Original Article

DOI: 10.14235/bas.galenos.2025.24892
Bezmialem Science

The Impact of Obesity Hypoventilation Syndrome on Exercise Capacity, Peripheral Muscle Strength, and Quality of Life in Obese Individuals - A Cross-sectional Comparison Study

Obez Bireylerde Obezite Hipoventilasyon Sendromunun Egzersiz Kapasitesi, Periferik Kas Kuvveti ve Yaşam Kalitesine Etkisi - Kesitsel Karşılaştırma Çalışması

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ABSTRACT

Objective: Obesity hypoventilation syndrome (OHS) is characterized by respiratory dysfunction in addition to obesity and may adversely affect exercise capacity, peripheral muscle strength and quality of life. The aim of this study was to investigate the effects of OHS on exercise capacity, peripheral muscle strength and quality of life in obese individuals.

Methods: A total of 64 participants, 32 with OHS and 32 with simple obesity, were included in the study. Demographic and clinical data were collected. Clinical data included polysomnography results and comorbid conditions (Charlson comorbidity index). Exercise capacity was assessed using the six-minute walk test, and peripheral muscle strength was assessed using a digital hand dynamometer and a hydraulic hand dynamometer. Quality of life was assessed using the Nottingham health profile (NHP) and sleep quality using the Pittsburgh sleep quality index (PSQI). Body composition and circumference measurements were recorded.

ÖZ

Amaç: Obezite hipoventilasyon sendromu (OHS), obeziteye ek olarak solunum fonksiyon bozukluğu ile karakterizedir ve egzersiz kapasitesini, periferik kas gücünü ve yaşam kalitesini olumsuz yönde etkileyebilir. Bu çalışmanın amacı, obez bireylerde OHS'nin egzersiz kapasitesi, periferik kas gücü ve yaşam kalitesi üzerindeki etkilerini araştırmaktır.

Yöntemler: Çalışmaya 32'si OHS'li ve 32'si basit obez olmak üzere toplam 64 katılımcı dahil edilmiştir. Demografik ve klinik veriler kaydedilmiştir. Klinik verileri içerisine polisomnografi sonuçları ile komorbid durumları (Charlson komorbidite indeksi) kaydedilmiştir. Egzersiz kapasitesi altı dakika yürüme testi ile değerlendirilmiş, periferik kas gücü dijital el dinamometresi ve hidrolik el dinamometresi kullanılarak ölçülmüştür. Yaşam kalitesi Nottingham sağlık profili (NHP) ile uyku kalitesi ise Pittsburgh Uyku kalitesi indeksi (PSQI) ile değerlendirilmiştir. Vücut kompozisyonu ve çevresel ölçümler kaydedilmiştir.

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Received: 31.03.2025
Accepted: 01.08.2025
Epub: 06.10.2025

Cite this article as: Açıkbaş E, Ertan Harputlu Ö, Kuran Aslan G, Akıncı B, Çalıkoğlu BF, Kıyan E. The impact of obesity hypoventilation syndrome on exercise capacity, peripheral muscle strength, and quality of life in obese individuals - a cross-sectional comparison study. Bezmialem Science.

ABSTRACT

Results: The obese group had significantly better six-minute walk distance [500.44±40.46; $p=0.021$; 95% confidence interval (CI)=0.59] and right/left quadriceps strength (186.66±35.14; $p=0.004$; 95% CI=0.75) / (184.56±34.56; $p=0.005$; 95% CI=0.74). The OHS group had significantly higher NHP total score (243.13±105.54; $p<0.001$; 95% CI=1.75) and subscores [energy level (58.90±35.51; $p=0.001$; 95% CI=0.87), emotional status (31.81±29.73; $p=0.029$; 95% CI=0.56), sleep (43.60±26.01; $p<0.001$; 95% CI=1.96), PSQI total (8.66±3.98; $p=0.001$; 95% CI=2.14) and neck circumference (42.62±3.77; $p=0.025$; 95% CI=0.57)]. No statistically significant differences were observed in the other outcome measures ($p>0.005$).

Conclusion: These findings suggest that people with OHS have lower exercise capacity and muscle strength, and poorer quality of life and sleep than those with simple obesity. This highlights the need for targeted interventions to improve physical function and overall well-being in patients with OHS.

