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ORIGINAL ARTICLE

Severity of Obstructive Sleep Apnea Predicts Functional Capacity

Janina Lied da Costa[1], Jéssica da Silva Pissolato[2], Gustavo do Nascimento Petter[3]
Lidianara de Moraes Mota[4], Michele Forgiarini Saccol[5], Carine Cristina Callegaro[6]

Highlights:
(1) Lower limb muscle endurance tends to be reduced in individuals with obstructive sleep apnea compared to predicted values.
(2) The severity of obstructive sleep apnea is inversely associated with lower limb muscle endurance and functional capacity.
(3)The apnea-Hypopnea Index is an independent predictor of functional capacity.

ABSTRACT

Obstructive Sleep Apnea (OSA) is characterized by partial or total upper airways obstruction, resulting in intermittent hypoxia, oxyhemoglobin desaturation, and sleep fragmentation. Male gender and obesity are risk factors. The objective was to compare the performance of individuals with OSA to predicted values for knee extensor muscle strength, lower limb muscle endurance (LLME), and functional capacity. Additionally, the study aimed to examine the relationship between OSA severity and body mass index (BMI) with physical performance. This cross-sectional observational analytical study was conducted between October 2019 and June 2022, with eighteen men diagnosed with OSA. The instruments used were a digital dynamometer (maximum isometric voluntary contraction), a 30-second chair stand test, and a six-minute walk test. The sample had a mean age of 40.6 ± 9.2 years and BMI: 32.9 ± 7.6 kg/m². Knee extensor muscle strength did not differ compared to predicted values. LLME showed a trend towards reduction (12.8 ± 3.7 repetitions versus 15.2 ± 2.1 repetitions; p= 0.071; d=0.798), and functional capacity (p = 0.429; d = 0.177) did not significantly differ from predicted values. We concluded that individuals with OSA exhibit a statistical trend toward reduced LLME compared to predicted values. However, knee extensor muscle strength and functional capacity appear to be preserved. The Apnea-Hypopnea Index (AHI) is an independent predictor of functional capacity, and the AHI and BMI variables were directly correlated.

Keywords: sleep disorders; functional physical performance; physical endurance; muscle strength.

[1] Universidade Federal de Santa Maria – UFSM. Santa Maria/RS, Brasil. https://orcid.org/0000-0002-9444-7406
[2] Universidade Federal de Santa Maria – UFSM. Santa Maria/RS, Brasil. https://orcid.org/0009-0008-9655-082X
[3] Universidade Federal do Rio Grande do Sul – UFRGS. Porto Alegre/RS, Brasil. https://orcid.org/0000-0003-3545-6895
[4] Universidade Federal de Santa Maria – UFSM. Santa Maria/RS, Brasil. https://orcid.org/0009-0005-1707-2216
[5] Universidade Federal de Santa Maria – UFSM. Santa Maria/RS, Brasil. https://orcid.org/0000-0002-7894-690X
[6] Universidade Federal de Santa Maria – UFSM. Santa Maria/RS, Brasil. https://orcid.org/0000-0001-9482-5457

INTRODUCTION

Obstructive Sleep Apnea (OSA) is marked by frequent partial (hypopnea) or complete (apnea) obstructions of the upper airway during sleep, resulting in intermittent hypoxia, oxyhemoglobin desaturation, and sleep fragmentation[1]. Important risk factors for OSA include male gender, obesity, and aging, primarily due to reduced activity of airway dilator muscles[2]. OSA affects one in four men and one in ten women globally[3], with its prevalence rising alongside increases in obesity and life expectancy.

Excess weight is responsible for approximately 40% to 60% of OSA cases, as it predisposes individuals to upper airway narrowing[4,5]. The combination of obesity and OSA can impair aerobic capacity and exercise tolerance through various mechanisms[6,7], including elevated C-reactive protein levels, increased inflammation, and dysregulation of the sympathetic nervous system[8]. This convergence of comorbidities can further deteriorate functionality and quality of life in affected patients[9].

