Association Between Body Composition with Pulmonary Function Tests

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Abstract

Background: Why is bodyweight not a predictor of lung function, however, height, sex, race, and age are predictors of lung capacity and function. In this study, we want to investigate the association between body composition and pulmonary function. And as much as possible, answer the question of why bodyweight is not predictive of lung function.

Method: This cross-sectional study was performed among 2967 employees of Tehran University of Medical Sciences (TUMS) who participated in the TUMS Employees Cohort (TEC) study. The body composition of the participants was measured using the Bioelectrical Impedance Analysis (BIA) method. Anthropometric variables were also measured as a confounder. The pulmonary function of participants was assessed by a forced spirometry test.

Results: The correlation of BIA values including fat-free mass and total body water with a pulmonary function such as FEV1, FVC, and FEF25-75 is higher than most anthropometric values such as weight, wrist circumference, and the waist to hip ratio. Also, in regression analysis, age and sex had an association with pulmonary function, but the weight did not show a significant relationship. On the other hand, fat-free mass and visceral fat were significantly associated with pulmonary function. One is direct and the other is inverse.

Conclusion: The hypothesis that the results of this study created in the minds of the authors were that; The direct association of fat-free mass with pulmonary function may be ineffective by the inverse association of visceral fat with pulmonary function, leading to a lack of association between weight and pulmonary function.

Introduction

The decreased pulmonary function can have serious consequences for people's health (1). Today, with the spread of the COVID-19 pandemic, the importance of Chronic Obstructive Pulmonary Disease (COPD) has increased (2). In recent years, the prevalence of COPD has been increasing, and according to the WHO, chronic obstructive pulmonary disease will be the third leading cause of death in the world by 2030 (3). Therefore, understanding the factors influencing changes in lung function is very important, such as inactivity, obesity, and fitness (1).

Global COPD prevalence is about 12% (4). In Iran, mortality from COPDs is 8.46% in women and 12.38% in men (5). The decreased pulmonary function can be considered as a predictor of death independent of lung disease (6). Many factors are known to reduce the risk of lung function, including genetic predisposition, exposure to cigarette smoke, exposure to occupational or environmental pollutants, and inactivity and physical activity (7).

Recently, concerns about the prevalence of inactivity and obesity and its association with a variety of diseases have increased (8). These diseases can lead to various consequences in health or even death (9). The worldwide prevalence of obesity is growing exponentially (10). The prevalence of obesity and high BMI is increasing worldwide. An increase in BMI, especially the fat mass index (FMI), is associated with an increase in cardiovascular disorders (11). More than two-thirds of high BMI deaths are due to cardiovascular diseases (12). Increased obesities are inversely related to pulmonary function (13). Obesity is also known as a risk factor for asthma in adults (14).

In previous studies, the association between some anthropometric and body analyzer indices and pulmonary function has been investigated. Sum of 5 Skinfold Measurements (SF5) and Waist Circumferences (WC) were the best predictors of pulmonary function in both men and women and were better than BMI (14–17). As well as a meta-analysis of the association between WC and lung function were proven (18). Visceral adipose tissue is inversely associated with FEV1 (Forced Expiratory Volume in one second) and FVC (Forced Vital Capacity) in both genders (19). Fat-Free Mass (FFM) also shows a positive relationship with pulmonary function (20). FEV1 is independently associated with the visceral fat area and FFM. FVC is also independently associated with the visceral fat area (21). Recent studies have shown an association between abdominal obesity and decreased pulmonary function (22).

In this study, we intend to investigate the association between Bioelectrical Impedance Analysis (BIA) variables and anthropometric dimensions and ratios with pulmonary function indices. And, based on these associations, we will introduce the best predictors of pulmonary function. The difference between this study and previous studies is the simultaneous study of anthropometric indices and analysis of body composition with pulmonary function in a population of about 3000 adults (staff).

