Relation between body composition, fat distribution, and lung function in elderly men[1–3]

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ABSTRACT

Background: Body composition changes with age, with increases in fat mass and visceral fat and declines in skeletal muscle mass; lung function also declines with age. Age-related changes in body composition and fat distribution may be associated with the pulmonary impairment observed in the elderly.

Objective: Our goal was to evaluate the relations between body composition, fat distribution, and lung function in elderly men.

Design: We studied 97 men aged 67–78 y with body mass indexes (BMIs; in kg/m^2) ranging from 19.8 to 37.1. Body composition was evaluated by using dual-energy X-ray absorptiometry and fat distribution was evaluated by using waist and hip circumferences, waist-to-hip ratio, and sagittal abdominal diameter (SAD). Spirometry was done in all subjects and the distance walked by each subject during a 6-min walking test was evaluated as was leg strength.

Results: A significant negative correlation was found between adiposity, fat distribution indexes, forced vital capacity (FVC), and forced expiratory volume in 1 s (FEV_1). A positive correlation was found between fat-free mass and FVC. After adjustment for age, height, and weight, SAD still correlated negatively with FVC and FEV_1 ($r = -0.367$ and -0.348, respectively; $P < 0.01$), whereas percentage body fat and fat mass correlated negatively and fat-free mass correlated positively with FVC ($r = -0.313$, -0.323, and 0.299, respectively; all $P < 0.01$). After the sample was subdivided by tertile of fat-free mass adjusted for age and BMI, FVC and FEV_1 were significantly lower in the lowest fat-free mass tertile ($P < 0.01$). Stepwise multiple regression analysis performed with use of lung function variables as the dependent variables and age, height, fat mass, fat-free mass, waist circumference, and SAD as the independent variables showed that 3 variables entered the regression for predicting FVC: height, which entered the regression first; SAD, which entered second; and fat-free mass, which entered third. Only 2 variables entered the regression for predicting FEV_1: height, which entered the regression first, and SAD, which entered second.

Conclusion: Our cross-sectional data show a significant association between body composition, fat distribution, and lung function in elderly men. *Am J Clin Nutr* 2001;73:827–31.

KEY WORDS Fat mass, fat-free mass, fat distribution, lung function, body composition, elderly men, Italy

INTRODUCTION

Both cross-sectional and longitudinal studies have shown age-related changes in body composition. With advancing age, elderly men and women tend to become more obese, their amount of visceral fat tends to increase, and their skeletal muscle mass declines (1–6). Lung function also declines with age (7). Age-related changes in pulmonary function are clinically relevant because impaired lung function is associated with increased mortality rates (8). It was reported that respiratory muscle strength and lung function are closely associated with body weight and lean body mass in patients with chronic obstructive pulmonary disease (COPD) (9) and that a central pattern of fat distribution is negatively associated with lung function in healthy adults (10, 11). Thus, age-related body-composition and fat-distribution changes could be associated with the pulmonary impairment observed in the elderly. Few studies have considered the association between body composition, fat distribution, and lung function in elderly subjects or the relation between physical performance and lung function. The aim of our study was to evaluate the relation between body composition, fat distribution, and lung function in a sample of elderly men with or without mild COPD.

SUBJECTS AND METHODS

Subjects

Subjects were recruited from the lists of 11 general practitioners in Verona, Italy, in such a way as to provide a good geographical representation of the city. Male subjects aged 67–78 y were selected randomly from each general practitioner's list. Men were eligible if they could walk ≥0.8 km (0.5 mi) without difficulty and if they were free of cognitive impairment on the

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basis of a Mini-Mental State Examination score >24 (12). Of the 120 men initially selected, 6 were excluded because of physical disability, 7 were excluded because of heart failure (New York Heart Association class 2 or higher) or moderate or severe COPD (as defined by clinical records or spirometric tests), and 10 refused to participate in the study. A total of 97 men resident in Verona with body mass indexes (BMIs; in kg/m^2) ranging from 19.8 to 37.1 gave their consent to participate in the study. The study protocol was approved by our ethical committee. None of the men included in this study had COPD or signs or symptoms of COPD, except for 10 who had mild COPD as quantified by spirometric tests with ratios of forced expiratory volume in 1 s to forced vital capacity (FEV_1:FVC) of from 61 to 69 (7).

