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Body composition in patients with chronic obstructive pulmonary disease: which method to use in clinical practice?

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The objective of the present study was to compare anthropometry with bioelectrical impedance (BIA) in relation to densitometry (dual-energy X-ray absorptiometry; DEXA) as methods of nutritional assessment and body composition in out-patients with chronic pulmonary obstructive disease (COPD). We conducted a cross-sectional clinical study with sixty-one patients with COPD (forty-two men and nineteen women), mean age of 66·5 (SD 7·9) years and forced expiratory volume in 1 s of 1·3 (SD 0·6) litres (52·2 (SD 19·8) % predicted), referred to the Pulmonary Rehabilitation Center. The patients were evaluated regarding nutrition status and body composition as determined by anthropometry, BIA and DEXA. In the results, 34·4 % showed mild obstruction, 31·2 %, moderate and 34·4 %, severe obstruction. According to the BMI (mean 24·5 (SD 4·5) kg/m^2), 45·9 % of the patients exhibited normal weight, while 27·9 % were underweight and 26·2 % were obese. Related to fat-free mass (FFM), anthropometry and BIA compared with DEXA presented high correlations (r 0·96 and 0·95 respectively; $P<0·001$) and high reliability between the methods (α 0·98; $P<0·001$). Agreement analysis between the methods shows that anthropometry overestimates (0·62 (SD of the difference 2·89) kg) while BIA underestimates FFM (0·61 (SD of the difference 2·82) kg) compared with DEXA. We concluded that according to the nutritional diagnosis, half of our population of patients with COPD showed normal weight, while the other half comprised equal parts obese and underweight patients. Body composition estimated by BIA and anthropometry presented good reliability and correlation with DEXA; the three methods presented satisfactory clinical accuracy despite the great disparity of the limits of agreement.

Chronic pulmonary obstructive disease: Nutritional assessment: Anthropometry: Electrical bioimpedance: Dual-energy X-ray absorptiometry

Patients with severe chronic pulmonary obstructive disease (COPD) present with weight loss due principally to muscle-mass depletion (Wouters & Schols, 1993). Independent of the severity of the bronchial obstruction, weight loss and low body weight correlate with increased morbidity, a poor prognosis, and may have far-reaching consequences (Engelen *et al.* 1994). Factors possibly contributing to the weight loss include imbalance between energy intake and expenditure, ageing, drug therapy, inactivity, systemic inflammation and hypoxia (Donahoe, 1997; Kyle *et al.* 1998). Insufficient energy intake may be justified by precocious satiety, anorexia, dyspnoea and fatigue, symptoms that are commonly observed in these patients. Additionally, an associated increase in basal metabolism may occur (Wouters & Schols, 1993; Donahoe, 1997; Wouters, 2000). The respiratory muscles may also be affected by the weight loss, lessening force generation while the respiratory work is simultaneously increased due to pulmonary hyperinflation. Both of these situations reduce the capacity of respiratory muscles to adapt themselves to the increase in ventilatory load (Serres *et al.* 1998). The existing hypoxaemia in COPD patients may contribute to the exercise limitation and fatigue of the peripheral and respiratory muscles (Jardim *et al.* 1981; Gosker *et al.* 2000). Additionally, ageing typically produces physiological alterations in body composition (Schols *et al.* 1991*b*; Gosker *et al.* 2000). An increasing amount of evidence is indicating that TNF-α may also contribute to muscle loss and atrophy, mediating an increase in energy expenditure, mobilising amino acids and leading to protein catabolism (Schols & Wouters, 2000; Paiva *et al.* 2000).

Monitoring weight loss and possible depletion, showing particular concern for fat-free mass (FFM) depletion, is essential for the assessment of nutritional status of COPD patients. Recent technological progress has made possible the estimation of body composition by different techniques, from the simplest and cheapest ones (skinfold anthropometry, bioelectrical impedance (BIA)) to the most expensive and sophisticated ones (computed tomography, magnetic resonance, ^{2}H dilution, whole-body counting). The choice of method depends not only on the type of study and the number of compartments to be studied, but also on its applicability in clinical practice (van Loan, 1998).

Abbreviations: BIA, bioelectrical impedance; COPD, chronic pulmonary obstructive disease; DEXA, dual-energy X-ray absorptiometry; FEV_1, forced expiratory volume in 1 s; FFM, fat-free mass; FFMI, FFM index; FM, fat mass; FVC, forced vital capacity.

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The purpose of the present study was to analyse skinfold anthropometry and BIA, in relation to dual-energy X-ray absorptiometry (DEXA), as methods for assessing nutritional and body composition with emphasis on FFM in out-patients with COPD.

Subjects and methods

The present study analysed sixty-one out-patients with COPD (forty-two men and nineteen women) referred to the Out-patient COPD Clinics of the Respiratory Division of Universidade Federal de São Paulo. Four patients, all diabetics, dropped out of the study. All patients presented with stable cardiac and pulmonary conditions at the time of assessment. Patients with other degenerative chronic or metabolic diseases, recent surgeries, or who had already participated in a pulmonary rehabilitation programme were excluded from the study. Those on long-term domiciliary O_2 therapy were not excluded. All participants in the study signed an informed consent form according to the research protocol approved by the Ethics Committee of the Brazilian Ministry of Health (Consenso Nacional de Saúde, 1996).