Method

This cross-sectional and observational study was conducted using the enrollment phase data of the Tehran University of Medical Sciences Employees Cohort (TEC) study in 2018-2019 (23). In this study, the association between body composition variables and anthropometric indices with pulmonary function indices was investigated.

Participants

Participants in this study were 2967 staff of Tehran University of Medical Sciences in various job categories, of which 1175 were men and 1792 were women who participated in this study with informed consent and voluntarily. All examinations and data collection were performed in one working day in a center by trained personnel and according to the approved protocol of the study. All data collection steps were supervised by independent quality control and assurance team.

Basic Information

All basic data including: age, gender, education, marital status, type of occupation, work experience, medical records, etc. were obtained by direct questioning.

Body Analyzer

One of the common methods for studying and analyzing body shape is the body composition analysis method, which is available with different technologies. There are various methods for analyzing body composition, including the use of Caliper, anthropometry, tracer dilution, densitometry, air displacement plethysmography, dual-energy X-ray absorptiometry, bioelectrical impedance analyzer, computed tomography, magnetic resonance imaging, 3D body scanning. In the BIA method, the impedance of different tissues of the body is analyzed and the composition of the body is predicted. A very weak electrical current of 800 microamperes with a frequency of 50 kHz is sent to the body and the impedance of the tissues is measured against this current. Water has a high conductivity due to the presence of electrolytes, but adipose tissue has a low conductivity (24, 25).

In the present study, body composition analysis was performed using Tanita-720 body analyzer made in Japan. At the time of measurement, all metal parts such as watches, rings, and other jewelry were removed from the person. All measurements were performed by the same trained personnel based on the same protocol. The variables studied included: Body Fat% (Percentage of total body fat), Muscle Mass% (Percentage of total muscle tissue in the body), Visceral Fat, Bone Mass (The mass of the bones), Fat-Free Mass FFM (Bodyweight excluding fat), Total Body Water (TBW), Extra Cellular Water (ECW), Intra Cellular Water (ICW).

Pulmonary function

Spirometry was performed under the same conditions of ambient pressure and temperature by a trained operator. All subjects underwent spirometry while sitting with nasal clips. It was done using the *Micro-lab CareFusion* Spirometer device. Each participant performed acceptable spirometry at least three times according to the American thoracic society recommendation (26). To evaluate the variable lung function index, lung function was examined including FEV1: Forced expiratory volume in one second, the amount of air that can be forced out of the lungs in a second. FVC: Forced vital capacity: the amount of air that can be forcibly exhaled from the lungs after taking the deepest breath

Anthropometry

The weight of the participants in light clothing was measured by the SECA scales with an accuracy of 0.1 kg. Height was also measured using the SECA stadiometer to an accuracy of one millimeter. Based on height and weight data, the BMI index was calculated by dividing weight (kg) by height squared (m^2). Also, all circumferences were measured with an accuracy of one millimeter by a standard tape soft meter. Waist circumferences were measured while subjects were standing and measured as the minimum abdominal circumference between the xiphoid process and the umbilicus. Hip circumferences were measured as the maximum circumferences over the buttocks. Also, the waist to hip ratio (WHR) circumference is the result of dividing the circumference of the abdomen around the buttocks and the waist to height ratio (WHtR) divides abdomen circumference by height (27).

Smoking Status We divided the smoking status between the participants into three categories. People who have smoked for at least one day in the last 30 days as Current Smokers or an adult who has smoked 100 cigarettes in his or her lifetime. People who used to smoke but do not smoke now (have not smoked a single cigarette in the last month), a former smoker, or an adult who has smoked at least 100 cigarettes in his or her lifetime but who had quit smoking at the time of interview). And people who have never smoked in their lifetime, as never smoker (an adult who has never smoked, or who has smoked less than 100 cigarettes in his or her lifetime) (28).

