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Anthropometric Methods in Evaluation of Chronic Obstructive Pulmonary Disease

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A B S T R A C T

Chronic Obstructive Pulmonary Disease (COPD) is mainly expressed by weight loss with especially fat-free mass (FFM) depletion and a low body weight correlates with increased mortality and a poor prognosis. We investigated whether anthropometric body composition equations could be used for evaluation of the body composition in COPD. Thirty clinically stable patients with COPD and 13 healthy age matched control subjects underwent the skinfolds and circumference measurements in addition to body mass index (BMI) calculations. Body fat mass (BFM) and FFM were determined by using anthropometric equations. The percent BFM, predicted from body density either using Siri's or Brozek's equations was determined lower than that of calculated with equations by using BMI, age and gender. The values of BFM and body weight were reduced in patients with FEV_1<%predicted compared to other participants. The FFM values also dropped depending on the severity of COPD. BMI was not statistically different among the participants while FFM index (FFMI) reflected the nutritional status of the disorders. Anthropometric equations easily and cost effectively applied for prediction of %BFM, FFM, and FFMI in patients with COPD. In addition, the FFMI can be possibly used for expressing COPD severity.

***Key words**: anthropometry, chronic obstructive pulmonary disease, body fat mass, fat free mass index, body mass index*

Introduction

Anthropometric methods are noninvasive, easy-to--use after minimal training, cost effective, widely available, safe and portable techniques that describe body size, fatness and leanness in subjects and can provide information about the body composition and nutritional status of these subjects[1]. Body weight & height, skinfold thickness at various sites, girth of abdomen & limbs, and various body diameters are measured by the anthropometric methods[2].

Body composition is not measured directly in human subjects. Therefore, various indirect methods have been developed to estimate body components. The two-compartment model, divided the body into fat and fat-free mass (FFM), has been largely accepted for the assessment of body composition. In this model, fat compartment includes all lipids while FFM comprises all the remaining constituents. The anthropometric body fat prediction models are based upon either skinfold thickness or circumference measurements. Some models rely on both selected skinfold and circumference measurements[3].

Weight and height measurements provide a general description of body size and mass while body mass index (BMI) is a descriptive index of fatness or obesity. Skinfold-thickness measurements estimate general fatness and the distribution of subcutaneous adipose tissue[3]. Girth measurements give information about internal adipose tissue. Thus, skinfold and circumference measurements can be used to evaluate the shape and composition of the human body[3].

Anthropometric methods are used to evaluate the growth and development of children, to determine the body composition changes in young adults, obese and/or elderly subjects, and to predict the risk and/or prognostic factors for haemodialysis subjects and chronic disorders such as cardiovascular diseases, hypertension, diabetes mellitus, and pulmonary disorders[4–7].

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Chronic Obstructive Pulmonary Disease (COPD) is characterized by weight loss and FFM depletions, which contains functional muscle mass. Skeletal muscle, a major component of FFM, depletion may cause peripheral muscle weakness and impaired exercise capacity in COPD patients that resulted to decline in quality of life[8]. Previous studies suggest that there is a stronger relationship between the depletion of FFM of COPD patients and severity of their disorders[9].

Body mass index (BMI), a prognostic factor in COPD, is used to evaluate a person's lung function and indicates association between decreasing body mass and increasing mortality[10]. Thus, low BMI causes harmful effects in COPD patients which are due to the effect of a low FFM Index. Normal weight subjects may have a high BMI because they have more muscle than fat mass. Waist circumference (WC), provided a quantity of visceral adipose tissue, can be better predictor than abdominal circumference for evaluating the lung function. Chen et al. (2007) reported that WC is negatively associated with the pulmonary function especially FVC and FEV_1[11]. So, if the subjects have greater waist circumferences, their lung function will be worsen. Thus, reduction of pulmonary functions in the elderly subjects may clinically associate with increased mortality rates. Waist circumference is related to lung impairment because the pressure in the abdomen pushes on the diaphragm. Therefore, losing a few cm from the waist may result in better breathing.

In this study, we purposed to evaluate the body composition of COPD and healthy male adults by using anthropometric methods.

Materials and Methods

Subjects

Thirty clinically stable COPD outpatients and 13 healthy volunteer adults participated in this study. A ratio of the forced expiratory volume in one second (FEV_1) to the forced vital capacity (FVC) <0.70 was used to diagnose to the presence of COPD. Patients with COPD were divided in two groups according to post-bronchodilator FEV_1: COPD patients with FEV_1<50% predicted and COPD patients with FEV_1>50%predicted. We excluded patients who had suffered from any medical conditions that would influence the integrity of the results such as cardiovascular or renal disorders. All subjects gave written informed consent for participation in the study which was approved by the Ethical Committee of Adnan Menderes University, Aydin, Turkey.