Keywords: Obesity hypoventilation syndrome, obesity, exercise capacity, peripheral muscle strength, quality of life

ÖZ

Bulgular: Basit obez grubunun altı dakika yürüme mesafesi [500,44±40,46; p=0,021; %95 güven aralığı (GA)=0,59] ve sağ ve sol kuadriseps kas güçleri (186,66±35,14; p=0,004; %95 CI=0,75) (184,56±34,56; p=0,005; %95 GA=0,74) anlamlı olarak daha yüksekti. OHS grubunun NHP toplam (243,13±105,54; p<0,001; %95 GA=1,75) ve alt skorları [enerji düzeyi (58,90±35,51; p=0,001; %95 GA=0,87), duygusal durum (31,81±29,73; p=0,029; %95 GA=0,56), uyku (43,60±26,01; p<0,001; %95 GA=1,96), PSQI toplam skoru (8,66±3,98; p=0,001; %95 GA=2,14) ve boyun çevresi (42,62±3,77; p=0,025; %95 GA=0,57)] anlamlı derecede yüksek bulundu. Diğer sonuç ölçütlerinde istatistiksel olarak anlamlı bir fark elde edilmedi (p>0,005).

Sonuç: Bu bulgular, OHS'li bireylerin basit obez bireylere kıyasla daha düşük egzersiz kapasitesine ve kas gücüne sahip olduğunu, ayrıca yaşam ve uyku kalitelerinin daha kötü olduğunu göstermektedir. Bu durum, OHS hastalarında fiziksel fonksiyon ve genel iyilik halini iyileştirmeye yönelik hedefe yönelik müdahalelerin gerekliliğini vurgulamaktadır.

Anahtar Kelimeler: Obezite hipoventilasyon sendromu, obezite, egzersiz kapasitesi, periferik kas gücü, yaşam kalitesi

Introduction

Obesity hypoventilation syndrome (OHS) is a condition seen in individuals with a body mass index (BMI) over 30 kg/m², characterized by elevated carbon dioxide levels during the day [partial carbon dioxide pressure ($PaCO_2$) >45 mmHg] and breathing disturbances during sleep, without any other identifiable cause of hypoventilation (e.g., chest wall disorders, neuromuscular disease or metabolic conditions) (1,2). Although the prevalence of OHS is not known exactly, it is thought that the prevalence of obesity and OHS are directly proportional (3,4).

The characteristic symptoms of OHS are described as a sensation of choking during sleep due to apnea, loud snoring, morning headaches, and excessive daytime sleepiness (5). In addition to these symptoms, research has also demonstrated that respiratory mechanics, respiratory muscle strength, pulmonary gas exchange, and lung functions are adversely affected (6).

The impact of obesity on the cardiovascular system, respiratory mechanics, respiratory muscle strength, respiratory control, gas exchange, breathing patterns, lung volumes, and work of breathing is serious. The evidence suggests that the accumulation of excess fat and a sedentary lifestyle in obese individuals result in a decrease in exercise capacity due to increased energy expenditure. Studies have indicated that people with obesity generally have reduced physical activity levels, diminished peripheral muscle strength, an increased risk of sleep-related breathing disorders, and a compromised health-related quality of life. The alterations observed in obesity account for the influence of various factors involved in the pathogenesis of OHS (7,8).

Hypercapnia ($PaCO_2$>45 mmHg) is a condition characterized by an increase in arterial carbon dioxide pressure ($PaCO_2$). The elevation in $PaCO_2$ occurs due to the cessation of ventilation during apneic events and the ongoing metabolic production of CO_2. In contrast, individuals with eucapnia are able to normalize their $PaCO_2$ levels by increasing alveolar ventilation. However, in patients with OHS, this compensatory mechanism is impaired, resulting in elevated CO_2 levels in the blood. In summary, the persistence of elevated carbon dioxide levels reflects a state of chronic hypercapnia. Elevated carbon dioxide levels are a key factor in the pathophysiology of OHS and act as a defining characteristic among sleep-related breathing disorders. The rise in $PaCO_2$ pressure in these patients results in symptoms such as daytime fatigue, excessive sleepiness, headaches and emotional changes, thereby indirectly contributing to a decline in quality of life (9).