Physical Activity:

International Physical Activity Questionnaire short form (IPAQ-SF). Physical activity was calculated using the short form of the IPAQ (International Physical Activity Questionnaire) and MET (metabolic equivalent of task) hours per week (MET-hours/week). The validity of IPAQ has already been done. The MET scores for intense, medium, and hiking activities (for at least 10 minutes) were multiplied by the time each participant spent on the activity, taking into account the frequency of participation in the activities mentioned over the past week. Then, to get the sum, the scores for the various activities were summarized as MET-min/week. Finally, they fall into three categories: low, medium, and high activity (29).

Statistical analysis

To describe quantitative data, we used mean and standard deviation, and to describe qualitative data, percentage and frequency indices were used. We used the Kolmogorov-Smirnov test to determine the normality of quantitative data distribution. For univariate analysis, if the distribution was normal, Pearson correlation test was used for quantitative data. If the data were not normally distributed, we used the Spearman correlation test. Linear regression was used for multivariate testing. The significance level was considered 0.05 in all tests. All analyses were performed using IBM SPSS-24 statistical analysis package.

Ethical considerations

This study was done with the approval of the ethics committee of Tehran University of Medical Sciences with the ethics code IR.TUMS.VCR.REC.1395.1484, IR.TUMS.VCR.REC.1398.246. All participants participated in this study voluntarily and with informed consent and signed the form of informed participation in the research plan approved by the ethics committee before starting the data gathering process. Participants were free to withdraw from the study at any stage. All the identity information of the participants was registered in complete confidentiality and by the study protocol in the form of a code that was provided to the researchers to analyze the information without name and mark, or any information revealing the identity of the individuals.

Result

In this study, which was performed on 2967 staff of Tehran University of Medical Sciences, 1175 men and 1792 women participated. According to Table 1, the mean age of the participants was 42.3 years with a standard deviation of 8.7 years. The mean age of men was 43.0 ± 9.1 years and the mean age of women was 42.0 ± 8.4 years. Also, according to anthropometric measurements, the average height of men was 173.3 ± 6.5 (cm) and for women it was 159.5 ± 5.8 (cm). On the other hand, the average weight of men was 82.9 ± 13.2 (kg) and the average weight of women was 67.0 and 11.4 (kg). Other anthropometric indicators can be seen in Table 1.

Regarding pulmonary function indices in this study, three indices FEV1, FVC, and FEF25-75 were measured. Accordingly, the FEV1 index in men was 3.8 liters and the standard deviation was 0.6 and in women, it was 3.3 ± 0.8. Also, FVC was 4.6 ± 0.7 and 3.3 ± 0.8 liters for men and women respectively.

In this study, 96.5% of the participants were divided into individuals with moderate physical activity. 12.2% of participants currently smoke and 30.4% of them are former smokers.

Data from Body Composition Analysis showed that the percentage of total body fat was 45.2 ± 20.1 for men and 38.1 ± 16.8 for women. Muscle mass was 39.9 ± 8.8 and 41.6 ± 9.1 (kg) for men and women, respectively. Other body composition analysis values can be seen in Table 1.

Table-1: Basic information, Pulmonary functions, anthropometrics, lifestyle, and body composition characteristics.