Anthropometry

With the subjects wearing light indoor clothes and no shoes, body weight was measured to the nearest 0.1 kg on a scale (Salus, Milan, Italy) and height to the nearest 0.5 cm with a stadiometer (Salus). BMI was then calculated as body weight adjusted for stature. Circumferences were measured to the nearest 0.5 cm with use of a 1-cm wide metal measuring tape while subjects were standing. Waist circumference was measured as the minimum abdominal circumference between the xyphoid process and the umbilicus. Hip circumference was measured as the maximum circumference over the buttocks. The waist-to-hip ratio (WHR) was calculated as the ratio between these 2 circumferences.

Sagittal abdominal diameter (SAD) was measured with a portable, sliding-beam, abdominal caliper while the subjects were in a supine position; this instrument was handmade by an artisan under our supervision. SAD was measured as the largest supine anteroposterior diameter between the xyphoid process and the umbilicus (13). The subjects were asked to inhale and exhale gently and the arm of the caliper was brought down to touch the abdominal wall without compression. All subjects were examined in a flat standard hospital bed.

Body composition

Total body fat, total fat-free tissue mass, and percentage body fat were measured by dual-energy X-ray absorptiometry (DXA) (QDR 2000; Hologic Inc, Waltham, MA) with software version 7.2. The characteristics and physical concept of DXA measurements are described elsewhere (14, 15). All metal objects (jewelry, belts, etc) were removed before the DXA measurements. Measurements were taken with the subject lying supine on the scanning table. Radiation exposure was <8 Sv; the mean measurement time was 6 min. All scans were analyzed by a single trained investigator. Total body fat was expressed as percentage body fat and in kg. Fat-free mass was expressed in kg. Daily quality-assurance tests were performed according to the manufacturer's instructions. The CV for double determinations in 11 subjects aged 65–75 y was 1% for total body fat, 1.3% for fat-free mass, and 2.3% for percentage body fat.

Lung function

Spirometry was performed under standard conditions of body temperature and ambient pressure and with water vapor saturation. Measurements were made with use of a closed-circuit spirometer (Pulmonet III; SensorMedics, Milan, Italy) with the subjects sitting down and wearing a nose clip. Each subject performed 3 acceptable FVC maneuvers according to the American Thoracic Society recommendations (16). The largest FVC and FEV_1 values were recorded after examining the data from all the acceptable curves, even if they did not come from the same curve (16).

Evaluation of physical performance

Each subject performed a 6-min walking test in which the number of meters walked was determined by each subject (17). Briefly, each subject was invited to walk at a normal speed in a corridor where various distances had been marked previously. Isometric strength of the knee extensors of the dominant leg was estimated in all men at 45° by using a Spark Handheld Dynamometer (model 160; Spark Instruments & Academics Inc, Iowa City). All procedures were standardized and measurements were performed by the same experienced examiner. Leg strength was recorded in kg and was calculated as the highest peak torque obtained in 3 trials. The CV for double determinations in 20 subjects was 7.7%.

Smoking status

Current cigarette smokers were defined as participants who smoked cigarettes daily or who had stopped smoking <5 y before the date of spirometry. Former smokers were defined as participants who had smoked cigarettes daily and had stopped smoking ≥5 y before the date of spirometry. Nonsmokers were participants who had smoked <5–10 packs of cigarettes during their lifetime.

Statistical methods

The bivariate correlation coefficient (r) was used as a measure of association; partial correlations were also calculated between ventilatory function, anthropometric variables, body composition, and physical performance with control for age, height, and weight. Covariance analysis was used to test differences in pulmonary variables between fat-free mass and SAD tertiles after adjustment for age and BMI. The cutoffs for fat-free mass tertiles were <49.79 kg, 49.79–53.86 kg, and >53.86 kg; the cutoffs for SAD were <22 cm, 22–23.8 cm, and >23.8 cm. Pairwise comparisons were performed with Bonferroni's test. Stepwise multiple regression analysis was used to test the joint effects of independent variables (age, height, BMI, waist circumference, WHR, SAD, fat mass, percentage body fat, and fat-free mass) on lung function variables. The CV was computed by dividing the square root of the within-subject variance by the overall mean value of the measurement. The cutoff for statistical significance was $P < 0.05$. All statistical analyses were done by using the SPSS statistical package (18).