Multiple studies have demonstrated that the excessive buildup of adipose tissue in individuals with obesity negatively affects peripheral muscle strength, exercise capacity, and quality of life (6,10). A comprehensive evaluation of exercise capacity, peripheral muscle strength, and quality of life in individuals with OHS is of particular importance for understanding the disease prognosis and management strategies. In view of the complex and heterogeneous nature of OHS, the specific effects of the syndrome on functional and clinical parameters remain insufficiently elucidated. In the absence of such evaluations, the development of targeted therapeutic interventions is significantly impeded. Incorporating these parameters into clinical assessment may also help clarify unexplained patient-reported symptoms and contribute to a more personalized and effective treatment approach. A deeper understanding of the effects of hypercapnia, which plays a key role in the pathogenesis of OHS, would facilitate a more detailed evaluation of its impacts and support the development of appropriate treatment programs based on assessment outcomes. Developing effective treatment strategies targeting hypercapnia and its related consequences may help improve health-related quality of life. The aim of this study was to investigate the effects of OHS on peripheral muscle strength, exercise capacity and quality of life in obese individuals.

Methods

The research was conducted in compliance with the Declaration of Helsinki, and informed voluntary consent was secured from all participants. Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of İstanbul University-Cerrahpaşa (number: E-74555795-050.04-899354, date: 26.01.2024), and the study was registered in the ClinicalTrials database under the registration number NCT06142513.

The study included a total of 64 participants. Thirty two individuals diagnosed with OHS by a pulmonologist and monitored at the Department of Pulmonary Diseases constituted the study group. OHS was diagnosed by a pulmonologist using polysomnography analysis. Arterial blood gas analysis was performed in polysomnography analysis to evaluate hypercapnia. An apnea-hypopnea index (AHI) of ≥5 per hour indicates sleep apnea (11). Thirty two obese individuals followed up at the Obesity Clinic of the Division of Endocrinology and Metabolism, İstanbul University, İstanbul Faculty of Medicine who were classified as having low risk according to the STOP-Bang assessment constituted the control group. Individuals with concomitant chronic respiratory disease, orthopedic or neurological conditions that could prevent exercise testing, or unstable cardiac disease were excluded from the study.

The BMI, gender, age, smoking habits, regular medication and presence of comorbidities of the individuals included in the study were questioned. None of the patients were using bronchodilators. In addition, AHI and mean saturation values according to polysomnography analysis and pH, CO_2 and saturation values according to arterial blood gas analysis performed in the morning were recorded in patients with OHS. The assessment process involved a multifaceted evaluation of various parameters, including functional peripheral muscle strength, exercise capacity, sleep quality, anthropometric measurements and quality of life. It is noteworthy that all assessments were conducted by a single physiotherapist, ensuring consistency and reliability in the data collection process. The entire evaluation process lasted approximately 45 minutes.

Functional Exercise Capacity

The six-minute walk test (6MWT) was utilized to evaluate the exercise capacity of the participants, with the test being conducted in accordance with the criteria established by the American Thoracic Society. Participants were instructed to walk at their own pace along a 30 m straight corridor, with standardised verbal instructions and encouragement phrases being employed at predetermined intervals. It was communicated to the participants that they were permitted to rest under specific conditions during the test, however, the test itself would proceed. Blood pressure, heart rate, and oxygen saturation were recorded before and after the test, and dyspnea and leg fatigue were assessed using the modified Borg scale. The total distance walked at the end of the test was recorded in m (12,13).

Muscle Strength

Quadriceps muscle strength was evaluated using a digital handheld dynamometer (K-Push Kinvent Hand Held Dynamometer, Montpellier, France). In a study using the K-Push Handheld Dynamometer to assess muscle strength in individuals, the device demonstrated intrarater reliability with results of ≥0.84 for torque, ≥0.80 for force, and ≥0.64 for normalised torque (14). Measurements were conducted three times for both the right and left quadriceps muscles, and the mean value of the three trials was recorded in Newtons (15,16).