Anthropometry

All anthropometric measurements were performed by the same trained investigator. Height and body weight were measured by using a SECA (Model 767, Germany) Digital Column Scale with subjects standing barefoot and wearing minimal clothing, respectively. Skinfold thickness was measured on the right side of the body by using a Harpenden caliper (British Indicators Ltd, St Albans, UK). The skinfolds were measured at the following sites: (1) triceps, distance between lateral projection of acromial process and inferior margin of olecranon process is measured on lateral aspect of arm with elbow flexed 90@ using a tape measure. Midpoint is marked on lateral side of arm. (2) biceps, fold is lifted over belly of the biceps brachii at the level marked for the triceps and on line with anterior border of the acromial process and the antecubital fossa. (3) subscapula, fold is along natural cleavage line of skin just scapula, with caliper applied 1 cm blow fingers. (4) suprailiac, fold is grasped posteriorly to midaxillary line and superiorly to iliac crest along natural cleavage of skin with caliper applied 1 cm below finger. (5) Abdominal, fold is taken 3 cm lateral and 1 cm inferior to center of the umbilicus[3]. The sum of four skinfolds (triceps, biceps, subscapularis and suprailiac) was entered into Durning & Womersley's equation[2] to determined body density (Eq. 1). Percentage of BFM was calculated from body density, using either Siri's[12] or Brozek's[13] equations (Eq. 2 and 3, respectively). Then, FFM was determined by subtracting BFM from body weight. Fat free mass index (FFMI) was calculated as FFM (kg) divided by square body height (m^2). The BMI (Eq. 4) was equal to mathematically summation of FFMI and BFM Index (BFMI). BMI of 18.5 to 25 may indicate optimal weight; a BMI lower than 18.5 suggests the subjects are underweight while a number above 25 may indicate the subject is overweight. If the index is above 30, the subject is defined as obese[3].

$$\text{Body density} = 1.1715 – 0.0779 \text{ Log } (\Sigma>4 \text{ skinfolds}) \quad \text{Eq. 1}$$

$$\%BFM = [(4.95 / \text{body density}) – 4.5] \times 100 \quad (\text{Siri's Equation})^{12} \quad \text{Eq. 2}$$

$$\%BFM = [(4.57 / \text{body density}) – 4.142] \times 100 \quad (\text{Brozek's Equation})^{13} \quad \text{Eq. 3}$$

$$BMI = \text{Body weight} / \text{height}^2 \quad (kg/m^2) \quad \text{Eq. 4}$$

Circumferences of waist and abdomen were measured as cm using a flexible standard measuring tape as reported in the Anthropometric Standardization Reference Manual.[3] Briefly; waist circumference was measured by applying tape snugly around the waist at level of narrowest part of torso which is between ribs and iliac crest. Abdominal circumference was measured on maximum anterior protuberance of abdomen, usually at umbilicus. All measurements were performed three times at each location and recorded values were the average of these measurements. The comparisons were made between some previously published elderly body composition anthropometric equations and the equation used during this study (Table 1)[14–18]. Also %BFM was estimated using the tables of Durnin & Womersley[2] and this value was compared to that of determined in our study.

Pulmonary function

A Jaeger MasterScope spirometer (VIASYS Healthcare GmbH, Hoechberg, Germany) was used for pulmonary function testing. Each subject was tested according to the criteria of the American Thoracic Society and European Respiratory Society[19]. All values of forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and the ratio of FEV_1 to FVC were examined after the three acceptable FVC maneuvers. Largest FVC and FEV_1 values recorded for the result of this test. Also post-dilatator FEV_1 were recorded for classified the COPD patients.

Statistical analysis

Data were analyzed using GraphPad Instat version (San Diego California USA). One way ANOVA with Tukey test was performed to compare anthropometric variables among the experimental groups. Data were expressed as means ± standard error of means (SEM). The significance level was defined as $p<0.05$.

Results

The characteristics of two groups of patients and control subjects are reported in Table 2. There were no statistically significant differences among the mean ages and heights of experimental groups ($p>0.05$). But body weight and BMI significantly lower in severe COPD patients than that of controls ($p<0.01$). The pulmonary function test parameters significantly decreased with increasing severity of COPD ($p<0.001$) except FVC value. The mean FVC values weren't statistically significant between the patients in $FEV_1>50\%$pred group and the control group ($p>0.05$) because almost half of the patients in this group were verified in GOLD stage of one (N=9). However, the mean FVC values in severe COPD groups were statistically differed than that of the other groups ($p<0.001$).