Individuals with OSA exhibit reduced muscle strength and endurance during isokinetic knee extensor exercises compared to healthy controls. This decline in strength and endurance is linked to systemic oxidative stress caused by the repetitive cycle of deoxygenation and reoxygenation[10]. The impairment of functional capacity in individuals with OSA is multifactorial, involving factors such as obesity, sedentary lifestyle, cardiovascular diseases, dyspnea, and respiratory abnormalities[6].

The fact that both OSA and obesity can independently impact performance, yet have not been thoroughly studied in combination, highlights a significant gap in current knowledge. Therefore, this study aims to compare the performance of individuals with OSA to predicted values for knee extensor muscle strength, lower limb muscle endurance (LLME), and functional capacity. Additionally, it will examine the relationship between the severity of OSA and body mass index (BMI) with physical performance.

MATERIALS AND METHODS

This is a cross-sectional observational analytical study conducted between October 2019 and June 2022, involving 18 male individuals diagnosed with OSA. The volunteers were recruited from the Sleep Laboratory, Pulmonology Service of the University Hospital of Santa Maria -UHSM, and through convenience sampling by disseminating the inclusion and exclusion criteria on social media, websites, and posters displayed at the Hospital and on the campus of the Federal University of Santa Maria, as shown in the flowchart in Figure 1.

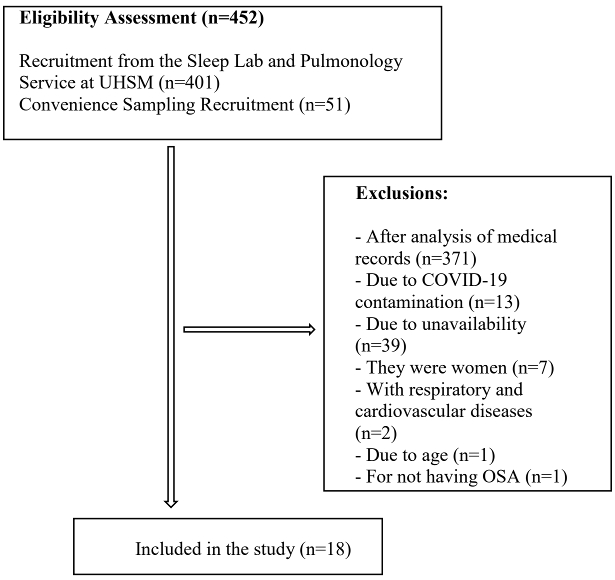

Figure 1 – Sample flowchart.

Male individuals, active, sedentary, non-smokers, aged between 25 and 60 years, with OSA confirmed by cardiorespiratory monitoring (type III polysomnography) were included. Individuals with pulmonary diseases (bronchial asthma, chronic obstructive pulmonary disease), neurological diseases (chronic neuropathies), or cardiac diseases (symptomatic coronary artery disease, left ventricular dysfunction) were excluded, as well as those using drugs such as corticosteroids or bronchodilators, those with acute health problems or emerging complaints in the last month (viral or bacterial infections, accidents, allergic reactions), and those with special conditions affecting cognition and understanding of the study, individuals using Continuous Positive Airway Pressure (CPAP), and those who had been diagnosed with Covid-19.

All participants signed the Informed Consent Form, and the study was approved by the Ethics and Research Committee of the Federal University of Santa Maria under CAAE No.: 22912619.8.0005346.

Screening of Volunteers

The individuals completed the short version of the International Physical Activity Questionnaire (IPAQ) to assess their level of physical activity and the Mini-Mental State Examination (MMSE) to check for cognitive impairment, which were used exclusively for volunteer screening[11,12]. Data were collected on age, history of past diseases, comorbidities, and family history.

OSA was diagnosed through cardiorespiratory monitoring, also known as type III polysomnography, using the Stardust II equipment (Philips Respironics, Pennsylvania, USA), which includes a monitor with a position sensor, an abdominal belt to detect respiratory movements, a nasal cannula, and a pulse oximeter. All patients were previously trained and instructed to perform the test at home, being advised to sleep with the monitor for at least seven continuous hours at night, as well as to avoid physical activity and alcohol consumption. The polysomnography analysis was conducted using the Stardust Host software version 2.0.22 by two evaluators trained in test interpretation, according to the American Academy of Sleep Medicine1 criteria. Those with an apnea-hypopnea index (AHI) of five or more events per hour of sleep were considered to have OSA, classified as mild OSA with five to fifteen events/hour, moderate OSA with sixteen to thirty events/hour, and severe OSA with more than thirty events/hour[1].

