Progress in Nutrition 2019; Vol. 21, N. 3: 542-551 DOI: 10.23751/pn.v21i3.8238

Original article

The effect of body composition on pulmonary function in elite athletes

Tuğba Kocahan[1], *Bihter Akınoğlu*[2]

[1]Dr, MD. The Ministry of Youth and Sports, Sports General Directorship, Department of Health Services, Center of Athlete Training and Health Research, Ankara, Turkey; [2]PT, PhD. Ankara Yıldırım Beyazıt University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey.

Summary. The pulmonary function is one of the most basic factors that determine athletic performance. The purpose of this study was to investigate the correlation of the body weight, body fat percentage (fat%), body fat mass, fat-free mass, muscle mass, abdominal muscle mass, and waist and hip circumference on the forced expiratory volume curve and maximal voluntary ventilation**.** A total of 398 elite athletes composed of 254 male and 144 female (mean age, 16.63±2.28 years) were enrolled for this study. The study involved the measurements of the body composition by bioelectrical impedance method, and forced vital capacity (FVC); forced expiratory volume at 1 second (FEV_1); forced expiratory flow during the middle half of the FVC (FEF_{25-75}) from the forced expiratory volume curve; and maximal voluntary ventilation (MVV) by spirometry. Correlation and multiple regression analysis between the body composition and pulmonary function were used. It was determined that there was an important relationship between the demographic characteristics and body composition parameters of the athletes and the pulmonary function test values. This relationship was categorized as low, medium, high and very high ($p < 0.05$). During the multiple regression analysis related to the body composition of the entire group, it was determined that the statistically significant predictors of FVC were age, body weight, height, hip circumference and body fat percentage (R=.883, R^2=.780, Adj R^2=.777) ($p<0.05$). Statistically significant predictors of FEV1 were age, body weight, height, hip circumference and body fat percentage (R=.872, R^2= .761, Adj R^2=.758) ($p<0.05$). Statistically significant predictors of FEF25-75 were age, body weight, height, body fat percentage and muscle mass (R= .728, R^2= .530, Adj R^2=.524) ($p<0.05$). Finally, significant predictors of MVV were age, body weight, height, waist circumference, hip circumference and body fat percentage (R= .774, R^2= .599, Adj R^2= .591) ($p<0.05$). At the end of our study, we have determined that the factors affecting the pulmonary function in both male and female athletes were not limited to age, gender, and body weight, but also included the body composition parameters such as the body fat percentage, body fat mass, muscle mass, fat-free body mass, trunk muscle mass, trunk fat mass, and waist and hip circumference.

Key Words: bioelectrical impedance, spirometry, vital capacity, performance, sport

Introduction

Body composition is one of the most important indicators of physical fitness of an athlete and is also a critical parameter in the assessment of nutrition and medical condition. Body composition mainly indicates the constant and variable rates of fat-free mass, bone mass and fat mass in the body (1, 2).

The fat mass in the body acts as an endocrine structure and influences many factors that affect metabolically balance (3). Body fat percentage (BFP) is a critical indicator for the assessment of athletic performance (4-6). It has been determined that there is an inverse relationship between the BFP and athletic performance (7, 8).

Pulmonary function tests (PFT) helps to evaluate the respiratory system and is conducted to identify the severity of pulmonary impairment (9). İt has been identified that there is a positive relationship between the pulmonary function and athletic performance (10). Age, body weight, height, and gender of an athlete are some of the factors that affect pulmonary function. These parameters are used to calculate the normal values of the pulmonary function tests using regression equations (11). Studies conducted on athletes from different age groups and different countries show that the pulmonary functions were affected in variable degrees in terms of body compositions such as mass index (BMI), waist circumference and fat mass (11-14).

Studies indicate that lung volume in adults decrease when their BFP levels increase since it leads to fat accumulation in the cavities of abdomen, and inability or restriction of diaphragm expansion (15, 16). Similarly, it is stated that low levels of fat-free body mass (FFBM) has a direct relationship with the respiratory muscle mass, and the decrease in FFBM rates results in also the decrease of forced vital capacity at 1 second (FEV1). Furthermore, it is shown that the waist-hip ratio, which is related to the body fat distribution, is also related to the pulmonary functions (16).

Despite the number of studies showing that athletic performance is related to the body composition (7) and pulmonary functions (17), there are limited studies on how the body composition in athletes affects pulmonary functions including comparisons between genders (18). In light of the available research, we hypothesize in our study that there is a relationship between an athlete's body composition and the pulmonary functions. Therefore, the purpose of our research is to investigate this relationship between the body composition parameters in athletes and the pulmonary functions.

