, and 10 min after the test. The measurement of MIP and MEP followed the methodological recommendations of the American Thoracic Society/European Respiratory Society[20] and the Brazilian Thoracic Association,[21] with the use of a manometer (model MVD300; Globalmed, Porto Alegre, Brazil). We selected three (not necessarily sequential) tests that were considered acceptable (i.e., that met the reproducibility criteria). We used the measurement with the highest value, as long as it did not vary more than 10% in relation to the other values.

Through spirometry, also following the methodological recommendations of the Brazilian Thoracic Association,[21] the following variables were obtained: FVC, FEV_1, and the FEV_1/FVC ratio.

We applied the incremental shuttle walk test (ISWT), in which the patient has to walk a 20-m path (10 m forward and 10 m back), according to the protocol
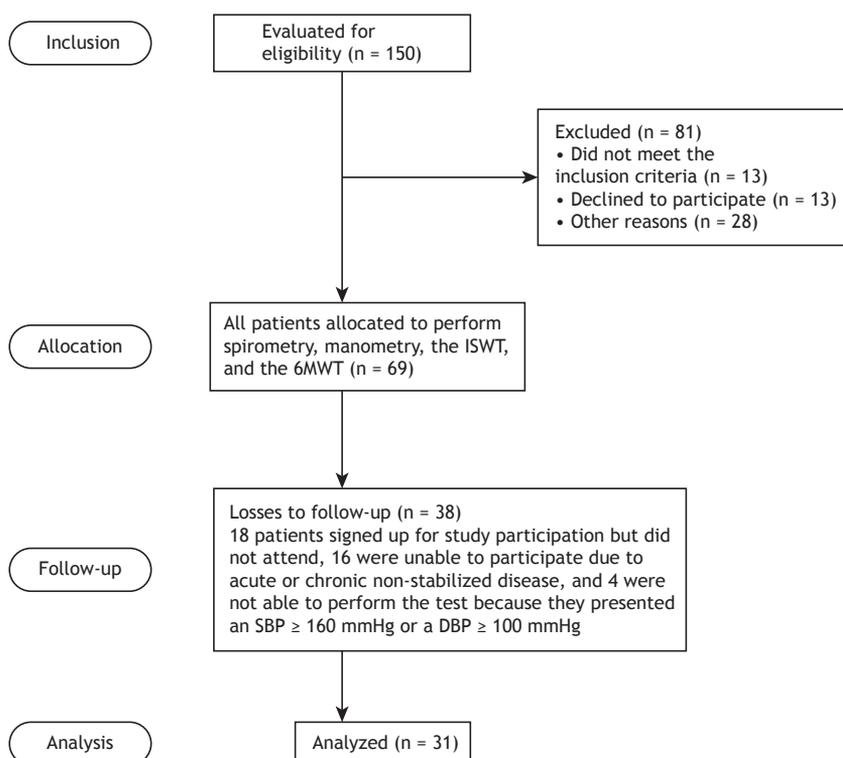

Figure 1. Flowchart of the study selection, allocation, follow-up, and analysis. ISWT: incremental shuttle walk test; 6MWT: six-minute walk test; SBP: systolic blood pressure; and DBP: diastolic blood pressure

developed by Singh et al.[22] The path was delineated with two traffic cones. We also applied the six-minute walk test (6MWT), which was performed in accordance with the American Thoracic Society specifications.[23]

Descriptive analyses were presented as a mean ± standard deviation or as median and interquartile range, as appropriate, according to the results of the Kolmogorov-Smirnov test. The correlations between variables were analyzed by Spearman's test, and the differences between the means were evaluated with the Student's t-test for independent samples. Values of p < 0.05 were considered significant. The data were processed with the Statistical Package for the Social Sciences, version 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Table 1 presents demographic and polysomnographic characteristics of the population studied. We evaluated 31 patients, of whom 10 (32.2%) were male and 21 (67.8%) were female. The mean age was 58.8 ± 5.4 years, and the mean BMI was 31.2 ± 5.0 kg/m². The mean AHI was 35.0 ± 12.8 events/h. Of the 31 patients evaluated, 14 (45.2%) had moderate OSAS and 17 (54.8%) had severe OSAS. Although all of the patients had poor sleep quality according to the Pittsburgh Sleep Quality Index, none showed excessive daytime sleepiness according to the Epworth Sleepiness Scale.