The anthropometric characteristics and comparisons of subjects are shown in Table 3. The mean values of five skinfolds were changed due to the severity of the COPD. But, these changes weren't statistically significant among the groups ($p>0.05$). On the country, skinfold measurements were used to calculated body densities which were significantly different between control and COPD patients ($p<0.05$). In addition to decrease in value of %BFM calculated with either Siri's or Brozek's equations, the FFM and FFMI values were significantly reduced in severe and mild COPD patients ($p<0.05$) with reduced BMI. Also waist and abdominal circumferences were decreased in severe and mild COPD patients ($p<0.05$ and $p<0.01$, respectively).

The predicted values determined by the previously published equations are shown in Table 4. There is a statistically significant different among the %BFM values of control group calculated by previously published equations (DW eq. vs Deurenberg 1991 eq., $p<0.01$; DW eq. vs lean 1996 eq., $p<0.01$; DW eq. vs other equations, $p>0.05$)[2,15–18]. But there are no statistical different neither %BFM values of COPD patients with $FEV_1>50\%$pred de-

TABLE 1
PREVIOUSLY PUBLISHED EQUATIONS CHOSEN FOR COMPARISON

Dependent Variable	Equation	Source
Body density	1.1582 – [0.0771 x Log (suprailiac + subscapular skinfolds)]	Durning&Womersley (1974)[2]
Body density	1.079538 – [0.001110 x (abdominal + suprailiac skinfolds)]	Demura and Sato (2007)[14]
%BFM	(1.20 x BMI) + (0.23 x age) – (10.8 x gender) – 5.4	Deurenberg et al. (1991)[15]
%BFM	(1.29 x BMI) + (0.20 x age) – (11.4 x gender) – 8.0	Deurenberg et al. (1998)[16]
%BFM	(1.46 x BMI) + (0.14 x age) – (11.6 x gender) – 10	Gallagher et al. (1996)[17]
%BFM	(0.567 x WC)+(0.101 x age) – 31.8	Lean et al. (1996)[18]

BFM – body fat mass, BMI – body mass index, WC – waist circumfarence

TABLE 2
PHYSICAL CHARACTERISTICS AND COMPARISONS OF SUBJECTS

Variable	COPD Patients with $FEV_1<50\%$pred. (N=10)	COPD Patients with $FEV_1>50\%$pred. (N=20)	Control Subjects (N=13)
Age (years)	65.0±1.6	60.0±1.8	60.8±2.0
Body weight (kg)	66.8±4.2	74.8±2.9	82.5±2.0
Height (cm)	167.3±2.0	168.6±1.2	167.1±1.3
BMI (kg/m^2)	23.8±1.2	26.3±0.9	29.6±0.8
FVC (% pred.)	67.0±2.5	103.9±5.1	105.7±5.3
FEV_1 (% pred.)	42.2±1.9	82.1±5.0	102.7±5.0
FEV_1 / FVC (%)	44.3±2.7	54.9±2.5	76.1±1.1

BMI – body mass index, FVC – forced vital capacity, FEV_1 – forced expiratory volume in 1 second, pred.– predicted value

TABLE 3
ANTHROPOMETRIC CHARACTERISTICS AND COMPARISONS OF SUBJECTS

Variable	Patients with FEV_1<50%pred. (N=10)	Patients with FEV_1>50%pred. (N=20)	Control Subjects (N=13)
Subscapular skinfold (mm)	18.5±2.3	20.4±2.0	21.6±1.9
Triceps skinfold (mm)	14.9±1.8	13.7±1.6	12.2±1.2
Biceps skinfold (mm)	8.2±1.2	8.2±1.2	7.8±1.0
Suprailiac skinfold (mm)	9.0±1.1	7.7±0.8	8.4±0.9
Abdominal skinfold (mm)	22.0±1.2	23.0±2.1	25.3±1.5
Waist circumference (cm)	88.3±5.0	96.3±2.6	104.4±2.0
Abdominal circumference (cm)	88.3±4.4	97.1±2.6	104.9±1.7
Body density (kg/L)[#]	1.0508±0.0026	1.0526±0.0028	1.0408±0.0031
%BFM calculated by using Siri's Formula	21.1±1.5	20.3±1.3	25.7±1.4
BFM (kg)[$]	14.4±1.5	15.7±1.5	21.4±1.5
FFM (kg)[$]	52.4±3.0	59.1±1.8	61.2±1.3
FFMI (kg/m^2)[$]	18.7±0.8	20.8±0.5	22.0±0.4
%BFM calculated by using Brozek's Formula	20.8±1.2	20.0±1.2	25.0±1.3
BFM (kg)[*]	14.1±1.5	15.5±1.4	20.8±1.4
FFM (kg)[*]	52.7±3.0	59.9±1.9	61.8±1.3
FFMI (kg/m^2)[*]	18.8±0.8	21.0±0.5	22.2±0.4