Handgrip strength was assessed utilizing a hydraulic hand dynamometer (Jamar Hydraulic Hand Dynamometer, Pennsylvania, USA). In a study evaluating the test-retest, intra- and inter-rater reliability of the Jamar device in healthy individuals, the intra-rater intraclass correlation coefficients (ICC) of the Jamar, which is commonly used, were reported to be between 0.996 and 0.998, and the inter-rater ICCs were reported to be between 0.94 and 0.98 (17). These findings support the robustness of Jamar-based grip strength measurements in our study. The measurement was performed three times on the dominant hand, and the average of the three trials was documented in Newtons (18,19).

The Quality of Life

The participants' quality of life was evaluated using the Nottingham health profile (NHP), a general questionnaire designed to assess individuals' health issues and the impact of these issues on daily activities. The questionnaire includes 38 statements, divided into six categories: pain (eight statements), energy level (three statements), sleep (five statements), social isolation (five statements), emotional reactions (nine statements), and physical mobility (eight statements). The answers follow a Yes / No structure, and each subscale is measured on a 0-100 scale, with increased scores representing a more severe health condition. The validity and reliability of the Turkish version of the questionnaire were established by Kucukkdeveci et al. (20).

Anthropometric Measurements

Participants' body fluid percentage (%), body fat percentage (%) and muscle mass (kg) parameters were assessed with the Tanita BC-545N body composition analyzer (14). Support for its reliability comes from a recent validation study in healthy adults, which reported excellent test-retest ICC values (≥0.999) for whole-body metrics and 0.973-1.000 for regional components, along with strong agreement versus Dual-energy X-ray absorptiometry (21). In our study, circumference measurements were performed while the patient was standing upright with equal weight on both feet. Neck, waist, abdominal, and hip circumferences were measured using a measuring tape and recorded in cm.

Comorbidity

The comorbidity status of the subjects was evaluated using the Charlson comorbidity index (CCI). The CCI encompasses 19 distinct comorbid conditions, each assigned a score ranging from 1 to 6, with a maximum total score of 37. In the calculation of the total score, a point is allocated for each decade of life beginning at the age of 40. A higher score signifies the presence of multiple comorbidities (22,23).

Sleep Quality

The study employed the Pittsburgh sleep quality index (PSQI) to gauge participants' sleep quality. The PSQI is a 19-question self-assessment tool designed to analyze sleep patterns and disturbances over the last month. It comprises seven components: sleep latency, habitual sleep efficiency, daytime dysfunction, subjective sleep quality, use of sleep medication, sleep duration and sleep disturbances. Items are scored 0-3, with cumulative scores spanning 0-21, a total exceeding 5 signifies impaired sleep quality (24,25). The scale's reliability and validity for Turkish populations were confirmed by Agargun et al. (26).

Sample Size Calculation

The required sample size was calculated a priori using G*Power 3.1. Based on an estimated medium effect size (f=0.3), 80% power, and α=0.05, the analysis indicated that a minimum of 64 participants would be required to detect significant effects (27). Considering a potential dropout rate of approximately 10%, a total of 70 participants were initially enrolled. During the study, six participants withdrew due to personal reasons; thus, the study was completed with 64 participants.

Statistical Analysis

The data obtained at the conclusion of the study were analysed using SPSS Statistics version 24 (IBM Statistical Package for the Social Sciences, New York, USA). Descriptive statistics were calculated for all variables and presented as mean (standard deviation) or frequency (percentage). The normality of the distribution was assessed using the Shapiro-Wilk test. Variables between groups were analysed using the independent samples t-test. Multivariate analysis of variance (MANOVA) was performed to evaluate the effects of group differences on multiple dependent variables simultaneously. A p-value of <0.05 was considered to be statistically significant.

Results

Seventy patients were enrolled to participate in the study. As the evaluation of three patients could not be completed and three patients did not wish to participate in the study, a total of 64 patients were included in the study. The demographic and clinical characteristics of the patients included in the study are shown in Tables 1 and 2. There were no differences between the groups in terms of age, gender, smoking and comorbidity scores (p>0.05). The results and comparisons of exercise capacity, peripheral muscle strength, quality of life and sleep quality are shown in Table 3. 6MWD was significantly higher in the obese group (p=0.021).

