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EFFECTS OF BODY COMPOSITION ON RESPIRATORY PARAMETERS, FUNCTIONAL CAPACITY, AND SLEEP QUALITY IN HEALTHY YOUNG ADULTS

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Summary

Background. The study aimed at examining the effects of body composition on respiratory function, muscle endurance, functional capacity, and sleep quality in healthy young adults.

Material and methods. The study involved 59 participants, with body composition measured using Tanita DC-360, respiratory function and muscle endurance assessed via a digital spirometer, functional capacity evaluated through the 6-minute walk test, and sleep quality assessed with the Pittsburgh Sleep Quality Index.

Results. A moderate correlation was found between the body mass index with forced vital capacity (r=0.395; *p*=0.002). A moderate relationship was also observed between respiratory muscle endurance and muscle mass (r=0.310; *p*=0.017), lean body mass (r=0.308; *p*=0.018), and total body water (r=0.285; *p*=0.045). Positive moderate correlations were found between forced vital capacity, forced expiratory volume in one second, between respiratory muscle endurance and muscle mass, lean body mass. There was a moderate relationship between body composition and functional capacity.

Conclusions. Respiratory muscle endurance is linked to lean body mass, muscle mass, and total body water, while other respiratory functions relate to lean body mass and muscle mass. Increased fat mass and decreased muscle mass can negatively impact functional capacity. As muscle mass increases with exercise, our findings may guide future research on respiratory muscle endurance and exercise.

Keywords: walk test, respiratory function test, body composition, respiratory muscles, sleep

Introduction

Human anatomy and physiology comprise peripheral and visceral muscles, bones, adipose tissue, water, and various inorganic substances stored primarily in the bones. Body composition is a broad and inclusive term that encompasses all of the structures. Body composition parameters are important predictors for cardiovascular diseases, among other comorbid conditions [1]. Spirometric values, such as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC ratio, and peak expiratory flow (PEF) are long-term predictors of mortality caused by cardiovascular diseases [2]. Performance of respiratory muscles can be measured by assessing respiratory muscle strength and endurance. Maximum voluntary ventilation (MVV), used to evaluate respiratory muscle endurance, provides information primarily about the endurance of respiratory muscles and reserve of respiration, offering comprehensive data on the mechanics of the pulmonary system. MVV is also an indirect indicator of respiratory muscle strength and maximal exercise capacity [3]. Accumulation of visceral and subcutaneous fat, combined with a decrease in lean body mass, higher body mass index (BMI), and elevated waist-to-hip ratio indicative of abdominal obesity, can negatively affect lung function and respiratory mechanics. The buildup of adipose tissue in the mediastinum and thoracic cavity limits diaphragmatic movement and raises pleural pressure. Additionally, adipose tissue promotes the production of pro-inflammatory cytokines, which may adversely affect pulmonary function [4].

Functional capacity is a measurement of the effort required to perform daily activities at a submaximal level. It is a factor influenced by pulmonary functions. Moreover, it has been demonstrated that obesity and increased BMI values reduce functional capacity [5].

Sleep is essential for sustaining physical, mental, and cognitive well-being. Numerous factors, such as age, gender, socio-economic status, dietary habits, mental and physical health, as well as genetic and environmental influences, can affect sleep quality [6]. Evidence indicates that sleep quality is associated with obesity, body fat percentage, and weight gain [7]. Especially reduced lean body mass affects sleep duration and quality; high body fat percentage is associated with reduced sleep duration and lower sleep quality. Coexistence of poor sleep quality and obesity-related respiratory problems can be explained by the presence of bidirectional mechanisms in the pathophysiology of the relationship [8].

In literature, there are reports on the relationship between body composition and respiratory functions in healthy young adults [8,9]. Assessment of respiratory muscle endurance is considered an indicator of both respiratory muscle performance and pulmonary capacity. However, knowledge about the connection between body composition and respiratory muscle endurance is still limited.

Aim of the work

The study primarily aimed at evaluating the relationship between body composition and respiratory muscle endurance in healthy young adults. The secondary aim was to explore the impact of body composition on respiratory functions, functional capacity, and sleep quality.

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Material and methods

The study was conducted between August 2024 and October 2024 at the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Istanbul Kent University, Türkiye.