BFM – body fat mass, FFM – fat free mass, FFMI – fat free mass index; [#] Body density was calculated by using Durnin and Womersley formula; [$] Using BFM% calculated by Siri's equation to determine BFM, FFM and FFMI; [*] Using BFM% calculated by Brozek's equation to determine BFM, FFM and FFMI

termined by various published equations nor %BFM values of COPD patients with FEV_1<50%pred calculated by various published equations (p>0.05). The statistically difference at %BFM values are observed between control subjects and COPD patients with FEV_1<50%pred. (p>0.05) in all published equations. In this study, body density was predicted from the sum of four skinfolds, using the appropriate equation from Durnin and Womersley[2] and converted to %BFM by using Siri's equation[12]. The %BFM values of control group weren't statistically different from that of reported in Table of Durnin and Womersley [2] (25.7±1.4 vs. 27.9 in the range of 50–72 y).

The correlation coefficients between BMI and % BFM were measured among the groups. This correlation coefficients were detected as 0.67, 0.65, and 0.55 in control subjects, COPD patients with FEV_1>50%pred. and COPD patients with FEV_1<50%pred., respectively.

Discussion

Present study has shown that anthropometric measurements are significantly associated with pulmonary function. Various studies reported that fat mass and central adiposity (WC and AC) negatively, but FFM positively, correlated with lung function[10,20]. Also, it was suggested that age, smoking and physical activity have a potential to effect these associations.

Durnin and Womersley[2] equation is widely used for estimating %BFM in the anthropometric measurements. In the present study, the equation of Durnin and Womersley combined with either Siri's or Brozek's equations to convert body density, which is calculated by using the sum of four skinfold thickness, to %BFM. Guerra et al. (2010) reported that Brozek's equation may be preferable to predict %BFM from body density. The bland and Altman plots confirmed that %BFM calculated by Brozek equation reflects a better agreement with %BFM calculated by Dual-Energy X-ray Absorptiometry equations[21]. On the otherhand, Heymsfield reported that there is a negligible difference between %BFM derived from Siri's equation vs that of Brozek's equations within the normal body fat range (<30% BFM)[3]. We observed similar %BFM values (p>0.05, see Table 3) in these equations.

The correlation coefficients between BMI, which is used for estimating adiposity, and %BFM are ranged from 0.58 to 0.86 for healthy men[17.] In our study, the correlation between BMI and %BFM was at this range in the control group. Hallin et al. reported that low body weight and body mass index is negative prognostic factor in patients with COPD[22]. We observed that body weight and BMI become lower than control group in patients with COPD. In addition, the correlation coefficients of BMI and %BFM become lower depending on severity stage of COPD. Therefore, BMI may not be good parameter in a prediction equation to determine the %BFM.

Predicted %BFM based on published BMI prediction equations gave higher value than that of estimated using the sum of four skinfolds measurements. The age, ethnicity and gender have strong influence on the relation between BMI and body fatness. Therefore, these pre-

TABLE 4
PREDICTED VALUES CALCULATED BY USING PREVIOUSLY PUBLISHED EQUATIONS

Variable & Equations	COPD Patients with FEV_1<50%pred. (N=11)	COPD Patients with FEV_1>50%pred. (N=20)	Control Subjects (N=13)
This study results: Body density	1.0508±0.0026	1.0526±0.0028	1.0408±0.0031
%BFM calculated with Siri's equation	21.1±1.5	20.3±1.3	25.7±1.4
Body density = 1.1582 – [0.0771 x Log (suprailiac + subscapular skinfolds)] %FM calculated with Siri's equation	1.0485±0.0034 22.2±1.4	1.0489±0.0029 22.0±1.3	1.0459±0.0031 23.4±1.4
Body density = 1.079538 – [0.001110 x (abdominal + suprailiac skinfolds)] %FM calculated with Siri's equation	1.0451±0.0020 23.7±0.9	1.0455±0.0028 23.5±1.3	1.0438±0.0025 25.0±1.0
%FM=(1.20xBMI)+(0.23xage) – (10.8xgender) – 5.4	27.2±1.2	29.1±1.2	33.3±1.0
%FM=(1.29xBMI)+(0.20xage) – (11.4xgender) – 8.0	24.2±1.3	26.5±1.2	30.9±1.0
%FM=(1.46xBMI)+(0.14xage) – (11.6xgender) – 10	22.4±1.6	25.4±1.3	30.3±1.1
%FM=(0.567xWC)+(0.101xage) – 31.8	25.2±2.5	28.9±1.5	33.5±1.2