Table 1. Demographic and clinical characteristics of the groups

	Obesity group (n=32)	OHS group (n=32)	Cohen's d (95% CI)	P-value
Age (years) Mean ± SD	45.06±11.46	49.69±8.55	0.46 (-0.04;0.95)	0.072
Gender n (%)				
Female	19 (59.4)	17 (53.1)	N/A	0.614
Male	13 (40.6)	15 (46.9)		
Smoking status n (%)				
Current smoker	6 (18.8)	6 (18.8)	N/A	
Non-smoker	26 (81.3)	26 (81.3)		
Charlson comorbidity index score	1.46±0.76	1.68±0.64	0.31(-0.18;0.80)	0.219

SD: Standard deviation, n: Number, N/A: Not available, CI: Confidence interval

Table 2. Polysomnography parameters of the OHS group

	OHS group (n=32) Mean ± SD	Normative value
Polysomnography Parameters		
AHI	54.25±36.03	<5
Average saturation in sleep	89.84±4.27	95-100%
$PaCO_2$	49.33±3.16	<45 mmHg
SaO_2	94.20±4.55	96-100%

OHS: Obesity hypoventilation syndrome, NIVM: Non-invasive mechanical ventilation, AHI: Apnea-hypopnea index, $PaCO_2$: Partial carbon dioxide pressure, SaO_2: Oxygen saturation, SD: standard deviation, n: Number

Right and left quadriceps muscles strengths were significantly higher in the obesity group (p=0.004 and p=0.005 respectively). There was no significant difference in hand grip strength between the groups (p=0.092). The NHP total score, NHP subscores for energy level, emotional status and sleep score were significantly higher in the OHS group (p=0.000, p=0.001, p=0.029 and p=0.000, respectively). There was no difference between groups for the NHP subscores of pain, physical activity and social isolation (p>0.05). The PSQI total score was statistically higher in the OHS group (p=0.000). The results of the MANOVA test are presented in Tables 4 and 5. The MANOVA analysis revealed that at least one of the dependent variables differed significantly between the independent variable groups tested (λ=0.382; p<0.001). Examination of the findings in the table indicated that, according to the one-way MANOVA results, there were statistically significant differences between the study groups (obesity and OHS) in terms of 6MWD (f=5.636; p=0.021), quadriceps muscle strength (right, f=9.017; p=0.004 and left, f=8.662; p=0.005), NHP scores (f=49.122; p<0.001), and PSQI scores (f=73.077; p<0.001). When examining the highest η^2 values, the presence of OHS explained 54.1% of the variance in PSQI scores (η^2=0.541) and 44.2% of the variance in NHP scores (η^2=0.442). At the 95% confidence level (1-α), the observed power (1-β) was 100% for the variable with the largest effect size (PSQI, d=2.14), and 64.7% for the variable with the smallest effect size (6MWD, d=0.593). The results and comparisons of body composition and anthropometric measurements are shown in Table 6. Body composition, abdominal, hip and waist circumferences were similar in both groups (p>0.05). Neck circumference was significantly higher in the OHS group than in the obese group (p=0.025).

Table 3. Comparison of exercise capacity, muscle strength, quality of life and sleep quality between groups

	Obesity group (n=32) Mean ± SD	OHS group (n=32) Mean ± SD	Cohen's d (95% CI)	P-value
6MWD (m)	500.44±40.46	474.09±47.99	0.59 (0.09;1.09)	**0.021**
QS - Right (N)	186.66±35.14	159.73±36.57	0.75 (0.24;1.26)	**0.004**
QS - Left (N)	184.56±34.56	158.38±36.57	0.74 (0.23;1.24)	**0.005**
Grip strength (N)	288.10±104.90	244.80±97.40	0.42 (-0.08;0.91)	0.101
NHP - Total score	95.98±54.42	243.13±105.54	1.75 (1.17;2.33)	**<0.001**
NHP - Pain	30.11±32.00	33.49±26.27	0.12 (-0.38;0.61)	0.645
NHP - Physical activity	22.53±13.04	27.42±19.47	0.30 (-0.20;0.79)	0.243
NHP - Energy level	29.60±31.90	58.90±35.51	0.87 (0.36;1.38)	**0.001**
NHP - Social isolation	20.39±30.18	14.45±20.71	0.23 (-0.26;0.72)	0.363
NHP - Emotional status	16.88±23.37	31.81±29.73	0.56 (0.06;1.06)	**0.029**
NHP - Sleep	6.06±4.44	43.60±26.01	1.96 (1.36;2.56)	**<0.001**
PSQI - Total score	2.28±1.37	8.66±3.98	2.14 (1.51;2.75)	**<0.001**