Table 2 presents data on lung function and respiratory muscle strength.

Table 3 presents comparisons of heart rates and blood pressure levels during the ISWT and the 6MWT. The following variables were significantly higher during the ISWT than during the 6MWT: SBP 1 min after the test (p = 0.004), SBP 3 min after the test (p = 0.01), SBP 5 min after the test (p = 0.03), DBP 3 min after the test (p = 0.07), and DBP 5 min after the test (p =

0.001). The other variables did not present significant differences in the comparison between the two tests.

Table 4 shows Spearman's correlation coefficients for the anthropometric, spirometric, and inspiratory muscle strength variables related to the distances covered on the ISWT and the 6MWT. There was a strong, positive correlation between FVC and the distance covered on the ISWT (r = 0.658, p = 0.001), as well as a moderate positive correlation between the FEV_1 and the distance covered on the ISWT (r = 0.522; p = 0.003). However, we found no correlations in relation to any of the other parameters evaluated.

DISCUSSION

The main findings of the present study show that, in our obese patients with OSAS, lung function and inspiratory muscle strength were impaired. In addition, the functional exercise capacity was reduced and there was a significant positive correlation between the distance covered on the ISWT and the variables related to pulmonary function.

In the present study, the values obtained for spirometric parameters and respiratory muscle strength were lower than the reference values for the healthy Brazilian population.[24] In the study conducted by Tassinari et al.,[25] no impairment of lung function or the respiratory musculature was observed in patients with OSAS. However, the OSAS patients evaluated in that study were of normal weight, unlike those in our sample, all of whom were obese. Likewise, Gontijo et al.,[26] studying obese individuals who did not present OSAS, obtained spirometric values within the limits of normality. The authors concluded that obesity would not be a factor associated with impairment of lung function. Studies indicate that obese individuals, due to the deposition of fat in the chest wall and abdomen, present a reduction in thoracic compliance, thus increasing the total work of breathing.[3,27,28] The upper airway collapse and the apnea-hypopnea events resulting from OSAS have respiratory consequences, such as hypoxemia, alveolar hypoventilation, and hypercapnia. Hypoxia-reoxygenation events lead to the activation of peripheral chemoreceptors leading to increased ventilation to correct alterations in blood gases.[10] Changes in O_2 and CO_2 concentrations result in a decrease in respiratory muscle activity and a reduction in lung volumes.[8,9]

Table 1. Characteristics of the sample (N = 31).[a]

Variables	Results
Female	21 (67.7)
Age, years	58.8 ± 5.4
Weight, kg	82.2 ± 16.7
Height, m	1.63 ± 0.06
BMI, kg/m	2 31.2 ± 5.0
Abdominal circumference, cm	99.4 ± 16.7
Neck circumference, cm	35.7 ± 2.8
AHI, events/h	35.0 ± 12.8
15-30 events/h	14 (45.2)
> 30 events/h	17 (54,8)
ESE	9.19 ± 4.4
PSQI	6.48 ± 1.61
Comorbidities[b]	
Hypertension	29 (91.0)
Diabetes	22 (61.5)

BMI: body mass index; AHI: apnea-hypopnea index; ESS: Epworth Sleepiness Scale; and PSQI: Pittsburgh Sleep Quality Index.[a]Values expressed in n (%) or mean ± SD.[b]Patients with these comorbidities were receiving antihypertensive or hypoglycemic medications.

Table 2. Data on pulmonary function and respiratory muscle strength.[a]

Variable	Result
FVC, L	2.4 ± 0.6
FVC, % predicted	76.4 ± 12.3
FEV_1,% predicted	80.1 ± 6.32
FEV_1, L	2.0 ± 0.4
FEV_1/FVC ratio	79.6 ± 5.8
MIP, cmH_2O	60.0 ± 21.9
MEP, cmH_2O	81.3 ± 22.2

[a]Values expressed as mean ± SD.