The study included male and female young adults aged 18-30 years who had no cognitive or mental disorders, no chronic comorbidities, were able to walk independently, could read and write in Turkish. Participants with insufficient cooperation, pregnant women, smokers and those with cardiac, pulmonary, neurological, major musculoskeletal or rheumatic diseases were excluded from the study.

Participants' body composition was assessed using the Tanita DC-360 (Tanita Corporation, Tokyo, Japan) and waist/hip circumference measurements. Respiratory functions and respiratory muscle endurance were measured using a digital spirometer (Pony FX, COSMED Inc., Italy). Functional capacity was evaluated by the 6-minute walk test (6MWT), and sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI).

Evaluation of body composition

Body composition was evaluated using the multi-frequency analysis device Tanita DC-360. Body composition analysis was conducted by the researcher in accordance with the instructions of the Tanita DC-360 (Tanita Corporation, Tokyo, Japan) device. After entering the participant's age, height, gender, and body type into the device, measurements were taken. Body weight (kg), BMI (kg/m^2), body fat percentage (%), body fat mass (kg), lean body mass (kg), muscle mass (kg), body fluid percentage (%), body fluid mass (kg), bone mass (kg) values were recorded.

To assess waist-to-hip circumference, participants were positioned in an upright stance, and measurements were obtained using a tape measure. Waist circumference was measured at the level of the umbilicus, while hip circumference was measured at the level of the greater trochanter, with both values recorded in centimeters. The waist-to-hip ratio was then derived from the measurements obtained.

Evaluation of respiratory function and respiratory muscle endurance

Respiratory functions were assessed using a digital spirometer in compliance with the American Thoracic Society (ATS) and European Respiratory Society (ERS) criteria [10]. The test was performed while participants sat upright in a chair. FVC, FEV1, FEV1/FVC ratio, PEF, and their predicted values (%) were obtained. Three measurements were taken, and the result closest to the predicted value was recorded [10].

Respiratory muscle endurance was evaluated by measuring the MVV value using a digital spirometer. Participants were asked to perform rapid, deep inhalation and exhalation for 12 seconds while sitting upright on a chair. At the end of the test, the MVV value and its predicted value (%) were recorded [10].

Evaluation of functional capacity

In our study, the 6MWT was used to evaluate functional capacity. Liu et al. demonstrated that the 6MWT is a suitable test for assessing functional capacity in healthy young adults [11]. Blood pressure, heart rate, and oxygen saturation levels were recorded both pre- and post-test. Blood pressure and oxygen saturation were assessed using a fingertip pulse oximeter (Havanna, Fingertip Pulse Oximeter, Blood Oxygen and Pulse Rate Monitor, Turkey). Blood pressure monitoring was evaluated using a digital blood pressure monitor (Omron M1 Basic, Japan) based on the upper arm measurement method. The participants' perceived fatigue was evaluated using the Modified Borg Fatigue Scale and perceived dyspnea was evaluated with the Modified Borg Dyspnea Scale. The distance walked by each participant was recorded in meters. The predicted 6-minute walking distance (6MWD) for each participant was determined using the reference equation by Enright et al. [12].

Evaluation of sleep quality

To evaluate sleep quality, the PSQI developed by Buysse et al. was used [13]. The index consists of 24 questions that evaluate seven components: sleep duration, subjective sleep quality, sleep latency, sleep efficiency, presence of sleep disturbances, use of sleep medication, and daytime dysfunction. Each question is scored between 0 and 3. The total score is obtained by summing the scores from all seven components. The total score ranges from a minimum of 0 to a maximum of 21, with a score above 5 indicating poor sleep quality [13].

Sample size calculation

Previous studies in young males found moderate correlations (r=0.3-0.4) between lean body mass and FVC [8]. The sample size for the study was determined using the G*Power 3.1.9.6 power analysis software (University of Kiel) based on the study results. With 95% power, a 0.05 margin of error, and a moderate effect size of 0.4, the sample size was calculated as 59 healthy subjects.

Statistical analysis

The data was analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, Illinois). The Shapiro-Wilk test was applied to assess normality of the data. Quantitative variables were expressed as mean and standard deviation, while qualitative variables were reported as frequencies and percentages. Spearman correlation coefficient was used for correlation analysis, and a *p*-value <0.05 was considered statistically significant.

Results

Participants' demographic and clinical characteristics are presented in Table 1.The study was completed with 59 healthy young adults, consisting of 36 women and 23 men, with a mean age of 24.5±3.2 years (Table 1).