		Total n = 2967	Male n = 1175	Female n = 1792
		Mean(SD)	Mean(SD)	Mean(SD)
Basic Information	Age	42.4 (8.7)	43.0 (9.1)	42.0 (8.4)
	Height	165.0 (9.1)	173.3 (6.5)	159.5 (5.8)
	Weight	73.3 (14.4)	82.9 (13.2)	67.0 (11.4)
	Body Mass Index (BMI)	26.9 (4.3)	27.6 (3.9)	26.4 (4.5)
Pulmonary Function	FEV_1	3.1 (0.7)	3.8 (0.6)	2.7 (0.4)
	FVC	3.9 (1.0)	4.6 (0.7)	3.3 (0.8)
	FEF_{25-75}	96.4 (24.3)	101.1 (27.0)	93.2 (21.8)
Anthropometric	Waist Circumference	87.2 (11.4)	94.7 (9.6)	82.2 (9.7)
	Hip Circumference	103.2 (7.9)	102.9 (6.8)	103.3 (8.5)
	Waist to Hip Ratio (WHR)	0.85 (0.1)	0.92 (0.1)	0.80 (0.1)
	Waist to Height Ratio (WHtR)	0.53 (0.06)	0.55 (0.1)	0.52 (0.1)
Life Style information	Active %	1.3	3.2	1.5
	Moderately Active %	96.5	95.2	97.3
	Inactive %	1.3	1.5	1.2
	Current Smoker %	12.2	25.1	3.7
	Former Smoker %	30.4	43.9	21.5
	Never Smoker %	57.4	31.0	74.8
Body Composition	Body Fat	40.9 (18.5)	45.2 (20.1)	38.1 (16.8)
	Muscle Mass	40.9 (9.1)	39.9 (8.8)	41.6 (9.1)
	Visceral Fat	0.15 (0.14)	0.24 (0.2)	0.1 (0.1)
	Bone Mass	2.7 (0.5)	3.2 (0.3)	2.3 (0.3)
	Fat Free Mass (FFM)	52.9 (10.9)	64.0 (7.2)	45.6 (5.3)
	Total Body Water (TBW)	37.8 (7.9)	45.8 (5.4)	32.6 (3.8)
	Extra Cellular Water (ECW)	15.9 (2.9)	18.7 (1.9)	14.1 (1.8)
	Intra Cellular Water (ICW)	21.9 (5.1)	27.1 (3.8)	18.5 (2.1)

To investigate the correlation between basic information, anthropometric data, and body composition variables with pulmonary function indices we used the Spearman correlation test. we observed that there was a significant inverse relationship increase age with all reported pulmonary function indices. Also, height and waist circumference were directly correlated with pulmonary function indices. Regarding the correlation between body composition variables and pulmonary function indices, Bone mass, FFM, TBW, ECW, and ICW showed a high and significant correlation. The correlation values between pulmonary function and the indices mentioned in Table-2 can be seen.

Table-2: The correlation coefficient between pulmonary function and body composition.

	FEV_1 (L)	FVC (L)	FEF_{25-75} (%)
Age	-0.294**	-0.225**	-0.073**
Height	0.784**	0.814**	0.654**
Weight	0.456**	0.486**	0.460**
Body Mass Index (BMI)	0.016	0.034	0.109**
Waist Circumference	0.321**	0.352**	0.398**
Hip Circumference	-0.006	0.018	0.044*
Waist to Hip Ratio (WHR)	0.429**	0.456**	0.491**
Waist to Height Ratio (WHtR)	-0.010	0.014	0.136**
Body Fat %	0.088**	0.082**	0.112**
Muscle Mass %	-0.173**	-0.167**	-0.105**
Visceral Fat	0.211**	0.229**	0.274**
Bone Mass	0.677**	0.711**	0.633**
Fat Free Mass (FFM)	0.680**	0.713**	0.635**
Total Body Water (TBW)	0.684**	0.715**	0.636**
Extra Cellular Water (ECW)	0.624**	0.657**	0.601**
Intra Cellular Water (ICW)	0.708**	0.736**	0.643**

*$p < 0.05$, **$p < 0.01$, [a]Spearman correlation coefficient.

In Table 3, to predict pulmonary function, we presented two models of linear regression. In the linear regression model to predict FEV1 with Adjusted R Square = 0.728, it was observed that the independent variables of age, gender, height, visceral fat, fat free mass, are predictors of FEV1 pulmonary function index and are associated with it.

Also, in linear regression model for FVC with (Adjusted R Square = 0.560) pulmonary function index, it was observed that, age, sex, height, fat free mass, visceral fat, Intra Cellular Water, and Body Mass Index are predictors of FVC pulmonary function index and are associated with it.

Table-3: The linear regression models to determine the predictor variables of FEV1, FVC.