RESULTS

The characteristics of the study population are shown in **Table 1**. Of our subjects, 49.5% never smoked cigarettes, 29.9% were former smokers, and 20.6% were current smokers.

A significant negative correlation was found between adiposity indexes (BMI and percentage body fat) and both FVC and FEV_1 (**Table 2**). A significant negative correlation was also found between fat distribution indexes (SAD and WHR) and FVC and FEV_1. A positive correlation was found between fat-free mass and FVC. The distance walked during the 6-min walking test and leg strength were significantly associated with both FVC and FEV_1.

After age, height, and weight were controlled for, SAD was still negatively correlated with FVC and FEV_1 ($r = -0.367$ and $r = -0.348$, respectively), whereas percentage body fat, fat

TABLE 1
Characteristics of the study sample[1]

	Value
Age (y)	71.80 ± 2.12
Weight (kg)	78.90 ± 11.57
Height (m)	1.70 ± 0.07
BMI (kg/m^2)	27.30 ± 3.55
Waist circumference (cm)	95.93 ± 9.15
WHR	0.97 ± 0.06
SAD (cm)	23.02 ± 2.89
FFM (kg)[2]	52.35 ± 5.59
Fat mass (kg)[2]	22.37 ± 7.37
Body fat (%)[2]	28.38 ± 5.96
Current smokers [*n* (%)]	20 (20.6)
Nonsmokers [*n* (%)]	48 (49.5)
Former smokers [*n* (%)]	29 (29.9)
6-min walking test (m)	391.75 ± 71.14
Leg strength (kg)	18.18 ± 5.86
FVC (L)	3.66 ± 0.68
FEV_1 (L/s)	2.85 ± 0.58
FEV_1:FVC	77.78 ± 8.13

[1] $\bar{x}$ ± SD; n = 97 men. FEV_1, forced expiratory volume in 1 s; FFM, fat-free mass; FVC, forced vital capacity; SAD, sagittal abdominal diameter; WHR, waist-to-hip ratio.
[2] Measured by dual-energy X-ray absorptiometry.

mass, and fat-free mass correlated only with FVC (r = −0.313, r = −0.323, and r = 0.299, respectively) (**Table 3**).

After we subdivided the study sample into fat-free mass tertiles adjusted for age and BMI, FVC and FEV_1 were significantly lower in the lowest fat-free mass tertile than in the other 2 tertiles; the distance walked during the 6-min walking test was significantly higher in the highest fat-free mass tertile (**Table 4**). After subdividing our study sample into SAD tertiles adjusted for age and BMI, FVC and FEV_1 did not differ significantly by tertile (data not shown).

Stepwise multiple regression analysis performed with use of the lung function variables (FVC and FEV_1) as the dependent variables and age, height, BMI, waist circumference, WHR, SAD, fat mass, percentage body fat, and fat-free mass as the independent variables showed that 3 variables entered the regression for predicting FVC (**Table 5**): height, which entered the regression first; SAD, which entered the regression second; and fat-free mass, which entered the regression third. Only 2 variables entered the regression for predicting FEV_1: height, which entered the regression first, and SAD, which entered the regression second.

DISCUSSION

Our data show that body composition and fat distribution are associated with lung function in elderly men in that a central pattern of fat distribution correlated negatively with lung function, whereas the amount of fat-free mass correlated positively with lung function. Our findings of a significant negative correlation between percentage body fat and FVC and between SAD and FVC and FEV_1 expand on and complement the findings of previous reports (10, 11, 19).

Impaired lung function is observed frequently in obese persons (20, 21). Lazarus et al (19), in a sample of 1235 nonobese subjects aged 18–78 y, showed a decrease in lung function with increasing fat mass and central body fat distribution. Similar findings were observed in middle-aged men, but not in those older than 60 y (11). In these 2 reports, fat mass was evaluated by using age- and sex-specific equations based on skinfold thicknesses and fat distribution was evaluated by measuring waist and hip circumferences (11, 19). Our data were obtained by using DXA, which is a direct, accurate method of assessing body composition (ie, fat mass, percentage body fat, and fat-free mass).