Table 1. Demographic and clinical characteristics of the participants (n=59)

Anthropometric and physiological variables (n=59)	Mean±SD
Age (year)	24.52±3.24
BMI (kg/cm²)	23.43±5.95
Body fat mass (kg)	16.12±11.6
Body fat percentage (%)	22.28±8.94
Muscle mass (kg)	49.63±12.53
Lean body mass (kg)	52.23±13.14
Body fluid mass (kg)	37.31±8.88
Body fluid percentage (%)	55.71±5.85
Waist circumference (cm)	74.33±15.92
Hip circumference (cm)	93.58±11.14

Waist-hip ratio (cm)	0.78±0.09
Respiratory functions	**Mean±SD**
FVC (L)	4.10±0.98
FVC (%)	93.44±11.1
FEV1 (L)	3.32±0.85
FEV1 (%)	88.83±17
FEV1/FVC (%)	81.44 ±10.62
PEF (L/sn)	4.97±2
PEF (%)	59.06±20.76
MVV (L/min)	119.57±28.9
MVV (%)	89.19±16.12
Functional capacity	**Mean±SD**
6MWT (m)	646.16±76.38
6MWD (pre%)	85.53±9.45
Sleep quality	**Mean±SD**
Pittsburg total score	5.86±2.45

Notes: All measurements were given as mean ± SD. SD – standard deviation, FVC – forced vital capacity, FEV1 – forced expiratory volume in the 1st second, PEF – peak expiratory flow rate, MVV – maximum voluntary ventilation, BMI – body mass index, 6MWT – 6-minute walk test, 6MWD – 6-minute walking distance, pre% – predicted %.

The participants' average heart rate before the 6MWT was measured at 84 beats per minute, blood pressure at 112/62 mmHg, and oxygen saturation at 98.8%. Following the 6MWT, the average heart rate increased to 120.4 beats per minute, blood pressure to 120/65 mmHg, and oxygen saturation to 99.2%. Mean levels of perceived dyspnea and fatigue, assessed using the Modified Borg Scale, were 0/10 before the test. Post-test measurements indicated an average fatigue level of 5.5/10 and a dyspnea level of 0.4/10.

The relationship between participants' body composition and respiratory parameters is given in Table 2. A moderate correlation was found between the BMI and FVC (%FVC) (r=0.395; *p*=0.002), and between fat mass and FVC (%FVC) (r=0.308; *p*=0.018). A moderate correlation was found between lean body mass (r=0.308; *p*=0.018), total body fluid (r=0.285; *p*=0.045), respiratory muscle endurance and muscle mass (r=0.310; *p*=0.017). There were moderate-high significant positive correlations between FVC(L), FEV1(L), PEF(L/sec), MVV(L/min) and muscle mass, lean body mass and total body fluid. There were moderate positive correlations between the BMI and respiratory parameters; and moderate negative correlations between fat percentage and respiratory muscle endurance (Table 2).

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Table 2. Relationship between participants' body composition and respiratory parameters

Body composition	**FVC (pre%)**		**FVC (L)**		**FEV1(pre%)**		**FEV1 (L)**		**FEV1/FVC (%)**		**PEF (pre%)**		**PEF (L)**		**MVV (pre%)**		**MVV (L)**	
	r	***p***	**r**	***p***	**r**	***p***	**r**	***p***	**r**	***p***	**r**	***p***	**r**	***p***	**r**	***p***	**r**	***p***
BMI (kg/cm²)	0.395	**0.002**	0.479	**0.000**	0.230	0.080	0.411	**0.001**	-0.135	0.309	0.181	0.170	0.275	**0.035**	0.240	0.067	0.321	**0.014**
Fat mass (kg)	0.308	**0.018**	0.151	0.254	0.175	0.185	0.117	0.117	-0.084	0.526	0.060	0.653	0.036	0.784	0.080	0.546	-0.030	0.825
Fat percentage (%)	0.181	0.170	-0.271	0.066	0.111	0.403	-0.237	0.071	0.001	0.993	-0.064	0.629	-0.225	0.087	-0.058	0.662	-0.334	**0.010**
Muscle mass (kg)	0.191	0.147	0.822	**0.000**	0.087	0.514	0.731	**0.000**	-0.207	0.116	0.218	0.098	0.514	**0.000**	0.310	**0.017**	0.724	**0.000**
Lean body mass (kg)	0.197	0.134	0.821	**0.000**	0.086	0.517	0.729	**0.000**	-0.207	0.116	0.207	0.116	0.511	**0.000**	0.308	**0.018**	0.725	**0.000**
Body fluid mass (L)	0.191	0.183	0.815	**0.000**	0.041	0.779	0.709	**0.000**	-0.217	0.098	0.169	0.240	0.503	**0.000**	0.285	**0.045**	0.709	**0.000**
Body fluid percentage (%)	-0.288	**0.027**	0.015	0.915	-0.137	0.299	0.032	0.808	0.073	0.584	-0.003	0.980	0.096	0.468	-0.032	0.813	0.162	0.224
Waist-hip ratio (cm)	0.214	0.103	0.604	**0.000**	0.191	0.146	0.595	**0.000**	0.019	0.885	0.333	**0.010**	0.533	**0.000**	0.265	**0.043**	0.522	**0.000**