	Dependent Variable FEV_1 *(Adjusted R Square = 0.728)*						Dependent Variable FVC *(Adjusted R Square = 0.560)*					
	Unstandardized Coefficients		Standardized Coefficients		95% C.I		Unstandardized Coefficients		Standardized Coefficients		95% C.I.	
	B	Std. Error	Beta	P value	Lower	Upper	B	Std. Error	Beta	P value	Lower	Upper
(Constant)	-0.95	1.293		0.461	-3.488	1.583	-1.643	2.353		0.485	-6.257	2.971
Age	-0.018	0.001	-0.216	< 0.001	-0.020	-0.016	-0.019	0.002	-0.164	< 0.001	-0.023	− .015
Gender	0.379	0.045	0.261	< 0.001	0.290	0.468	0.391	0.082	0.189	< 0.001	0.229	0.552
Waist circumference	-0.003	0.002	-0.543	0.151	-0.008	0.001	-0.008	0.004	-0.940	0.051	-0.017	0.000
Hip circumference	-0.001	0.001	-0.074	0.309	-0.002	0.001	< 0.001	0.001	-0.008	0.936	-0.002	0.002
Height	0.003	0.001	0.370	< 0.001	0.001	0.004	0.003	0.001	0.279	0.023	0.000	0.006
Weight	0.012	0.010	0.241	0.243	-0.008	0.032	0.034	0.019	0.485	0.065	-0.002	0.071
WHtR	5.348	3.738	0.473	0.153	-1.982	12.678	12.750	6.803	0.790	0.061	-0.590	26.089
WHR	-0.452	0.710	-0.055	0.524	-1.845	0.940	0.211	1.293	0.018	0.870	-2.323	2.746
Body fat percentage	< 0.001	0.001	0.003	0.819	-0.001	0.001	< 0.001	0.001	-0.006	0.734	-0.002	0.002
Muscle Mass %	-0.002	0.001	-0.020	0.127	-0.004	0.000	-0.001	0.002	-0.005	0.788	-0.004	0.003
Fat Free Mass	0.049	0.015	0.745	0.001	0.020	0.078	0.076	0.027	0.814	0.005	0.023	0.129
Visceral Fat	-0.336	0.087	-0.067	< 0.001	-0.508	-0.165	-0.363	0.159	-0.051	0.023	-0.674	-0.051
Bone Mass	-0.161	0.235	-0.116	0.492	-0.621	0.299	0.204	0.427	0.103	0.633	-0.633	1.041
ECW	-0.016	0.021	-0.065	0.441	-0.056	0.024	-0.046	0.037	-0.131	0.217	-0.119	0.027
ICW	-0.021	0.013	-0.155	0.089	-0.046	0.003	-0.0064	0.023	-0.320	0.006	-0.109	-0.019
BMI	-0.041	0.028	-0.243	0.152	-0.096	0.015	-0.125	0.051	-0.525	0.015	-0.226	-0.024

WHtR: waist to height ratio, WHR: waist to hip ratio, ECW: Extra Cellular Water, ICW: Intra Cellular Water, BMI: Body Mass Index.

Discussion

In this study, we investigated the association between BIA variables and pulmonary function indices, assuming that body composition analysis can be related to pulmonary function indices. Body composition analysis is associated with many known diseases such as cardiovascular diseases, diabetes, cancer, osteoporosis, osteoarthritis as well as body composition with obstructive pulmonary disease (24).

In previous studies, the association between anthropometric indices and dimensions with pulmonary function indices had been investigated (13). In the present study, it was observed that the correlation coefficient between BIA measures and pulmonary function indices was relatively higher than anthropometric indices and dimension ratio correlation coefficient with pulmonary function indices. The only anthropometric index that correlates to or better than BIA indices with the pulmonary function was height. The best BIA indicators in correlation with pulmonary function are Bone mass, FFM, TBW, ECW, and ICW.