Material and methods

The sample group in our research is composed of elite athletes, who have applied to the Athletic Health Education and Research Center and volunteered for this study. The applicants have signed consent forms after being briefed on the details of the tests. The tests were conducted following the 2008 Helsinki Declaration Principles after obtaining the required approvals from the Yildirim Beyazıt University's Social and Human Sciences Ethical Board in Ankara (2018/400/74).

The criteria to be selected for the sample group were the following; to be healthy, to cooperate following the test parameters, to volunteer for the study and having FEV1/FVC values to be between 80-90% measured by the forced vital capacity maneuver. The exclusion criteria were; not meeting the above requirements, having dental braces, having a past history of acute or chronic respiratory infections, having a prosthesis, having suspicions of or being pregnant, being on period, and having an acute or chronic condition related to the respiratory, muscle or skeleton system.

Collection of Data

During the first day of the study, the demographic information of the athletes was collected. Then, waist-hip circumference measurements were taken and the bioelectrical impedance analysis (BIA) readings were recorded after an 8-hour fasting period. The second-day activities involved pulmonary function tests and maximal voluntary ventilation (MVV) tests conducted minimum 2 hours after having breakfast.

Research Group

Out of 551 elite athletes, 398 athletes (254 male and 144 female) met the inclusion criteria. The athletes had a mean age of 16.63+/-2.28 years, sports age of 6.76+/-2.67 years, the body weight of 64.19+/-15.44 kg and height of 168.38+/-9.79 cm. While there was a significant difference in average age, body weight, and height values when comparing the male and female participants ($p<0,05$), the sports age was similar ($p>0,05$). The statistics related to the demographic characteristics of the participants are shown in Table 1.

Bioelectrical Impedance Analysis (BIA)

The body composition measurements of the participants were conducted by the bioelectrical impedance testing device (MC-980, Tanita Corp, Tokyo, Japan). Within 24 hours prior to this test, the athletes were asked not to perform any intense physical activi-

Table 1. Demographic characteristics of athletes

	Male (n= 254)	Female (n= 144)	Total (n= 398)	P¥
Age (year)	16.81± 2.22	16.31±2.35	16.63±2.28	**0.033***
Sports age (year)	6.71±0.76	6.80±2.52	6.75±2.67	0.711
Body weight (kg)	68.99±15.88	55.72±10.15	64.19±15.44	**0.000***
Height (cm)	172.12±8.56	161.70±8.16	168.35±9.79	**0.000***

¥: Independent Samples t test, *: $p<0.05$.

ties, not to consume diuretic drinks such as tea or coffee and fast at least 8 hours. During the tests, the participants were asked to stand barefoot and straight on the metal electrodes of the testing device and hold the hand electrodes. Any metal accessories such as watches, rings, necklaces, etc. had to be removed. The tests involved measurements of body weight, BFP, body fat mass (BFM), FFBM, body muscle mass (BMM), abdominal muscle mass and abdominal fat mass to be later used for the statistical analysis (19).

Measurement of Waist-Hip Circumference

The waist-hip circumference measurements were done by using a non-extensible tape measure. The waist circumference measurement was done with the participants standing up with their arms lose on the sides of the body following normal breathing and at the narrowest part of the body between the arcus costarum and spine iliaca anterior superior. The hip measurement was taken from the peak of gluteus maximus at the back and the widest section of the symphysis pubis at the front. During the measurements, the tape measure was held parallel to the ground and was not tightened up (20).

Analysis of the Pulmonary Function

The pulmonary function was analyzed by using a digital spirometer (Pony FX Cosmed, Rome, Italy). The participants were briefed prior to the tests. Tests were conducted with the participants in the comfortable sitting position and minimum 15 minutes breaks were taken between tests. During the tests, the participant's nose was closed with a clamp and air leakage from the spirometer's mouthpiece was prevented. Each test was repeated 3 times and the best scores were used for the statistical analysis.

In order to evaluate the respiratory functioning of the participants, forced vital capacity maneuver and maximal voluntary ventilation tests were conducted. Tests help to find forced vital capacity (FVC), forced expiratory volume at 1 second (FEV1), FEV1/FVC and FEF 25-75 (L/sec) values. For the maximal voluntary ventilation (MVV) test, the participant was asked to breathe deep, fast and intense for 12 seconds, which helped to measure the maximal minute ventilation (MVV) (12).

Data Analysis

SPSS for Windows Release 20.0 (Statistical Package for Social Sciences Inc. Chicago, IL, USA) statistics software was used for the analysis of the participants' test measurements. All the definitive statistical values related to the variables were calculated, and the mean value of the variables was shown as the mean+/-standard deviation. The relationship between the body composition and respiratory function measurements of the athletes were analyzed using Pearson correlation. Afterward, multiple regression analysis was conducted in order to determine the effect of the body composition measurements on the respiratory function by predicting the variable parameters of FVC (L), FEV1 (L), FEF 25-75 (L/sec), MVV (L/min). Stepwise selection method was used in order to investigate the test parameter factors between the body composition measurement and pulmonary function tests. Predictions related to the pulmonary function tests were done indirectly by calculating the body composition measurements, and corrected R^2 was used as the explanatory value. Statistically, valid level was set as $p<0.05$.