Notes: The presence of a significant relationship is indicated in bold. FVC – forced vital capacity, FEV1 – forced expiratory volume in 1st second, PEF – peak expiratory flow rate, MVV – maximum voluntary ventilation, BMI – body mass index, pre% – predicted %.

The relationship between participants' body composition, functional capacity and sleep quality is given in Table 3. Moderate relationships were observed between body composition components and functional capacity, whereas no significant relationships were observed between body composition and the PSQI (Table 3).

Table 3. Relationship between participants' body composition, functional capacity and sleep quality

Body composition	6MWT (m)		6MWD (pre%)		Pittsburg total score	
	r	*p*	r	*p*	r	*p*
BMI (kg/cm²)	-0.019	0.888	0.263	**0.044**	0.080	0.545
Fat mass (kg)	-0.290	**0.026**	0.076	0.568	0.046	0.728
Fat percentage (%)	-0.583	**0.000**	-0.177	0.181	0.016	0.905
Muscle mass (kg)	0.442	**0.000**	0.390	**0.002**	-0.026	0.843
Lean body mass (kg)	0.439	**0.001**	0.388	**0.002**	-0.027	0.841
Body fluid mass (kg)	0.434	**0.001**	0.403	**0.002**	0.003	0.984
Body fluid percentage (%)	0.432	**0.001**	0.030	0.821	-0.032	0.811
Waist-hip ratio (cm)	0.248	0.058	0.278	**0.033**	-0.069	0.606

Notes: The presence of a significant relationship is indicated in bold. 6MWT – 6-minute walk test, 6MWD – 6-minute walking distance, pre% – predicted %.

Discussion

In our study, in which we investigated the effect of body composition on respiratory parameters, functional capacity and sleep quality in healthy young adults, the relationship between FVC(L), FEV1(L), PEF (L/sec), MVV(L/min), MVV(%) and muscle mass, lean body mass and total body fluid was shown.

The relationships we discovered between respiratory functions and muscle mass, lean body mass, and total body fluid align with the findings of previous research [14,15]. For example, Pi et al. [15] evaluated body composition using bioelectrical impedance analysis and respiratory functions by digital spirometry. In the experiment on 776 healthy adults, they found that muscle mass and lean body mass were positively correlated with FEV1 and FVC [15]. Komici et al. [16] found similar results in a study conducted on 435 professional athletes practicing strength and endurance sports.. An increase in muscle mass and lean body mass may reduce abdominal adiposity, thereby improving lung capacity. Reduced muscle mass is associated with an increase in adipose tissue. The increase in adipose tissue may elevate mechanical pressure on the diaphragm, reduce the elasticity and mobility of the chest wall, and negatively affect lung compliance. Furthermore, the accumulation of adipose tissue in the thoracic region may increase airway resistance, trigger the release of proinflammatory cytokines, and consequently alter pleural pressure [17].

The MVV value used in the determination of respiratory muscle endurance provides important information about respiratory muscle functions [18]. Previous reports suggest that it should be included in lung capacity assessment in both healthy adults and those suffering chronic lung disease. Bairapareddy et al. [19] evaluated the relationship between the MVV and respiratory muscle strength with physical activity and the BMI in 165 healthy young adults aged 18-30 years with a mean BMI of 25.6 kg/m². In conclusion, they found no relationship between the BMI and MVV(%) [19]. Similarly, no significant relationship was found between the BMI and MVV(%) in our study; however, MVV(L/min) value increases with increasing BMI. We did not find any reports on the relationship between muscle mass, lean body mass and total body fluid with respiratory muscle endurance. Our study demonstrated that an increase in muscle mass, lean body mass, and total body fluid is associated with an improvement in respiratory muscle endurance.