Evaluations

Anthropometric Assessment

Body weight and height of each volunteer were measured. BMI was calculated by dividing weight (kg) by height squared (m^2) and classified according to the World Health Organization guidelines[13].

Physical-Functional Assessments

Volunteers were instructed by phone or in person to refrain from physical activity and alcohol consumption starting the day before the evaluations. The physical-functional assessments took place on different days. Participants underwent evaluations of isometric strength of the knee extensors and lower limb endurance tests on one day, with a 15-minute interval between the tests, and functional capacity assessment on another day, as described below:

Assessment of Knee Extensor Muscle Strength

The maximum isometric strength of the quadriceps was measured using a digital dynamometer (Microfet 2, Hoogan Health Industries, West Jordan, UT, USA). The assessment was conducted in a seated position, with the knee flexed at 90°, and the dynamometer positioned on the anteroinferior region of the leg, five centimeters (cm) above the lateral malleolus, secured by a safety belt[14].

While seated with arms crossed in front of the torso, participants were instructed to perform a knee extension with maximum force for five seconds, with verbal encouragement provided. Both the dominant and non-dominant limbs were assessed, starting with the participant's preferred leg, first evaluating one leg and then the other. Three repetitions of the measurement were performed, with a one-minute interval between each repetition. The arithmetic mean of the repetitions was used in kilogram-force (kgf) and this value was corrected for the participant's body mass (kg)[15].

To calculate the predicted value, the following reference equation was used15:

- Left Knee Extension:

$-204.36 + (43.69 \times S) - (1.13 \times A) + (1.90 \times W) + (2.19 \times H)$

- Right Knee Extension:
  $-215.54 + (40.73 \times S) - (0.82 \times A) + (2 \times W) + (2.22 \times H)$

Where:

S = sex (1 for men and 0 for women), **A** = age, **W** = weight, **H** = height

Lower Limb Muscle Endurance Assessment

The 30-second chair stand test was used to assess lower limb endurance. We used a stopwatch and a chair with a backrest, no arms, and a seat height of approximately 43 cm for this task. The chair was placed against a wall for safety, preventing movement during the test. The volunteer sat in the chair with their back against the backrest and feet flat on the floor. The participant crossed their arms over their chest, and at the signal from the evaluator, the participant stood up fully and then returned to the seated position. The volunteer was encouraged to complete as many full stands and sits as possible within 30 seconds. The evaluator demonstrated the test beforehand to ensure the participant understood it correctly. The score was determined by the number of correct executions within the 30-second interval. The predicted value was obtained using the equation: $27.633 - (\text{age} \times 0.069) - (\text{BMI} \times 0.28)$[16].

Functional Capacity Assessment

The six-minute walk test (6MWT) was conducted on a separate day. It involved walking back and forth along a 30-meter corridor, marked every three meters, with cones at the beginning and end of the path for the volunteer to turn around. A chair was positioned nearby if the individual needed to stop the test[17].

Before starting the test and after 10 minutes of rest, vital signs were measured: heart rate (HR), oxygen saturation (SpO2), respiratory rate (RR), and blood pressure (BP). While the volunteer stood, dyspnea and perceived effort were assessed using the Borg scale (0 to 10). The participants were instructed to walk as fast as possible for six minutes, with the pace being self-selected. They could rest or stop the test at any time[17]. Standardized encouragement phrases were used during the test. HR, SpO2, and the Borg scale for dyspnea and effort were monitored every minute, and vital signs were checked again at the end of the test. The equation used to calculate the predicted value was from Iwama[9]:

$\text{6MWD} = 622.461 - (1.846 \times \text{age}) + (61.503 \times \text{gender})$

where age is in years and gender is scored as 1 for male and 0 for female.