Results

The body fat percentage determined through BIA measurements among male and female athletes showed that; fat mass values were significantly different in female athletes (p<0,05) and muscle mass, abdominal muscle mass values were significantly different in male athletes (p<0,05). However, abdominal fat mass values were not significantly different statistically (p>0,05). Waist and hip circumference values were significantly different in male athletes (p<0,05). FVC (L), FEV_1 (L), FEF $_{25-75}$ (L/sec) and MVV (L/min) values determined by the pulmonary function tests were significantly different between the male and female athletes, but the difference was more significant in male athletes (p<0,05) (Table 2).

The athletes' demographic characteristics and body composition data were closely related to the pulmonary function tests values, and this relationship was found to be at low, medium, high and very high levels (p<0,05) (Figure 1).

The statistically valid predictors of FVC were determined to be age, body weight, height, hip circumference, and body fat percentage. This model was statistically important (p<0.05) as it accounted for 77% of the total variance for the FVC value. When FVC value was analyzed in terms of gender; it was determined that the model for male athletes that is composed of height, hip circumference, body fat percentage, body fat mass accounted 67% of the total variance, whereas the model for female athletes that is composed of age, height, hip circumference, body fat percentage and muscle mass accounted for 65% (p<0.05). Hip circumference was part of the model in female athletes, but it was not a significant predictor (p>0.05) (Table 3).

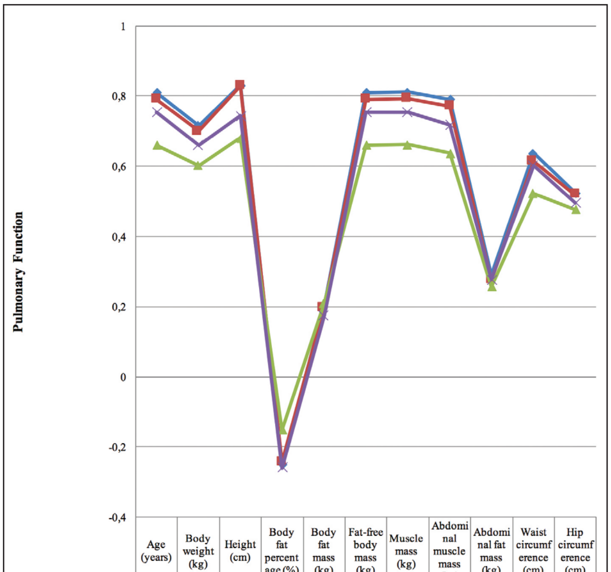
It was determined that the significant predictors of FEV1 were age, body weight, height, hip circumference, and body fat percentage. This model was statistically important (p<0.05) as it accounted for 76% of the total variance for the FVC value. When FEV1 value was analyzed in terms of gender; it was determined that the model for male athletes that is composed of height, hip circumference, body fat percentage, body fat mass accounted 66% of the total variance, whereas the model for female athletes that is composed of age, height, hip circumference, body fat percentage and muscle mass accounted for 64% (p<0.05). Hip circumference was part of the model in male athletes, but it was not a significant predictor (p>0.05) (Table 4).

It was determined that the significant predictors of FEF_{25-75} were age, body weight, height, body fat percentage, and muscle mass. This model was statistically important (p<0.05) as it accounted for 52% of the total variance for the FEF_{25-75} value. When FEF_{25-75} value was analyzed in terms of gender; it was determined that the model for male athletes that is composed of body weight, height, waist circumference, body fat percentage, body fat mass, fat-free body mass, abdominal muscle mass and age accounted 44% of the total variance, whereas the model for female athletes that is composed of height and muscle mass accounted 39% (p<0.05). Waist circumference and muscle mass were

Table 2. Comparison of the body composition, waist and hip circumference and pulmonary function test results between genders