Respiratory functions are affected by the BMI. In literature, it has been reported that respiratory functions will be adversely affected in individuals with low and high BMI [20,21]. In obese individuals with high BMI and increased waist/hip ratio, adipose tissue accumulated in the neck, abdomen and thorax prevents downward displacement of the diaphragm results in increased pleural pressure. It basically affects functional residual capacity and impairs respiratory mechanics [20]. In a cross-sectional study by Leone et al. [22], the relationship between lung functions and metabolic syndrome showed that respiratory functions may be adversely affected as the BMI increases.. Jones et al. [20] studied 373 subjects who were classified as overweight, obese and morbidly obese. The researchers found that the decrease in pulmonary function in morbidly obese individuals could reach up to 33% [20]. In individuals with low BMI, decreased pulmonary functions were directly attributed to decreased mass of skeletal muscle, diaphragm, abdominal and intercostal muscles. The condition results in a decrease in pulmonary function by affecting respiratory muscle strength and mechanics [23]. In an experiment designed to show the relationship between low weight and pulmonary functions, Do et al. [21] found decreases in FEV1, FVC and PEF values in Korean population with low BMI (mean BMI 17.6 kg/m²). In a similar study conducted in Croatia, when 370 university students were evaluated, a greater decrease in the FVC value was once again shown in students with low BMI [24]. Unlike results reported previously in the literature, we found that respiratory functions increased as the BMI increased. The fact that our participants had a mean BMI of 24.5 kg/m² and were in the normal weight class clarifies the situation.

Our results show that as the 6MWD increases, body fat percentage and body fat mass will decrease, while body muscle mass, lean body mass and total body fluid will increase. Increased fat mass is associated with decreased muscle mass. It may affect physical fitness and may adversely affect the 6MWD used to evaluate aerobic and functional capacity. In literature, the relationship between functional capacity and body composition was investigated in the elderly population and obese individuals [25,26]. In a study exploring the relationship between the 6MWT and body composition parameters in seventy-seven elderly individuals, decreased walking distance was reported in participants with high BMI and fat mass [25]. Similar results were shown in another study on obese young girls [26]. Makni et al. [26] found relationships between the 6MWT, BMI and lean body mass in 190 obese young girls with a mean age of 12 years and a mean BMI of 26.4 kg/m^2.

Our results demonstrate the relationship between fat mass, fat percentage, muscle mass and functional capacity in healthy young adults. Enright et al. [12] stated that there would be decreases in 6MWD results when the BMI was above 30 kg/m^2.. The fact that our participants had normal BMI values may be the reason why we could not demonstrate a relationship between the BMI and 6MWD. However, we found a positive correlation between the BMI and the predicted value of 6MWD. Gender, age, height and weight values are used in calculation of the predicted value of the 6MWD. It may have influenced the relationship between the BMI and 6MWD (pre%) rather than 6MWD.

We could not demonstrate a relationship between Pittsburg total score and any component of body composition. Studies exploring the relationship between sleep quality, the BMI, lean tissue, and muscle mass have shown inconsistent outcomes. Babu et al. [27] investigated the association between sleep quality and the BMI, waist-to-hip ratio, and fat percentage using the PSQI in a sample of 100 university students with an average BMI of 21 kg/m^2. They found that Pittsburg total score was not related to body composition [27]. Kristicevic et al. [28] categorized 2,100 university students aged 18-24 years as having the BMI lower and higher than 25 kg/m^2. Their results indicate the presence of poor sleep quality in obese subjects [28]. Poor sleep quality results in insufficient sleep, which increases the need for energy, therefore affecting hunger and satiety hormones. The condition drives weight gain, and high fat rates may result. Poor sleep quality in obese individuals can be explained by the situation [29]. Kahlhöfer et al. [30] evaluated sleep quality in 132 young adults by wrist actigraphy and found that inadequate sleep quality was linked to increased fat mass.. The fact that the Pittsburg sleep quality scale is a subjective questionnaire may have affected our results.