Table 3. Variables collected during the incremental shuttle walk test and the six-minute walk test.[a]

Variable	ISWT	6MWT	Δintergroup (95% CI)	p*
HR_{rest}, bpm	72.9 ± 7.9	73.2 ± 8.3	−2.5 (−4.3 to 3.6)	0.901
HR_{max}, bpm	121.9 ± 14.7	109.7 ± 18.6	12.1 (3.6-20.7)	0.006
SBP_{rest}, mmHg	117.1 ± 5.8	115.8 ± 6.7	1.2 (−1.9 to 4.4)	0.424
$SBP_{recovery\ 1'}$, mmHg	152.2 ± 13.0	138.3 ± 10.0*	13.8 (7.9-19.7)	0.001
$SBP_{recovery\ 3'}$, mmHg	137.1 ± 9.4	128.0 ± 7.9*	9.0 (4.6-13.4)	0.01
$SBP_{recovery\ 5'}$, mmHg	127.4 ± 6.3	119.3 ± 6.9*	8.0 (4.7-11.3)	0.001
$SBP_{recovery\ 10'}$, mmHg	119.3 ± 4.4	117.1 ± 5.8	2.2 (−3.8 to 4.9)	0.093
DBP_{rest}, mmHg	82.5 ± 7.2	82.2 ± 7.1	3.3 (−3.3 to 3.8)	0.861
$DBP_{recovery\ 1'}$, mmHg	118.0 ± 10.4	108.0± 11.3*	10.0 (4.4-15.5)	0.001
$DBP_{recovery\ 3'}$, mmHg	112.9 ± 9.3	103.5 ± 13.5*	9.3 (3.4-15.2)	0.002
$DBP_{recovery\ 5'}$, mmHg	101.9 ± 12.2	88.0 ± 11.3*	13.8 (7.8-19.8)	0.001
$DBP_{recovery\ 10'}$, mmHg	88.0 ± 11.3	82.9 ± 7.8*	5.1 (0.19-10.1)	0.042
Walk distance, m	221.0 ± 97.0	480.8 ± 67.3		

ISWT: incremental shuttle walk test; 6MWT: six-minute walk test; SBP: systolic blood pressure; and DBP: diastolic blood pressure. [a]Values expressed as mean ± SD. *t-test for independent samples.

Table 4. Correlation between the selected variables and the distances covered on the incremental shuttle walk test and six-minute walk test.

Variables	ISWT		6MWT	
	r	p	r	p
BMI	−0.320	0.07	−0.062	0.741
FEV_1	0.522	0.003	0.117	0.532
FVC	0.658	0.001	0.189	0.308
MIP	0.075	0.069	−0.105	0.575
Abdominal circumference	0.056	0.996	−0.110	0.858
Neck circumference	−0.032	0.862	−0.121	0.574
AHI	0.070	0.710	−0.111	0.551

ISWT: incremental shuttle walk test; 6MWT: six-minute walk test; BMI: body mass index; and AHI: index of apnea and hypopnea.

Regarding the association between pulmonary function and exercise tolerance, we found that FVC and FEV_1 showed significant positive correlations with the distance covered on the ISWT. This finding demonstrates that smaller lung volumes translate to lower exercise tolerance, underscoring the idea that pulmonary function affects exercise capacity in individuals with OSAS. Impairment of exercise capacity in obese individuals was also shown in another study, in which the authors concluded that being overweight is associated with a loss of self-esteem and lower psychic well-being.[29] Factors such as dyspnea, abnormalities in respiratory mechanics, respiratory muscle dysfunction, and arterial hypoxemia contribute to limiting exercise tolerance in OSAS patients.[14]