6MWD: Six minute walking distance, QS: Quadriceps strenght, N: Newton, NHP: Nottingham health profile, PSQI: Pittsburgh sleep quality index, SD: Standard deviation, n: Number, CI: Confidence interval

Table 4. Multivariate analysis of variance (MANOVA) results showing the overall group effect on exercise capacity, muscle strength, quality of life, and sleep quality

Effect	Wilks lambda (λ)	F	P-value
Group	**0.382**	5.636	**0.001**

Table 5. Univariate ANOVA results for group effect on exercise capacity, muscle strength, quality of life, and sleep quality

Dependent variable	F	p-value	Partial η^2	Observed power (1-β)
6MWD (m)	5.636	0.021	0.083	0.647
QS - Right (N)	9.017	0.004	0.127	0.840
QS - Left (N)	8.662	0.005	0.123	0.826
Grip Strength (N)	2.766	0.101	0.043	0.374
NHP - Total score	49.122	<0.001	0.442	1
PSQI- Total score	73.077	<0.001	0.541	1

ANOVA: Analysis of variance, 6MWD: Six minute walking distance, QS: Quadriceps strenght, N: Newton, NHP: Nottingham health profile, PSQI: Pittsburgh sleep quality index, n: Number, CI: Confidence interval

Table 6. Comparison of body composition and anthropometric measurements between groups				
	Obesity group (n=32) Mean ± SD	OHS group (n=32) Mean ± SD	Cohen's d (95% CI)	p-value
BMI (kg/m^2)	35.05±3.02	36.17±3.10	0.37 (-0.13;0.86)	0.149
Body Fat (%)	39.29±5.82	40.08±7.18	0.12 (-0.37;0.61)	0.631
Total body water (%)	43.18±7.57	41.79±7.43	0.19 (-0.31;0.68)	0.462
Muscle mass (kg)	54.42±11.90	54.29±11.28	0.01 (-0.48;0.50)	0.964
Neck circumference (cm)	40.75±2.66	42.62±3.77	0.57 (0.07;1.07)	**0.025**
Waist circumference (cm)	110.72±8.71	111.94±7.16	0.15 (-0.34;0.64)	0.543
Abdominal circumference (cm)	118.41±9.16	121.12±8.71	0.30 (-0.19;0.80)	0.229
Hip circumference (cm)	119.78±9.95	122.22±10.37	0.24 (-0.25;0.73)	0.341
Waist-hip ratio	0.92±0.070	0.92±0.075	0.09 (-0.40;0.58)	0.720

BMI: Body mass index, SD: Standard deviation, n: Number, CI: Confidence interval

Discussion

This study examined the impact of OHS on peripheral muscle strength, exercise tolerance, and quality of life in obese individuals, comparing these parameters between OHS patients and those with simple obesity.

The assessment of patients suffering from sleep-related breathing disorders is of crucial importance in order to understand the progression of the disease and to interpret health-related quality of life. Cardiopulmonary exercise testing (CPET) and the 6MWT are the most common tests used to evaluate exercise capacity. The 6MWT is recognized for its simplicity, reproducibility, and ease of administration, offering a reliable reflection of daily life activities (28). In obese individuals, the 6MWD has been shown to be shorter compared to normal-weight individuals due to higher energy expenditure and metabolic demands during walking (29). In the presence of sleep-related breathing disorders, reduced functional residual capacity and increased respiratory workload lead to elevated energy expenditure in patients. Tidal volume is reduced, breathing becomes superficial, and respiratory rate increases. As both the respiratory effort and energy consumption increase, fatigue may occur, which can have a negative impact on exercise capacity. Furthermore, chronic hypoventilation has been shown to impair respiratory muscle endurance, while apneic episodes during sleep exacerbate intermittent hypoxemia, further reducing oxygen delivery to the muscles and deteriorating functional performance (30,31). In the present study, we demonstrated that exercise capacity was further reduced in individuals with OHS compared to those with simple obesity. The greater impairment in exercise capacity in OHS patients compared to those with simple obesity may be associated with other clinical features related to sleep disorders. Therefore, although sleep-disordered breathing is undoubtedly a factor, it is believed that these mechanisms associated with hypercapnia play an important role and require further investigation in future studies.