	Male (n = 254)	Female (n = 144)	Total (n = 398)	$P^{¥}$
Body fat percentage (%)	15.656±5.025	22.80±4.92	18.24±6.05	**0.000***
Body fat mass (kg)	11.23±6.18	12.98±4.69	11.86±5.74	**0.003***
Fat-free body mass (kg)	57.75±11.22	42.81±6.57	52.34±12.14	**0.000***
Muscle mass (kg)	54.85±10.70	40.56±6.37	49.68±11.62	**0.000***
Abdominal muscle mass (kg)	29.70 ±5.50	23.74± 3.42	27.54±5.63	**0.000***
Abdominal fat mass (kg)	5.04±3.49	5.11±2.30	5.07±3.11	0.809
Waist circumference (cm)	76.71±9.13	68.34±6.70	73.68±9.25	**0.000***
Hip circumference (cm)	94.0±9.41	91.12± 8.37	92.96±9.14	**0.002***
FVC (L)	4.92±0.86	3.72±0.61	4.49±0.97	**0.000***
FEV_1 (L)	4.18±.72	3.22±0.51	3.84±0.80	**0.000***
FEF $_{25-75}$ (L/sec)	4.50±0.92	3.65±0.70	4.20±0.95	**0.000***
MVV (L/min)	159.52±33.01	121.73±23.24	146.38±33.64	**0.000***

¥: Independent Samples t test, *: p<0.05



	Age (years)	Body weight (kg)	Height (cm)	Body fat percent age (%)	Body fat mass (kg)	Fat-free body mass (kg)	Muscle mass (kg)	Abdominal muscle mass (kg)	Abdominal fat mass (kg)	Waist circumference (cm)	Hip circumference (cm)
FVC (L)	0,809	0,716	0,831	-0,251	0,203	0,809	0,811	0,791	0,289	0,637	0,524
FEV1 (L)	0,791	0,7	0,829	-0,244	0,198	0,791	0,793	0,772	0,276	0,614	0,518
FEF25-75 (L/sec)	0,66	0,602	0,681	-0,152	0,21	0,66	0,662	0,638	0,256	0,522	0,476
MVV (L/min)	0,753	0,66	0,744	-0,26	0,174	0,753	0,754	0,718	0,277	0,602	0,496

Figure 1. The correlation between the demographic characteristics and body composition with the pulmonary function test results

part of the model in male athletes, but it was not a significant predictor ($p>0.05$) (Table 5).

It was determined that the significant predictors of MVV were age, body weight, height, waist circumference, hip circumference, and body fat percentage. This model was statistically important ($p<0.05$) as it accounted for 59% of the total variance for the MVV value. When MVV value was analyzed in terms of gender; it was determined that the model for male athletes that is composed of body weight, height, waist circumference, body fat percentage, body fat mass, fat-free body mass, abdominal muscle mass and age accounted 45% of the total variance, whereas the model for female athletes that is composed of height and muscle mass accounted 43% ($p<0.05$). Age was part of the model in female athletes, but it was not a significant predictor ($p>0.05$) (Table 6).

The regression equations to find FVC (L), FEV_1 (L), FEF_{25-75} (L/sec), MVV (L/min) values determined through the pulmonary function tests based on the multiple regression analysis, is given in Table 7.

Table 3. Multiple regression analysis results for FVC

		B	Standard error	β	t	p
Total		-4.366	0.787		-5.549	0.000
	Age	-0.171	0.027	-1.015	-6.350	0.000
	Body weight	0.080	0.008	1.267	9.440	0.000
	Height	0.042	0.004	0.423	10.110	0.000
	Hip circumference	-0.026	0.008	-0.242	-3.240	0.001
	Body fat percentage	0.082	0.019	0.511	4.345	0.000
	R=.883 R²=.780	Adj R²=.777				
Male		-5.607	1.166		-4.809	0.000
	Height	0.050	0.006	0.494	8.926	0.000
	Hip circumference	-0.032	0.013	-0.350	-2.532	0.012
	Body fat percentage	0.122	0.026	0.713	4.609	0.000
	Body fat mass	-0.112	0.027	-0.807	-4.127	0.000
	R=.825 R²=.680	Adj R²=.673				
Female		-4.714	1.171		-4.024	0.000
	Age	-0.151	0.044	-1.163	-3.411	0.001
	Height	0.031	0.006	0.413	5.366	0.000
	Hip circumference	-0.018	0.010	-0.250	-1.832	0.069
	Body fat percentage	0.128	0.036	1.042	3.598	0.000
	Muscle mass	0.102	0.019	1.071	5.438	0.000
	R=.814 R²=.662	Adj R²=.650				