Statistical Analysis

Data were expressed as mean, standard deviation, median, and interquartile range. The normality of the data distribution was tested using the Shapiro-Wilk test. No variable showed a normal distribution, so independent samples were compared using the Mann-Whitney U test. Correlations between variables were assessed using Spearman's correlation test. Stepwise regression was used to determine the predictors of functional capacity. The significance level for all analyses was set at 0.05. The classification of the correlation coefficient r followed Callegari-Jacques's[18].

RESULTS

The study sample consisted of 18 male individuals with a mean age of 40.6 ± 9.2 years and an average BMI of 32.9 ± 7.6 kg/m². Five individuals were classified as grade I obesity, eight as grade II obesity, two as overweight, and three as normal weight. They also had an average AHI of 39.2 ± 27.4 events/hour, with three individuals having mild OSA, seven with moderate OSA, and eight with severe OSA.

The results of the physical-functional assessments are presented in Table 1. The strength of the knee extensor muscles did not show a statistically significant difference compared to the predicted values, both for the right lower limb (p=0.107; d=0.567) and the left lower limb (p=0.107; d=0.440).

Table 1. Physical-functional assessments

Variable analyzed	Values obtained	Predicted values	p-value
Strength LLR (Kgf)			
Mean ± SD	45.7 ± 13.3	39.3 ± 8.8	0.107
Median (IR)	45.1 (36.2 - 55.7)	36.8 (35.1 - 39.4)	
Strength LLL (Kgf)			
Mean ± SD	42.5 ± 12.1	37.9 ± 8.5	0.174
Median (IR)	40.8 (33.4 - 50.2)	35.8 (33.6 - 39.1)	
LLME (repetitions)			
Mean ± SD	12.8 ± 3.7	15.2 ± 2.1	0.071
Median (IR)	13.0 (9.3 -16.0)	15.2 (14.1 - 16.6)	
6MWT (m)			
Mean ± SD	589.8 ± 152.0	609.1 ± 17	0.429
Median (IR)	618.8 (580.7 - 694.8)	606.4 (597.7 - 626.3)	

Values expressed as mean and standard deviation (SD); IR = interquartile range; LLR = lower limb right; LLE = lower limb left; LLME= lower limb muscle endurance; 6MWT = six-minute walk test; Kgf = kilogram-force; m = meters.

Individuals in this sample showed a non-statistically significant trend of reduced lower limb endurance, with a moderate effect size (p = 0.071; d = 0.798), compared to the predicted values from the Furlanetto equation [16]. However, the distance covered in the 6MWT showed no significant difference (p = 0.429; d = 0.177) when compared with the predicted values from the Iwama equation[9], indicating that there was no change in the functional capacity of these individuals. Figure 2 shows a negative correlation (p = 0.003) between the distance covered in the 6MWT and the severity of OSA (AHI), with a correlation coefficient considered strong (r = - 0.65).

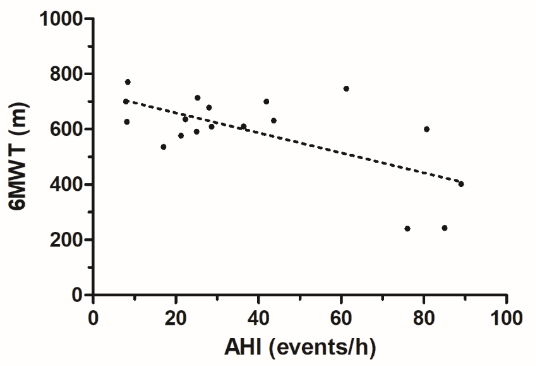

Figure 2 – Association between the distance covered in the six-minute walk test (6MWT) and the apnea-hypopnea index (AHI).

Figure 3 shows that there was also a negative correlation (p = 0.003) between the distance covered in the 6MWT and BMI, with a correlation coefficient considered strong (r = -0.65).

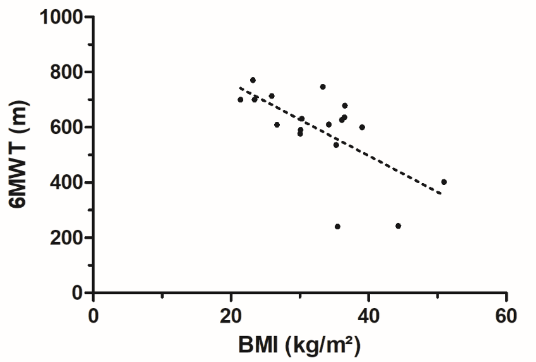

Figure 3 – Association between the distance covered in the six-minute walk test (6MWT) and body mass index (BMI).