It has been suggested that individuals with obesity tend to exhibit reduced antigravity muscle strength compared to those with normal weight (32). Increased adipose tissue may contribute to diminished sympathetic neural activation and alterations in muscle fiber structure (33). In individuals diagnosed with obstructive sleep apnea syndrome (OSAS), previous studies have reported lower quadriceps muscle strength and poorer functional performance compared to healthy controls (34). Although the distribution of muscle fiber types appeared similar in a study comparing individuals with severe OSAS and healthy subjects, differences in fiber diameter and protein content were observed. In the context of sleep-disordered breathing, the repetitive cycles of deoxygenation and reoxygenation caused by apneas and hypopneas are thought to contribute to intermittent hypoxemia (35). Sauleda et al. (36) have reported that chronic hypoxemia may influence skeletal muscle structure and enzyme activation. In our study, we observed that peripheral muscle strength was lower in individuals with OHS compared to those with obesity. We believe that chronic hypoxemia and hypercapnia in individuals with OHS might contribute to disturbances in skeletal muscle pH homeostasis, which could in turn affect enzymatic activity and reduce blood flow to muscle tissue, potentially impacting muscle strength. We suggest that future studies focus on exploring the underlying mechanisms of peripheral muscle weakness in patients with OHS, potentially through muscle biopsies and pH-related biochemical assessments.

Handgrip strength is a widely accepted metric for evaluating overall muscular function in the upper limbs. A recent study examined the relationship between handgrip strength, insulin resistance, C-reactive protein levels, and body composition in obese and normal-weight individuals across various age groups. The findings revealed a negative correlation between prolonged excess adipose tissue and handgrip strength, suggesting that prolonged exposure to excess adipose tissue might contribute to a decline in muscular strength (37). In a further study, the relationship between apnea severity, sleep duration, and handgrip strength in individuals diagnosed with OSAS was examined. No significant difference in handgrip strength was observed among individuals with varying apnea severity (38). Lee (39), emphasised a robust correlation between sleep duration of five hours or less and diminished handgrip strength, along with an augmented risk of sleep-related breathing disorders. In this study, there was no statistically significant difference between obese group and OHS group in terms of grip strength. When the normative data of healthy individuals were compared according to gender in both groups, it was observed that only women in the OHS group had decreased hand grip strength compared to healthy individuals (40). Obese group had higher grip strength. We think that this may be explained by the advantageous effects of increased body mass, especially associated with obesity, on hand muscles. Hand grip strength may be preserved in obese men with OHS and obese women, but it is important to evaluate these individuals in terms of muscular endurance and functional capacity.

Obesity has an effect on many factors such as physical functions, social behaviors and emotional status. Studies reported that the quality of life of individuals diagnosed with OHS was worse compared to OSAS patients (41,42). In our study, similar to other studies, it was observed that the general quality of life score of individuals diagnosed with OHS was worse than that of obese individuals. In addition, the NHP emotional status sub-score was also more affected than obese group. Anxiety and depression scores were higher in individuals with OHS compared with healthy controls (43). In our study, no scale was used to assess anxiety and depression. However, this difference in the NHP emotional state subscore suggests that chronic hypoxaemia and hypercapnia, which are characteristic features of OHS, may affect emotional functioning. Unlike obesity, OHS has a wider impact on an individual's quality of life. The more pronounced clinical symptoms of OHS may increase the perception of chronic illness in individuals. This may explain the poorer overall quality of life and emotional status of people with OHS. We believe that this is due to impaired sleep quality, reduced physical activity levels and variable emotional state due to the presence of hypercapnia associated with chronic hypoxaemia with excess adipose tissue. There was no difference between individuals with OHS and obese individuals in the quality of life sub-scores of pain, physical activity and social isolation. Both groups may be affected by physical difficulties from obesity, sedentary lifestyles, and similar barriers to social participation.