Table 4. Multiple regression analysis results for FEV1

		B	Standard error	β	t	p
Total		-4.405	0.665		-6.625	0.000
	Age	-0.140	0.023	-1.009	-6.072	0.000
	Body weight	0.060	0.007	1.163	8.323	0.000
	Height	0.004	0.003	0.478	11.209	0.000
	Hip circumference	-0.020	0.006	-0.226	-3.101	0.002
	Body fat percentage	0.072	0.016	0.548	4.486	0.000
	R=.872 R^2= .761 Adj R^2=.758					
Male		-5.416	1.003		-5.402	0.000
	Body weight	0.054	0.010	1.198	5.567	0.000
	Height	0.046	0.005	0.546	9.578	0.000
	Hip circumference	-0.020	0.011	-0.263	-1.860	0.064
	Body fat percentage	0.096	0.023	0.666	4.195	0.000
	Body fat mass	-0.147	0.029	-1.264	-5.034	0.000
	R=.814 R^2= .663 Adj R^2=.656					
Female		-4.999	0.823		-6.075	0.000
	Age	-0.145	0.038	-1.330	-3.867	0.000
	Height	0.028	0.004	0.444	6.245	0.000
	Body fat percentage	0.114	0.030	1.097	3.806	0.000
	Muscle mass	0.074	0.013	0.926	5.892	0.000
	R=.808 R^2= .654 Adj R^2=.644					

Table 5. Multiple regression analysis results for FEF_{25-75}

		B	Standard error	β	t	p
Total		-5.032	0.891		-5.646	0.000
	Age	-0.875	0.211	-5.333	-4.146	0.000
	Body weight	0.783	0.208	12.834	3.772	0.000
	Height	0.036	0.006	0.371	6.308	0.000
	Body fat percentage	0.077	0.026	0.496	3.017	0.003
	Muscle mass	-0.766	0.217	-9.443	-3.530	0.000
	R=.728 R^2= .530 Adj R^2=.524					
Male		-6.727	1.782		-3.775	0.000
	Body weight	0.747	0.232	12.868	3.225	0.001
	Height	0.048	0.008	0.450	5.736	0.000
	Wiest circumference	-0.032	0.017	-0.321	-1.911	0.057
	Body fat percentage	0.128	0.039	0.700	3.251	0.001
	Body fat mass	-0.792	0.237	-5.312	-3.348	0.001
	Fat free mass	-0.675	0.231	-8.218	-2.924	0.004
	Abdominal muscle mass	-0.044	0.025	-0.261	-1.733	0.084
	Abdominal fat mass	-0.100	0.040	-0.378	-2.486	0.014
	Age	0.092	0.036	0.222	2.551	0.011
	R=.681 R^2= .464 Adj R^2=.444					
Female		-1.113	1.032		-1.078	0.283
	Height	0.016	0.008	0.191	2.063	0.041
	Muscle mass	0.052	0.010	0.478	5.157	0.000
	R=.628 R^2= .395 Adj R^2=.386					

Table 6. Multiple regression analysis results for MVV

		B	Standard error	β	t	p
Total		-178.029	45.854		-3.882	0.000
	Age	-3.683	1.340	-0.605	-2.748	0.006
	Body weight	1.631	0.448	0.722	3.639	0.000
	Height	1.440	0.209	0.404	6.903	0.000
	Waist circumference	0.660	0.387	0.175	1.707	0.089
	Hip circumference	-1.001	0.387	-0.262	-2.586	0.010
	Body fat percentage	1.686	0.941	0.292	1.791	0.074
	R= .774 R^2= .599	Adj R^2= .591				
Male		-278.382	50.573		-5.505	0.000
	Body Weight	0.979	0.427	0.471	2.295	0.023
	Height	1.814	0.284	0.471	6.382	0.000
	Body fat percentage	2.755	1.353	0.419	2.036	0.043
	Body fat mass	-3.781	1.679	-0.708	-2.251	0.025
	Age	3.412	1.045	0.230	3.265	0.001
	R= .684 R^2= .468	Adj R^2= .457				
Female		-92.781	38.147		-2.432	0.016
	Age	1.347	0.812	0.136	1.659	0.099
	Height	0.089	0.273	0.311	3.241	0.001
	Muscle mass	1.216	0.416	0.333	2.925	0.004
	R= .663 R^2= .440	Adj R^2= .428				