Figure 4 shows a correlation (p = 0.020) between lower limb endurance and the severity of OSA, with a moderate correlation coefficient (r = - 0.52). There was no significant correlation between lower limb endurance and BMI (r = - 0.38, p = 0.116).

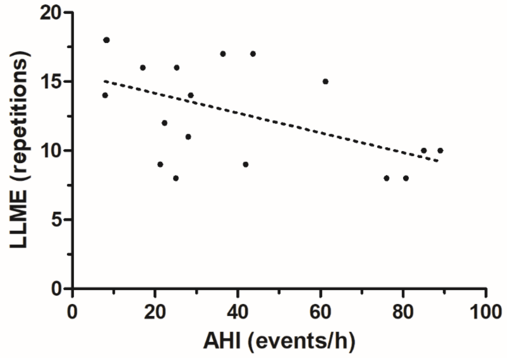

Figure 4- Association between the lower limb mucle endurance (LLME) and the apnea-hypopnea index (AHI).

Figure 5 shows a direct correlation between AHI and BMI (p = 0.003), with a strong correlation coefficient (r = 0.66) and Spearman values (p = 0.041; r = 0.48).

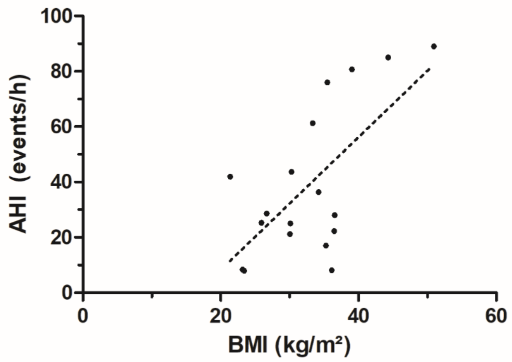

Figure 5 – Association between the apnea-hypopnea index (AHI) and body mass index (BMI).

Linear regression analysis with AHI and BMI variables showed that AHI is an independent predictor of the distance covered in the 6MWT, with 42.7% of the variance in the distance covered in the 6MWT explained by the variance in AHI.

The strength of the right knee extensor muscles showed no significant correlation with BMI (r = - 0.38, p = 0.116) or AHI (r = - 0.33, p = 0.179), and similarly, the strength of the left knee extensor muscles showed no correlation with BMI (r = - 0.30, p = 0.906) or AHI (r = 0.11, p = 0.64).

DISCUSSION

The isometric strength of the knee extensor muscles, lower limb endurance, and functional capacity of individuals with OSA did not significantly differ from predicted values. However, the severity of OSA (AHI) was inversely associated with lower limb muscle endurance and functional capacity, as well as directly correlated with BMI. As expected, functional capacity was inversely correlated with BMI, but only the severity of OSA was an independent predictor of functional capacity.

In the present study, the average strength of the right and left knee extensor muscles did not differ from predicted values, indicating that the combination of obesity and OSA does not affect this physical quality. Contrary to our findings, a study of men aged 40 to 65 years diagnosed with obstructive sleep apnea (OSA) reported reduced strength and endurance in the knee extensor muscles in the OSA group compared to the control group, independent of BMI[10]. The preservation of knee extensor strength observed in our sample may be attributable to the prediction equation used, which was validated for a Dutch population. This could explain the differences in the values obtained across populations. Since no reference equations are available for the Brazilian population, we chose the Douma equation,[15] as it employs the same methodology and device (a dynamometer) as our study and includes participants within the same age range. The 6MWT is used to globally assess the body's response during exercise[7], with the distance covered representing functional capacity/exercise tolerance[7,19]. The functional capacity of individuals with OSA did not differ from predicted values, possibly due to the fact that not all volunteers had severe OSA. This hypothesis can be supported by the strong inverse association between AHI and the distance covered in the 6MWT, indicating that the greater the severity of OSA, the lower the functional capacity. In addition to AHI, BMI also showed an inverse association with the distance covered in the 6MWT, indicating that the higher the BMI of these individuals, the worse their functional capacity[8].