OHS is a sleep-related breathing disorder characterised by the presence of hypercapnia, alongside obesity, and its impact on the quality of sleep in individuals with the condition has been extensively researched. In a study evaluating sleep quality and respiratory muscle strength in individuals diagnosed with simple obesity and OHS, it was shown that hypercapnia accompanying chronic hypoventilation decreased sleep quality, caused excessive daytime sleepiness and increased the severity of fatigue (44). Another study compared sleep parameters, daytime sleepiness, and quality of life among obese OSAS patients, normal-weight OSAS patients, and individuals with OHS. The results indicated that individuals with OHS exhibited higher levels of daytime sleepiness and poorer sleep quality in comparison to the two other groups (41). Consistent with the findings of these studies and in line with the prevailing theories, our study also demonstrated that the presence of hypercapnia in individuals with OHS resulted in diminished sleep quality when compared to obese individuals. This phenomenon is attributed to the disruption of the respiratory cycle during sleep, a consequence of the combination of obesity and chronic hypoventilation.

To evaluate multivariate effects across outcome measures, a MANOVA analysis was performed. The results were consistent with our pairwise comparisons and confirmed significant group effects. According to the MANOVA results, the strongest effect sizes were observed in the NHP and PSQI scores, both demonstrating a statistical power of 100% ($1-\beta=1$). In contrast, the weakest effect was found in the 6MWD, with a statistical power of 64.7% ($1-\beta=0.647$). These findings highlight the varying impact of OHS on different functional domains and strengthen the clinical relevance of evaluating exercise capacity, peripheral muscle strength, quality of life, and sleep in this population.

Study Limitations

There are some limitations to this study. The exercise capacity of the participants was assessed using the 6MWT. However, employing the gold standard measurement method, CPET instead of the 6MWT, could enhance the objectivity of the results obtained. Polysomnography analysis was performed exclusively on subjects diagnosed with OHS according to the inclusion criteria of the study. In the control group, which consisted of individuals with simple obesity, polysomnography and arterial blood gas analysis were not conducted. Consequently, a comparison of polysomnography findings between the two groups was rendered unfeasible. Although participants with high STOP-Bang scores were excluded from the study, objective diagnostic assessments were not performed. This represents a potential limitation in interpreting the comparisons between groups. The study did not collect data on potential confounding variables such as patients' physical activity levels, glycemic control in diabetic patients, and nutritional status. We consider it necessary to include these parameters in future studies to increase the validity and interpretability of the results. In our study, assessments were performed by a single physiotherapist who was not blinded. Furthermore, our study had a cross-sectional design, which limited causal inference. These factors may affect the internal validity of the study and should be taken into account when interpreting the findings.

Conclusion

The results demonstrate significantly poorer outcomes in OHS patients compared to those with simple obesity, including reduced peripheral muscle strength, diminished exercise capacity, impaired quality of life and worse sleep quality scores. Persistent hypercapnia in obesity induces intracellular acidosis in skeletal muscle, impairing both contractile function and mitochondrial enzyme activity. This pathophysiology leads to measurable declines in peripheral muscle strength, exercise tolerance, and ultimately health-related quality of life. In future studies, comparing the effectiveness of exercise training in individuals with OHS and simple obesity may contribute to the development of more targeted individualised rehabilitation programmes.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of İstanbul University-Cerrahpaşa (number: E-74555795-050.04-899354, date: 26.01.2024)

Informed Consent: Informed voluntary consent was secured from all participants.

Footnotes

Authorship Contributions

Surgical and Medical Practices: E.A., Ö.E.H., G.K.A., Concept: E.A., Ö.E.H., G.K.A., E.K., Design: E.A., Ö.E.H., G.K.A., B.A., Data Collection or Processing: E.A., Ö.E.H., G.K.A., B.A., B.F.Ç., E.K., Analysis or Interpretation: E.A., Ö.E.H., G.K.A., Literature Search: E.A., Ö.E.H., G.K.A., Writing: E.A., Ö.E.H., G.K.A., B.A., B.F.Ç., E.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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