Table 7. Equality formulas

	Equality formulas for all athletes (n=398)
FVC (L) =	(-4.366) + (-.171) *Age + (0.080) * Body weight + (0.042) * Height + (-0.026) * Hip circumference + (0.082) * Body fat percentage
FEV_1 (L) =	(-4.405) + (-0.140) * Age + (0.060) * Body weight + (0.004) * Height + (-0.020) * Hip circumference + (0.072) * Body fat percentage
FEF_{25-75} (L/sec) =	(-5.032) + (-0.875) * Age + (0.783) * Body weight + (0.036) * Height + (0.077) * Body fat percentage + (-0.766) * Muscle mass
MVV (L/min) =	(-178.029) + (-3.683) * Age + (1.631) * Body weight + (1.440) * Height + (0.660) * Waist circumference + (-1.001) * Hip circumference
	Equality formulas for male athletes (n=254)
FVC (L) =	(-5.607) + (0.050) * Height + (-0.032) * Hip circumference + (0.122) * Body fat percentage + (-0.112) * Body fat mass
FEV_1 (L) =	(-5.416) + (0.046) * Height+ (-0.020) * Hip circumference + (0.096) * Body fat percentage +(-0.147) * Body fat mass
FEF_{25-75} (L/sec) =	(-6.727) +(0.747) * Body weight + (0.048) * Height + (-0.032) * Waist circumference + (0.128) * Body fat percentage + (-0.792) * Body fat mass + (-0.675) * Fat free mass + (-0.044) * Abdominal muscle mass + (-0.100) * Abdominal fat mass + (0.092) * Age
MVV (L/min) =	(-278.382) + (0.979) * Body weight + (1.814) * Height + (2.755) * Body fat percentage + (-3.781) * Body fat mass + (3.412) * Age
	Equality formulas for female athletes (n=144)
FVC (L) =	(-4.714) + (-0.151) *Age + (0.031) * Height + (-0.018) * Hip circumference + (0.128) *Body fat percentage + (0.102) *Muscle mass
FEV_1 (L) =	(-4.999) + (-0.145) * Age+(0.028) * Height +(0.114) *Body fat percentage + (0.074) * Muscle mass
FEF_{25-75} (L/sec) =	(-1.113) + (0.016) * Height + (0.052) * Muscle mass
MVV (L/min) =	(-92.781) + (1.347) *Age + (0.089) * Height + (1.216) *Muscle mass

Discussion

Respiratory functions are the basis for the evaluation of the respiratory system. Respiratory functions in athletes are expected to be higher than their peers having a sedentary lifestyle, and therefore it is suggested that the assessment of the respiratory functions be performed internally only among athletes (22). The purpose of this study is to investigate this relationship between the body composition parameters in athletes and the respiratory function, and to determine the body composition parameters that affect the respiratory functions. Our research indicates that the body composition of athletes may affect the respiratory functions at low, medium, high and very high levels. Also, the factors affecting the respiratory function in both male and female athletes were not limited to age, body weight, and height, but also included other body composition parameters such as the body fat percentage, body fat mass, fat-free body mass, muscle mass, abdominal muscle mass, abdominal fat mass, and waist and hip circumference.

It is revealed that the pulmonary function tests results are significantly affected by the gender, age, height and body weight of an athlete (11), that the respiratory functions improve with exercise (23), and that respiratory functions vary depending on the type of sports branch (24, 25). When reviewing the pulmonary test result parameters with the anthropometric characteristics, it was seen that there was a negative and positive relationship between various pulmonary test results in terms of body fat percentage, fat-free body mass, body fat mass, waist circumference and waist/hip ratio (16, 19, 26). According to the study conducted on individuals with a sedentary lifestyle by Park et al, it was shown that there was also a relationship between the respiratory functions and the BFP, muscle mass, FFBM, BMI and waist/hip ratio rates obtained through MIA testing (19). The same study also suggests that there was a relationship between the demographic characteristics and the pulmonary function tests parameters, and at the same time, the body composition data is related to the pulmonary function test parameters.

An increase in BFP, which is one of the anthropometric characteristics, has a negative effect on the respiratory functions (12, 15, 27). Various other studies also suggest that an increase in BFP leads to low lung volume (expiratory reserve capacity – ERV) (12, 15, 27). Durmic et al's study suggested that body fat percentage shows a negative correlation with spirometric parameters, while showing the highest correlation with FEV1 values (18). In our study, we have determined a small negative correlation between the body fat percentage and pulmonary function test parameters.

When reviewing the studies related to the effect of body fat mass and abdominal fat mass on the pulmonary function tests, a negative correlation was seen between the rate of fat mass contained in the abdominal or visceral area and the pulmonary functions (5, 16, 28-30). However, these studies were mostly performed on old and obese individuals. Particularly in obese people, it is accepted that an increase in fat mass in the abdominal area creates a global effect and leads to peripheral obstruction of airways due to an air blockage and a decrease in maximum expiratory flow volume, which at the end may negatively affect the pulmonary function tests (29). Apart from the available studies, what we found differently was that there was a small positive correlation between the pulmonary function tests and body fat mass/abdominal fat mass. We believe that this result was due to the fact that our study involved only athletes, who have very low-fat mass in their abdominal.

Fat-free body mass is composed of muscles, bones, tendons, and water. Therefore, an increase in FFBM should result in an improvement in respiratory functions (31). Studies show that there is a positive correlation between the respiratory functions and muscle mass (28, 31). In parallel with these studies, we also found that there is a very high positive correlation between the respiratory functions and fat-free body mass/muscle mass/abdominal muscle mass.