Limitations

The current study has some limitations. The fact that we did not use objective methods such as polysomnography or actigraphy to evaluate sleep quality in our study could have impacted our inability to demonstrate the relationship between sleep quality and body composition. The fact that we did not use an objective method to evaluate the sleep quality of our participants may have been effective in our inability to reveal the relationship between sleep quality and body composition.

Conclusions

In our study, primarily designed to examine the relationship between respiratory muscle endurance and body composition, a significant positive correlation was found between lean body mass, muscle mass, total body fluid, and waist-to-hip ratio with the MVV. Other parameters of the respiratory function are also related to the MVV, particularly lean body mass, muscle mass, and total body fluid. Increased fat mass and decreased muscle mass directly affect functional capacity. It is known that greater muscle mass can be achieved through exercise. Therefore, we believe that the results of our study may provide guidance for future research on respiratory muscle endurance and physical fitness.

Disclosures and acknowledgements

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The study was conducted in compliance with the principles outlined in the Declaration of Helsinki. Prior to participation, all individuals were provided with details about the study, and written consent was secured from all participants. The study was approved by the Clinical Research Ethics Committee of Istanbul Kent University (2024/06) and registered with ClinicalTrials.gov under ID number NCT06507969.

Artificial intelligence (AI) was not used in the creation of the manuscript.

References:

1. Borga M, West J, Bell JD, Harvey NC, Romu T, Heymsfield SB, et al. Advanced body composition assessment: from body mass index to body composition profiling. J Investig Med. 2018; 66(5): 1-9. https://doi.org/10.1136/jim-2018-000722
2. Schünemann HJ, Dorn J, Grant BJ, Winkelstein W Jr, Trevisan M. Pulmonary function is a long-term predictor of mortality in the general population: 29-year follow-up of the Buffalo Health Study. Chest. 2000; 118(3): 656-664. https://doi.org/10.1378/chest.118.3.656
3. Colwell KL, Bhatia R. Calculated versus measured MVV-Surrogate marker of ventilatory capacity in pediatric CPET. Med Sci Sports Exerc. 2017; 49(10): 1987-1992. https://doi.org/10.1249/MSS.0000000000001318

4. Peters U, Suratt BT, Bates JHT, Dixon AE. Beyond BMI: obesity and lung disease. Chest. 2018; 153(3): 702-709. https://doi.org/10.1016/j.chest.2017.07.010
5. Arena R, Myers J, Williams MA, Gulati M, Kligfield P, Balady GJ, et al. Assessment of functional capacity in clinical and research settings: a scientific statement from the American Heart Association Committee on Exercise, Rehabilitation, and Prevention of the Council on Clinical Cardiology and the Council on Cardiovascular Nursing. Circulation. 2007; 116(3): 329-343. https://doi.org/10.1161/CIRCULATIONAHA.106.184461
6. Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, et al. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. J Clin Sleep Med. 2015; 11(6): 591-592. https://doi.org/10.5664/jcsm.4758
7. Hairston KG, Bryer-Ash M, Norris JM, Haffner S, Bowden DW, Wagenknecht LE. Sleep duration and five-year abdominal fat accumulation in a minority cohort: the IRAS family study. Sleep. 2010; 33(3): 289-295. https://doi.org/10.1093/sleep/33.3.289
8. Kapuš O, Fellnerová I, Chaloupková P, Martišová K. Relationship between body composition and pulmonary function in healthy adolescents. Pediatr Int. 2022; 64(1): e15114. https://doi.org/10.1111/ped.15114
9. Ergezen G, Yılmaz Menek M, Demir R. Respiratory muscle strengths and its association with body composition and functional exercise capacity in non-obese young adults. Fam Med Prim Care Rev. 2023; 25(2): 146-14. https://doi.org/10.5114/fmpcr.2023.127671
10. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, Hall GL, et al. Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med. 2019; 200(8): e70-e88. https://doi.org/10.1164/rccm.201908-1590ST