On the other hand, one of the variables that traditionally predicts lung function is the age variable. Pulmonary function decreases with age (30). One of the common predictors of pulmonary function in various studies is the age, which was also used as a predictor of pulmonary function in this study.

In previous studies, it was observed that pulmonary function indices such as FVC, FEV1, and FEF25-75 were significantly different in the three groups of underweight, normal, and overweight. Body fat percentage has a higher correlation coefficient with lung function than BMI. In a study, pulmonary function and body composition indices in male and female athletes were found to have a significant correlation between pulmonary function and body fat percentage, muscle mass, FFM, trunk muscle mass, trunk fat mass, and wrist and hip circumference. In another study, age, sex, body weight, BMI, fat percentage, FFM, WHR were significantly associated with lung function, but their R^2 was not high enough to interpret it (31).

In the present study, no correlation was observed between BMI and pulmonary function. This may be due to the essential role of the weight component in BMI. Body mass index does not differentiate between FM and FFM (13).

In the present study, the FFM index was suggested as a strong correlation coefficient with pulmonary function. In a study that looked at the incidence of adolescents with cystic fibrosis, the Lean Body Mass Index, or Fat-Free Mass, was found to be strongly correlated with lung function relative to BMI (32). Similar results were observed in the present study.

One of the most important factors in reducing pulmonary function is obesity, especially since the increase in adipose tissue in the abdominal and chest areas can lead to limited chest dilation (13). Obese people experience a vicious cycle due to reduced mobility and a sedentary lifestyle, resulting in increased mortality rate (33). Abdominal obesity as a major component in the development of metabolic syndrome causes mechanical impairment of pulmonary function in middle-aged adults (34). Accumulation of visceral fat with insulin resistance and impaired glucose tolerance, high blood pressure, impaired lipid metabolism such as metabolic syndrome, and arteriosclerosis are involved (35).

Also, one of the findings of the present study was the inverse and significant relationship between visceral fat and pulmonary function. Previous studies have shown that airway inflammation is more likely to occur in people with a higher body fat percentage (36).

In previous studies, one of the indicators that had an association with the pulmonary function was waist circumference., In the present study in the presence of other anthropometric indicators, demographic information and BIA, and in the presence of all mentioned indicators, age, sex, height, visceral fat, and FFM, waist circumference had a statistical association with FEV_1 that, in the FVC index in addition to the mentioned factors, ICW is also considered as a predictor.

In different spirometry devices and based on several studies that have been done to predict the normal range of spirometry, four components are used: age, sex, race, and height. It is expected that weight is also a predictor of the normal spirometry range. However, various studies show that weight is not a predictor of the normal range of pulmonary function in spirometry.

Based on the regression results of the present study, we observed an interesting result. The total body weight is composed of two components: Fat weight and Fat-Free Mass (weight of other lean components). In regression analysis, it was observed that FFM has a direct association with FEV1 and FVC. The visceral fat mass has an inverse association with both indicators of pulmonary function.

Since Visceral fat can be considered as a representative of a large part of body fat, it can be concluded that the result of FFM and body fat, which are considered as total body weight, counteract the effect of each other and therefore weight. It is not included in various studies as a predictor of normal lung function.

On the other hand, obtaining FFM, Visceral fat by direct weight measurement method is fairly expensive and not available to everyone, so it is possible to estimate FFM or visceral fat by measuring some dimensions and enter this predictor into the lung function normal range estimates formula.

Conclusion

In the present study, we observed a negative association between visceral fat and pulmonary function tests and a direct association between Fat-free mass pulmonary function tests (FEV1 and FVC) adjusted for age, sex, and anthropometric indices.

Declarations

Ethics approval and consent to participate

This study was done with the approval of the ethics committee of Tehran University of Medical Sciences with the ethics code IR.TUMS.VCR.REC.1395.1484, IR.TUMS.VCR.REC.1398.246. All participants participated in this study voluntarily and with informed consent and signed the form of informed participation in the research plan approved by the ethics committee before starting the data gathering process.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

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