Respiratory functions are one of the most important factors affecting athletic performance (31). Therefore, it is important to determine the factors affecting respiratory functions and control the variable factors in order to achieve maximum athletic performance. In this study, we have performed a regression analysis in order to determine the predictors of the respiratory function parameters. As a result, FVC and FEV1 values were affected by age, body weight, height, hip circumference, and body fat percentage. While FEF25-75 value was affected by age, body weight, height, body fat percentage, and muscle mass, MVV was affected by age, body weight, height, waist circumference, hip circumference and body fat percentage. Similar studies to ours also suggest that there was a relation between the body composition parameters of triathletes and their respiratory functions (31). Our studies conclude that body composition parameters are important indicators of respiratory functions, and these parameters should be taken into consideration in order to improve athletic performance.

Respiratory functions vary by gender. These differences associated with gender are related to the physiological and anatomical structure and the gender-specific hormones. Therefore, it is normal to expect different results in pulmonary function tests (32). When reviewing studies related to the relationship between the respiratory functions and body compositions for both genders, an important correlation was found between age/height and FVC/FEV1 values (12). Our study shows that respiratory functions are affected by the body composition parameters in both genders (Tables 3, 4, 5, 6, 7). Moreover, fat percentage and fat mass, which are variable physical characteristics in males, affect the respiratory functions in male athletes, whereas, muscle mass, which is a variable characteristic in females, affect the respiratory functions in female athletes. Therefore, we suggest that it is important to monitor the body fat percentage and fat muscle levels in male athletes and reduce these rates to reach optimum levels as needed in order to improve respiratory functions. On the other hand, for female athletes, the body muscle mass needs to be monitored and increased as necessary. We believe that the difference of parameters affecting the pulmonary function test results between male and female athletes was due to the fact that male athletes have lower body fat percentage and body fat mass and higher muscle mass as compared to the female athletes (Table 2).

Our research was limited as it did not categorize the outcome based on various sports branches and assessment parameters did not include the respiratory muscle mass. We think that additional studies should be conducted on various sports branches.

Conclusion

We suggest that the factors affecting the respiratory function in both male and female athletes were not limited to age, gender and, body weight, but also included other body composition parameters such as the body fat percentage, body fat mass, fat-free body mass, abdominal muscle mass, abdominal fat mass, and waist and hip circumference. Also, the most important variable that affects the respiratory function is body fat percentage and fat mass in male athletes, and muscle mass in female athletes.

Acknowledgment

We would like to thank Dietitian Miss Ebru Arslanoğlu for her contributions in our study.

References

1. Andreoli A, Garaci F, Cafarelli FP, Guglielmi G. Body composition in clinical practice. European journal of radiology. 2016;85(8):1461-8.
2. Aragon AA, Schoenfeld BJ, Wildman R, Kleiner S, VanDusseldorp T, Taylor L, et al. International society of sports nutrition position stand: diets and body composition. Journal of the International Society of Sports Nutrition. 2017;14(1):16.
3. Coelho M, Oliveira T, Fernandes R. State of the art paper Biochemistry of adipose tissue: an endocrine organ. Archives of Medical Science. 2013;9(2):191-200.
4. Mujika I, Burke LM. Nutrition in team sports. Annals of Nutrition and Metabolism. 2010;57(Suppl. 2):26-35.
5. Santana H, Zoico E, Turcato E, Tosoni P, Bissoli L, Olivieri M, et al. Relation between body composition, fat distribution, and lung function in elderly men–. The American journal of clinical nutrition. 2001;73(4):827-31.
6. Harik-Khan RI, Wise RA, Fleg JL. The effect of gender on the relationship between body fat distribution and lung function. Journal of clinical epidemiology. 2001;54(4):399-406.
7. Gil SM, Badiola A, Bidaurrazaga-Letona I, Zabala-Lili J, Gravina L, Santos-Concejero J, et al. Relationship between the relative age effect and anthropometry, maturity and performance in young soccer players. Journal of Sports Sciences. 2014;32(5):479-86.
8. Chadorneshin HT, Rabiee M-A, Arefi RG, Ramazani F, Yaghoubi A. Correlation Between Anthropometric, Physical Fitness Traits, Lung Capacity, and Success of Iranian Elite Greco-Roman Wrestlers. 2018.