It is known that the combination of comorbidities can impair functional capacity and lead to negative consequences for an individual's quality of life[7,8,20]. A study examined exercise capacity in individuals with OSA using the 6MWT and found correlations with AHI, oxygen desaturation index, BMI, age, and the number of comorbidities associated with the clinical condition[21]. Obesity can increase absolute strength and power due to the need to support a higher body weight; however, the muscle performance of obese individuals is reduced compared to normal-weight individuals[20]. In this sense, obesity can cause a decline in the contractile function of skeletal muscles, and in adults, it can cause a substantial reduction in muscle strength and power, impairing functional capacity[22]. On the other hand, another study, with a sample of women aged 45 to 60 years diagnosed with OSA or without OSA, found no significant correlation between the distance covered in the 6MWT and OSA or obesity[19].

The linear regression analysis found that only AHI is an independent predictor of functional capacity. These findings are consistent with the literature, which reports that obesity impairs functional performance[23, 24].

OSA also shows a strong positive correlation with obesity, as the higher the BMI, the greater the severity of OSA. Supporting our findings, a recent study reports a frequent association between OSA and obesity[4], and another study notes that 78% of the population in their research with OSA was obese, and these individuals experienced a reduction in respiratory muscle strength associated with a reduction in functional capacity[8].

Limitations

The main limitation of our study is the sample size. The exclusion of individuals infected with COVID-19 may have contributed to the difficulty in recruiting volunteers for the study. This exclusion avoids the bias of COVID-19's influence on the nervous, musculoskeletal, and cardiovascular systems, which could result in fatigue, muscle loss, and decreased functional capacity[25-27]. Including only men in the study may have also made it more difficult to recruit participants, as demonstrated in Figure 1, where out of 493 men diagnosed with OSA, only 18 agreed to participate. It is estimated that 936 million adults of both sexes, aged 30 to 79 years, present symptoms ranging from mild to severe OSA[28]. The majority of OSA cases occur in male individuals with obesity or overweight[29], which is why we chose to study men with OSA.

The 6MWT evaluates functional capacity as a submaximal test. Although cardiopulmonary exercise testing is a maximal and more representative test of aerobic capacity, it is costly and not widely available in clinical practice, unlike the 6MWT.

CONCLUSION

While lower limb muscle endurance tends to be reduced in individuals with OSA compared to predicted values, the isometric strength of knee extensor muscles and functional capacity appear to be preserved in these adults. The severity of OSA showed a significant inverse correlation with lower limb muscle endurance and functional capacity, indicating that the higher the individual's AHI, the worse their physical performance. AHI is an independent predictor of functional capacity.

We suggest that further research be conducted on OSA and its relationship with muscle strength and overall physical condition to better understand the harmful effects of this sleep disorder. This research could also inform the development of prevention programs and strategies to alleviate symptoms and clinical-functional impairments, ultimately aiming to improve quality of life.

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Author contributions

Janina Lied da Costa: Formal analysis, Methodology, Validation, Visualization, Writing – review & editing.

Jéssica da Silva Pissolato: Writing – original draft, Visualization.

Gustavo do Nascimento Petter: Formal analysis, Visualization.

Lidianara de Moraes Mota Investigation, Writing – original draft.

Michele Forgiarini Saccol: Data curation, Investigation, Resources, Validation, Visualization.

Carine Cristina Callegaro: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Visualization, Writing – review & editing.

All authors approved the final version of the text.

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Corresponding author

Carine Cristina Callegaro

Universidade Federal de Santa Maria – UFSM

Av. Roraima, n° 1000, Cidade Universitária, Centro de Ciências da Saúde, Prédio 26, Anexo B, Sala 002, Laboratório de Fisiologia e Reabilitação – Lafir, Bairro Camobi, Santa Maria/RS. Brasil. CEP: 97105-900

carine.callegaro@ufsm.br

Editor: Eliane Roseli Winkelmann. PhD

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