The amount of body fat and a central pattern of fat distribution might be related to lung function via several mechanisms, such as mechanical effects on the diaphragm (impeding descent into the abdominal cavity) and on the chest wall (changes in compliance and in the work of breathing and elastic recoil) (11). Because total adiposity and visceral fat tend to increase with aging (1–4), our data appear to provide evidence of an association between the age-related increase in these variables and the decline in lung

TABLE 2
Correlations between ventilatory function, anthropometric variables, body composition, and physical performance[1]

	FVC (L)	FEV_1 (L/s)	FEV_1:FVC
Age (y)	−0.124	−0.136	−0.011
Height (cm)	0.548[2]	0.444[2]	−0.106
Weight (kg)	0.025	−0.018	−0.113
BMI (kg/m^2)	−0.317[3]	−0.301[3]	−0.060
Waist circumference (cm)	−0.200[4]	−0.216[4]	−0.110
WHR	−0.202[4]	−0.234[4]	−0.150
SAD (cm)	−0.318[3]	−0.312[3]	−0.110
FFM (kg)[5]	0.286[3]	0.179	−0.191
Fat mass (kg)[5]	−0.212[4]	−0.188	−0.019
Body fat (%)[5]	−0.355[2]	−0.274[3]	0.078
6-min walking test (m)	0.218[4]	0.239[4]	0.093
Leg strength (kg)	0.254[4]	0.202[4]	−0.154

[1] FEV_1, forced expiratory volume in 1 s; FFM, fat-free mass; FVC, forced vital capacity; SAD, sagittal abdominal diameter; WHR, waist-to-hip ratio.
[2] $P < 0.001$.
[3] $P < 0.01$.
[4] $P < 0.05$.
[5] Measured by dual-energy X-ray absorptiometry.

TABLE 3
Partial correlations adjusted for age, height, and weight between ventilatory function, anthropometric variables, body composition, and physical performance[1]

	FVC (L)	FEV_1 (L/s)	FEV_1:FVC
Waist circumference (cm)	−0.114	−0.142	−0.103
WHR	−0.060	−0.117	−0.151
SAD (cm)	−0.367[2]	−0.348[2]	−0.108
Thigh circumference (cm)	0.092	0.013	−0.118
FFM (kg)[3]	0.299[4]	0.166	−0.164
Fat mass (kg)[3]	−0.323[4]	−0.179	0.169
Body fat (%)[3]	−0.313[4]	−0.151	0.203[5]
6-min walking test (m)	0.102	0.130	0.093
Leg strength (kg)	0.198	0.094	0.002

[1] FEV_1, forced expiratory volume in 1 s; FFM, fat-free mass; FVC, forced vital capacity; SAD, sagittal abdominal diameter; WHR, waist-to-hip ratio.
[2] $P < 0.001$.
[3] Measured by dual-energy X-ray absorptiometry.
[4] $P < 0.01$.
[5] $P < 0.05$.

TABLE 4
Description of men by tertile of fat-free mass (FFM) adjusted for age and BMI[1]

	FFM tertile		
	Low <49.79 kg (n = 32)	Mid 49.79–53.86 kg (n = 32)	High >53.86 kg (n = 33)
FFM (kg)[2]	47.19 ± 0.52[a]	51.95 ± 0.49[b]	58.28 ± 0.52[c]
Weight (kg)	73.38 ± 1.02[a]	78.18 ± 0.96[b]	85.09 ± 1.03[c]
Waist circumference (cm)	94.44 ± 0.77[a]	96.02 ± 0.72[b]	97.17 ± 0.77[b]
WHR	0.97 ± 0.01	0.97 ± 0.01	0.96 ± 0.01
SAD (cm)	23.00 ± 0.32	22.80 ± 0.30	23.06 ± 0.32
Fat mass (kg)[2]	22.50 ± 0.79	22.28 ± 0.74	22.29 ± 0.80
Body fat (%)[2]	30.49 ± 0.73[a]	28.49 ± 0.69[a]	26.01 ± 0.74[b]
FVC (L)	3.12 ± 0.11[a]	3.81 ± 0.10[b]	4.07 ± 0.11[b]
FEV_1 (L/s)	2.43 ± 0.09[a]	2.99 ± 0.09[b]	3.15 ± 0.10[b]
FEV_1:FVC	77.71 ± 1.60	78.39 ± 1.50	76.97 ± 1.61
Leg strength (kg)	18.09 ± 1.09[a]	16.16 ± 1.02[b]	20.34 ± 1.10[a]
6-min walking test (m)	377.73 ± 13.00[a]	377.49 ± 12.21[a]	417.36 ± 13.11[b]