In our study, the distance covered on both walk tests was lower than the reference distance for healthy individuals in the Brazilian population,[30-32] indicating that exercise tolerance was below normal in our obese patients with OSAS. The patients in our sample also had comorbidities such as hypertension and type 2 diabetes mellitus. Exercise tolerance is directly related to the good performance of the cardiopulmonary system. Therefore, the impairment of functional exercise capacity in OSAS patients is multifactorial,

being associated with obesity, a sedentary lifestyle, cardiovascular diseases, dyspnea, and respiratory abnormalities.[14,15] However, there are conflicting data regarding the impaired exercise capacity resulting from the combination of OSAS with obesity in relation to exercise capacity. A study conducted by Beitler et al.[11] showed that peak oxygen consumption (VO_{2peak}) was significantly lower in obese OSAS patients than in controls, also reporting an association between VO_{2peak} and the AHI. In contrast, Rizzi et al.,[15] in a study of normal-weight OSAS patients, observed no impairment of the functional exercise capacity. However, in a subsequent study—a randomized clinical trial involving obese and normal-weight individuals, with or without OSAS—Rizzi et al.[33] observed a significant difference in exercise tolerance between the obese and non-obese groups regardless of the presence ofOSAS, in terms of CO_2 production and the maximum VO_2. The authors concluded that obesity would be the main condition of low functional capacity, given that the obese patients presented low exercise tolerance, regardless of the presence or absence of OSAS.

Regarding the cardiovascular responses to the 6MWT in the present study, the cardiac parameters measured immediately after the test demonstrated marked

increases in relation to the data collected during the test, results that are in agreement with those obtained by Rizzi et al.[33] in their study of obese patients with OSAS. However, the cardiovascular responses were even more pronounced during and after the ISWT, as was also reported by Gonçalves et al.[34] in a study of healthy individuals. In another study involving obese patients with OSAS, in which cardiopulmonary exercise testing (CPET) with the Bruce protocol was employed,[34] patients with severe apnea were found to show an increase in blood pressure during peak exercise with a return to basal blood pressure levels after exercise. Green et al.[35] stated that the ISWT provokes a physiological response to exercise similar to that observed during CPET.

Although the 6MWT is a standard test in the clinical assessment of effort in patients with OSAS[25] and obese patients,[36] the ISWT has also proven to be feasible and reliable in the assessment of effort tolerance in individuals with OSAS. Green et al.[35] studied patients with heart failure, comparing the responses obtained with CPET, the ISWT, and the 6MWT. They concluded that the ISWT provided a valid index to determine functional capacity in individuals with heart failure and that the predictive power of the ISWT could exceed that of the 6MWT. In a study evaluating patients with moderate or severe OSAS, Billings et al.[37] used the ISWT to compare physical fitness before and after treatment with continuous positive airway pressure. The authors concluded that the ISWT is safe, well tolerated, and easily reproducible in OSAS patients,

supporting the idea that it can be used safely in the evaluation of exercise tolerance in such patients.

Our study has limitations, such as the small sample size. However, the number of patients evaluated was within the limits set in the sample calculation. In addition, we did not perform CPET, which is the gold standard test in the analysis of functional capacity and of cardiopulmonary impairment and would have allowed a more reliable evaluation of the cardiovascular parameters, as well as their subsequent correlation with those found on the two other tests. Another limitation was the fact that our study evaluated only obese patients with OSAS and there was no control group of obese patients without OSAS. Furthermore, data regarding cardiovascular comorbidities were not available for the patients in the sample studied. Therefore, studies with greater methodological rigor, such as randomized clinical trials, are needed in order to increase knowledge about the subject in the future.

The results found in the present study show that obese subjects with untreated OSAS presented below-normal lung function, inspiratory muscle strength, and physical capacity. In addition, it was observed that the decline in lung function, but not inspiratory muscle strength, is associated with physical effort tolerance in these patients, which makes it necessary to use therapeutic interventions to improve variables such as physical exercise. We can also emphasize that the ISWT was able to evaluate the exercise tolerance in OSAS, making it quite useful in the clinical investigation of the disease, due to its low cost, reproducibility, and ease of application.

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