11. Liu F, Tsang RCC, Jones AYM, Zhou M, Xue K, Chen M, et al. Cardiodynamic variables measured by impedance cardiography during a 6-minute walk test are reliable predictors of peak oxygen consumption in young healthy adults. PLoS One. 2021; 16(5): e0252219, https://doi.org/10.1371/journal.pone.0252219
12. Enright PL. The six-minute walk test. Respir Care. 2003; 48(8): 783-785.
13. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989; 28(2): 193-213. https://doi.org/10.1016/0165-1781(89)90047-4
14. Peralta GP, Marcon A, Carsin AE, Abramson MJ, Accordini S, Amaral AF, et al. Body mass index and weight change are associated with adult lung function trajectories: the prospective ECRHS study. Thorax. 2020; 75(4): 313-320. https://doi.org/10.1136/thoraxjnl-2019-213880
15. Pi YY, Hu WX, Jiao ZM, Hou PY, Zhang YH, Zhao Y, et al. Relationship between body composition and pulmonary function in the general population-a cross-sectional study in Ningxia. Sci Rep. 2023; 13(1): 17877. https://doi.org/10.1038/s41598-023-44486-9
16. Komici K, D'Amico F, Verderosa S, Piomboni I, D'Addona C, Picerno V, et al. Impact of body composition parameters on lung function in athletes. Nutrients. 2022; 14(18): 3844. https://doi.org/10.3390/nu14183844
17. Smith MP, Standl M, Berdel D, von Berg A, Bauer CP, Schikowski T, et al. Handgrip strength is associated with improved spirometry in adolescents. PLoS One. 2018; 13(4): e0194560. https://doi.org/10.1371/journal.pone.0194560
18. Amann M. Pulmonary system limitations to endurance exercise performance in humans. Exp Physiol. 2012; 97(3): 311-318. https://doi.org/10.1113/expphysiol.2011.058800
19. Bairapareddy KC, Augustine A, Alaparthi GK, Hegazy F, Shousha TM, Ali SA, et al. Maximal respiratory pressures and maximum voluntary ventilation in young Arabs:

association with anthropometrics and physical activity. J Multidiscip Healthc. 2021; 14: 2923-2930. https://doi.org/10.2147/JMDH.S333710

20. Jones RL, Nzekwu MM. The effects of body mass index on lung volumes. Chest. 2006; 130(3): 827-833. https://doi.org/10.1378/chest.130.3.827
21. Do JG, Park CH, Lee YT, Yoon KJ. Association between underweight and pulmonary function in 282,135 healthy adults: a cross-sectional study in Korean population. Sci Rep. 2019; 9(1): 14308. https://doi.org/10.1038/s41598-019-50488-3
22. Leone N, Courbon D, Thomas F, Bean K, Jégo B, Leynaert B, et al. Lung function impairment and metabolic syndrome: the critical role of abdominal obesity. Am J Respir Crit Care Med. 2009; 179(6): 509-516. https://doi.org/10.1164/rccm.200807-1195OC
23. Park CH, Yi Y, Do JG, Lee YT, Yoon KJ. Relationship between skeletal muscle mass and lung function in Korean adults without clinically apparent lung disease. Medicine. 2018; 97(37): e12281. https://doi.org/10.1097/MD.0000000000012281
24. Cvijetić S, Pipinić IS, Varnai VM, Macan J. Relationship between ultrasound bone parameters, lung function, and body mass index in healthy student population. Arh Hig Rada Toksikol. 2017; 68(1): 53-58. https://doi.org/10.1515/aiht-2017-68-2869
25. Vilaça KH, Alves NM, Carneiro JA, Ferriolli E, Lima NK, Moriguti JC. Body composition, muscle strength and quality of active elderly women according to the distance covered in the 6-minute walk test. Braz J Phys Ther. 2013; 17(3): 289-296. https://doi.org/10.1590/S1413-35552012005000093
26. Makni E, Hachana Y, Elloumi M. Allometric association between six-minute walk distance and both body size and shape in young obese girls. Children. 2023; 10(4): 658. https://doi.org/10.3390/children10040658

27. Babu R, Bahuleyan B. Correlation of sleep quality with anthropometric parameters in young healthy individuals. Int J Res Med Sci. 2018; 6(2): 613-617. https://doi.org/10.18203/2320-6012.ijrms20180308

28. Krističević T, Štefan L, Sporiš G. The associations between sleep duration and sleep quality with body-mass ındex in a large sample of young adults. Int J Environ Res Public Health. 2018; 15(4): 758. https://doi.org/10.3390/ijerph15040758

29. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med. 2004; 1(3): e62. https://doi.org/10.1371/journal.pmed.0010062

30. Kahlhöfer J, Karschin J, Breusing N, Bosy-Westphal A. Relationship between actigraphy-assessed sleep quality and fat mass in college students. Obesity. 2016; 24(2): 335-341. https://doi:10.1002/oby.21326 https://doi.org/10.1002/oby.21326