[1] FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; SAD, sagittal abdominal diameter; WHR, waist-to-hip ratio. Means within a row with different superscript letters are significantly different, $P < 0.01$ (with Bonferroni correction).
[2] Measured by dual-energy X-ray absorptiometry.

function observed in the elderly. Our findings also seem to be in line with those of Chinn et al (22), who observed an association between changes in fat mass and those in FVC and FEV_1.

A relation between muscle mass and lung function has been postulated. In patients with COPD and low body weight (<80% of usual body weight), a significant association was observed between respiratory muscle strength and fat-free mass measured by DXA (9) along with a concomitant decline in fat-free mass and pulmonary function (23). In adults with cystic fibrosis, a significant positive correlation was found between FEV_1 and fat-free mass measured by DXA (24). In our study population, after adjustment for age and BMI, subjects in the lowest fat-free mass tertile had the lowest FVC and FEV_1 values. Thus, our data showing a correlation between fat-free mass and lung function in elderly men seem to suggest that altered lung function must be added as a clinical consequence of sarcopenia in the elderly (25).

It is interesting to note that in our study population the positive association between fat-free mass and FVC and the negative association between SAD and lung function persisted even after smokers were excluded from the analysis. This finding seems to agree with those of Lazarus et al (19), who observed that the pattern of association between lung function and body composition was not altered when the analysis was restricted to nonsmokers or to specific smoking status groups.

In our subjects, both fat-free mass and SAD seemed to be related to lung function in opposite but independent ways, as shown by the multiple regression analysis. Even if the effect of height on lung function seems to be more relevant than the effects of any of the other body-composition variables, our results suggest that age-related changes in body composition (ie, an increase in central fat and a decrease in fat-free mass) have additive negative effects on ventilator function. The relation between height and pulmonary function was observed previously; height is one of the variables used in estimating lung function (7, 26, 27) and therefore age-related changes in height may significantly affect pulmonary function.

Several limitations of our study must be recognized. Our study sample was relatively small and included only men in good health. In particular, only 2 subjects had BMIs <20 and none had lost body weight in the year before the examination; thus, no frail elderly men were included in the study sample. Because we excluded persons with physical disabilities, our data indicating an association between body composition and lung function appear to represent a normal-aged male population. More thorough assessment of pulmonary function would also be important. Others showed that other lung function indexes such as expiratory reserve volume are related to fat mass and degree of obesity (28) and that expiratory reserve volume improves after fat mass loss (29). It may also be important to evaluate maximal inspiratory and expiratory pressures, which are indexes of the strength of the diaphragm and the strength of the abdominal and intercostal muscles, respectively, rather than FVC and FEV_1. In fact, it was shown that maximal respiratory pressure decreases with age (30). FVC and FEV_1, however, seem to be the lung function variables most closely related to body composition and fat distribution as well as the pulmonary variables most widely used in clinical studies.

In conclusion, our data show that a central pattern of fat distribution is negatively associated with lung function in elderly subjects, whereas the amount of muscle mass correlates positively

TABLE 5
Stepwise multiple regression with use of age, anthropometric measurements, and body-composition variables as independent variables and ventilatory function indexes as dependent variables[1]

Dependent and independent variables	R	P	R^2
FVC (L)			
Step 1: height	0.548	<0.01	0.301
Step 2: SAD	0.664	<0.01	0.441
Step 3: FFM[2]	0.686	<0.01	0.470
FEV_1 (L/s)			
Step 1: height	0.444	<0.01	0.198
Step 2: SAD	0.575	<0.01	0.330

[1] FEV_1, forced expiratory volume in 1 s; FFM, fat-free mass; FVC, forced vital capacity; SAD, sagittal abdominal diameter.
[2] Measured by dual-energy X-ray absorptiometry.

with lung function. Cross-sectional studies such as ours are capable of only describing phenomena; longitudinal analyses are needed to better understand the cause-effect relation.

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