COPD – Chronic Obstructive Pulmonary Disease, FEV_1 – forced expiratory volume in 1 second, BFM – body fat mass, FM – fat mass, BMI – body mass index, WC – waist circumfarence

dicted %BFM values may determined higher as in shown in this work. In addition, waist circumference based prediction equations may not reflect the exact body fat mass in the body. However, all these equations may help to follow up the the severity of disorders in patients with COPD.

Chen et al. (2007) reported that WC is significantly associated with FVC and FEV_1 in normal weight, overweight and obese subjects[11]. However, low body weight is positively associated with low WC. Our study showed that WC data are significantly reduced in severe & very severe stage of COPD patients compared to control subjects because our patients have low body weight and BMI.

The main cause of weight loss in COPD is the loss of skeletal muscle mass, indicating depletion of FFM. Also loss of fat mass contributes to the weight loss in a small amount. The body composition changes in patient with COPD can occur without clinically significant weight loss[8–10]. Furthermore, reduction of fat stores and wasting of muscle mass were observed in tuberculosis patients[23]. Moreover, FFM progressively decreases in elderly, particularly in men likewise COPD patients[24]. Therefore, measuring of FFM becomes important in not only COPD but also restrictive pulmonary disorders patients.

Ischaki et al. (2007) reported that FFMI values reflected the GOLD staging of COPD, presenting the highest values in stage 0 where no or minimal airflow limitation and obstruction exists[25]. Vestbo et al. (2006) suggested that low FFMI is significantly correlated with severity of COPD[10]. In our work, FFMI values in COPD patients with FEV1<%50 pred were lower than FFMI values of other COPD and control patients.

The reliability of anthropometric measurements basically depends on standardizing the site of measurements which were already standardized in the Anthropometric Standardization Reference Manual and trained investigator who were either a medical personal or an anthropometrist[3]. Therefore trained investigators were used in our study.

Some methodological limitations of our study should be discussed. The sample size was smaller and stable COPD outpatients were accepted in this study. Therefore our study should be viewed as a pilot investigation to use anthropometry to evaluate COPD patients. It will be important in future studies that the study population should represent all the GOLD stages of COPD.

Anthropometric equations easily and cost effectively applied for prediction of body composition of elderly male patients with COPD. In addition, the FFMI can be possibly used for expressing COPD severity.

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ANTROPOMETRIJSKE METODE U EVALUACIJI KRONIČNE OPSTRUKTIVNE BOLESTI PLUĆA

S A Ž E T A K

Kronična opstruktivna bolest pluća (COPD) uglavnom je izražena mršavljenjem, posebice trošenjem nemasnog tkiva (FFM), i niska tjelesna težina korelira s povećanom smrtnosti i lošom prognozom. Istražili smo mogu li se antropometrijske jednadžbe sastava tijela koristiti za procjenu sastava tijela u KOPB. Na trideset klinički stabilnih bolesnika s KOPB i 13 zdravih iste dobi u kontrolnoj skupini mjereni su kožni nabori i opsezi te su izračunati indeksi tjelesne mase (BMI). Masa tjelesne masnoće (BFM) i FFM određeni su pomoću antropometrijskih jednadžbi. Postotak BFM, predviđen iz gustoće tijela ili pomoću Siri-a ili Brozek jednadžbe, utvrđen je niži od onog koji je izračunat jednadžbom pomoću BMI, dobi i spola. Vrijednosti BFM i tjelesne težine su manje kod pacijenata s FEV1 <50% u odnosu na druge ispitanike. Vrijednosti FFM također su se smanjile, ovisno o ozbiljnosti KOPB. BMI se statistički ne razlikuju među ispitanicima, a FFM indeks (FFMI) odražava status uhranjenosti. Antropometrijske jednadžbe jednostavno i jeftino se primijenjuju za predviđanje %BFM, FFM, i FFMI u bolesnika s KOPB. Osim toga, može se eventualno FFMI koristiti za izražavanje ozbiljnosti COPD.