9. Miller A, Becklake M, Crapo R, Buist S, Burrows B, Clausen J, et al. Lung function testing: Selection of reference values and interpretative strategies [4]. American Review of Respiratory Disease. 1992;146(5):1368-9.
10. Pringle EM, Latin RW, Berg K. The relationship between 10 km running performance and pulmonary function. Journal of Exercise Physiology Online. 2005;8(5).
11. Kim SR, Choi US, Choi JH, Koh HJ. Association of Body Fat and Body Mass Index with Pulmonary Function in Women in Their Forties. Journal of the Korean Academy of Family Medicine. 2003;24(9):827-32.
12. Cotes J, Chinn D, Reed J. Body mass, fat percentage, and fat free mass as reference variables for lung function: effects on terms for age and sex. Thorax. 2001;56(11):839-44.
13. Li A, Chan D, Wong E, Yin J, Nelson E, Fok T. The effects of obesity on pulmonary function. Archives of disease in childhood. 2003;88(4):361-3.
14. Wang R, Custovic A, Simpson A, Belgrave DC, Lowe LA, Murray CS. Differing associations of BMI and body fat with asthma and lung function in children. Pediatric pulmonology. 2014;49(11):1049-57.
15. Sutherland TJ, McLachlan CR, Sears MR, Poulton R, Hancox RJ. The relationship between body fat and respiratory function in young adults. European Respiratory Journal. 2016:ERJ-02216-2015.
16. Wannamethee SG, Shaper AG, Whincup PH. Body fat distribution, body composition, and respiratory function in elderly men–. The American journal of clinical nutrition. 2005;82(5):996-1003.
17. Salinero JJ, Soriano ML, Ruiz-Vicente D, Gonzalez-Millan C, Areces F, Gallo-Salazar C, et al. Respiratory function is associated to marathon race time. The Journal of sports medicine and physical fitness. 2016;56(12):1433-8.
18. Durmic T, Lazovic B, Djelic M, Lazic JS, Zikic D, Zugic V, et al. Sport-specific influences on respiratory patterns in elite athletes. Jornal Brasileiro de Pneumologia. 2015;41(6):516-22.
19. Park JE, Chung JH, Lee KH, Shin KC. The effect of body composition on pulmonary function. Tuberculosis and respiratory diseases. 2012;72(5):433-40.
20. Heitmann BL, Frederiksen P, Lissner L. Hip circumference and cardiovascular morbidity and mortality in men and women. Obesity research. 2004;12(3):482-7.
21. Kocahan T, Akınoglu B, Mete O, Hasanoglu A. Determination of the relationship between respiratory function and respiratory muscle strength and grip strength of elite athletes. Medical Journal of Islamic World Academy of Sciences. 2017;25(4):118-24.
22. Pezelj L, Milavic B, Erceg M. Respiratory parameters in elite finn-class sailors. Montenegrin Journal of Sports Science and Medicine. 2019;8(1):Ahead of Print.
23. Khosravi M, Tayebi SM, Safari H. Single and concurrent effects of endurance and resistance training on pulmonary function. Iranian journal of basic medical sciences. 2013;16(4):628.
24. Neogi A, Chakraborty C, Chatterjee S, Dey SK. Anthropometric profiles and pulmonary function parameters of male Football & Hockey players according to their specific playing position: A Comparative Study. International Journal of Applied Exercise Physiology. 2018;7(3):10-23.
25. Durmic T, Popovic BL, Svenda MZ, Djelic M, Zugic V, Gavrilovic T, et al. The training type influence on male elite athletes' ventilatory function. BMJ open sport & exercise medicine. 2017;3(1):e000240.
26. Joshi AR, Singh R, Joshi A. Correlation of pulmonary function tests with body fat percentage in young individuals. Indian J Physiol Pharmacol. 2008;52(4):383-8.
27. Maiolo C, Mohamed E, Carbonelli M. Body composition and respiratory function. Acta diabetologica. 2003;40(1):s32-s8.
28. Lim S, Kwon SY, Yoon JW, Kim SY, Choi SH, Park YJ, et al. Association between body composition and pulmonary function in elderly people: the Korean Longitudinal Study on Health and Aging. Obesity. 2011;19(3):631-8.
29. Sahebjami H, Gartside PS. Pulmonary function in obese subjects with a normal FEV1/FVC ratio. Chest. 1996;110(6):1425-9.
30. Babb TG, Wyrick BL, DeLorey DS, Chase PJ, Feng MY. Fat distribution and end-expiratory lung volume in lean and obese men and women. Chest. 2008;134(4):704-11.
31. Johari HM, Zainudin HA, Knight VF, Lumley SA, Subramanium AS, Caszo BA, et al. Effect of gender specific anthropometric characteristics on lung function in young competitive triathletes from Malaysia. The Journal of sports medicine and physical fitness. 2017;57(4):396-401.
32. Card JW, Zeldin DC. Hormonal influences on lung function and response to environmental agents: lessons from animal models of respiratory disease. Proceedings of the American Thoracic Society. 2009;6(7):588-95.

Correspondence:
Bihter Akınoğlu,
Ankara Yıldırım Beyazıt University,
Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey 05059384136
E-mail: rgkardelen@yahoo.com