Measurements were performed on 3 consecutive days; anthropometry was performed on day 1, BIA on day 2 and DEXA on day 3. Patients fasted between 07.00 and 10.00 hours and all anthropometric measurements and BIA assessments were performed by an expert in the field (M. C. L.) (Neder *et al.* 1999*a*,*b*, 2001).

Anthropometry

Anthropometric assessment consisted of determination of weight (kg) and height (m), using an anthropometric scale while the patients were dressed in light clothes and without shoes. BMI was calculated as weight/height^2 (kg/m^2). Patients $<22{\cdot}0$ kg/m^2 were considered underweight; from 22·0 to 27·0 kg/m^2 normal weight; and $>27{\cdot}0$ kg/m^2 obese, according to the American Academy of Family Physicians, American Dietetic Association and National Council on the Aging (Harmon-Weiss, 1999). Biceps, triceps, subscapular and supra-iliac skinfold measurements were performed in triplicate on the right side of the body using the Lange skinfold caliper and following the procedures established by Lohman *et al.* (1988). Percentage FFM was derived from the sum of triceps, biceps, supra-iliac crest and subscapular skinfold thicknesses using the sex- and age-specific regression equations of Durnin & Womersley (1974).

Bioelectrical impedance

BIA was performed using a tetrapolar RJL Systems Quantum II (RJL Systems, Clinton Twp, MI, USA) with the emission of a low electrical current (500 to 800 μA and 50 kHz). The patient was studied in the supine position, without shoes and stockings. The patient's upper and lower limbs were arranged at an angle of approximately 30° from the midline. Electrodes were connected to the hands (wrist and middle finger) and feet (ankle and above the knuckle of the toe), after the areas were cleaned with alcohol. The patient's right side was standardised for the test. The instructions for use of the equipment were obtained from the manufacturer (RJL Systems). Body composition was calculated according to the equation developed by Schols *et al.* (1991*a*,*b*) and validated for COPD patients.

Dual-energy X-ray absorptiometry

DEXA was performed by the scanning technique (QDR-4500A, Hologic Inc., Bedford, MA, USA), which is based upon the principle that attenuation is suffered by ionising radiation (X-rays) upon passing through different body tissues. The X-ray source releases a beam with two different energies (80 and 140 kVp) that undergo different attenuation while passing through body tissues, allowing the separation between mineralised tissue (bone), fat and FFM.

FFM index (FFMI) was obtained by dividing FFM (kg) by body height^2 (m^2). FFM depletion is indicated by the cut-off points proposed by Mostert *et al.* (2000); FFMI $\leq 16{\cdot}0$ kg/m^2 for men and $\leq 15{\cdot}0$ kg/m^2 for women.

Pulmonary function tests

Spirometry was performed before and after 15 min of inhalation of 400 μg salbutamol (MGC-CPX Medical Graphics Corp., St Paul, MN, USA) connected to a Fleish no. 3 pneumotachograph. The technique followed the recommendations of the American Thoracic Society (Anonymous, 1995). Forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1) and the FEV_1:FVC ratio were obtained, both in absolute values and as a percentage of predicted values. The COPD diagnosis was determined when the FEV_1:FVC ratio was under 0·70; bronchial obstruction was based on predicted FEV_1, ≥ 60 % for mild obstruction, 40 to 60 % for moderate obstruction and <40 % for severe obstruction (Anonymous, 1995). Arterial blood gases were determined by withdrawing approximately 5 ml blood from the radial artery with a heparinised syringe and using a Radiometer 330 for the measurements. Partial pressure of arterial O_2 values below 55 mmHg were considered hypoxaemia (Douglas *et al.* 1979) while hypercapnia was considered when partial pressure of arterial CO_2 values were above 45 mmHg (Rochester, 1993).

Statistical analysis

Patient characteristics (Table 1) are expressed as means and SD. A χ^2 test was used to analyse the different degrees of bronchial obstruction with different nutritional status. A Mann–Whitney test was used to analyse body composition variables in relation to sex, bronchial obstruction and nutritional status. Cronbach's α coefficient measured the internal consistency and reliability between variables of the different methods of body composition. Bland–Altman analysis was calculated to assess the agreement of two methods of body composition and reported as mean values and 2 SD. The sensitivity and specificity of BIA and anthropometry relative to DEXA for identifying nutritionally depleted patients were also calculated. Significance was accepted at $P<0{\cdot}05$.

Results

Table 1 shows the characteristics of the sixty-one patients (68·9 % men and 31·1 % women). There was no statistically

Table 1. Characteristics of the studied group
(Mean values and standard deviations)

Characteristics	Total (*n* 61) Mean	SD	Male (*n* 42) Mean	SD	Female (*n* 19) Mean	SD
Age (years)	66·5	7·9	66·4	8·1	66·8	7·6
Weight (kg)	64·0	15·2	69·1	13·8	52·6*	1·8
Height (cm)	160·9	9·1	165·2	7·1	151·4*	4·8
BMI (kg/m^2)	24·5	4·5	25·2	4·2	22·8	4·7
FEV_1 (post) (litres)	1·3	0·6	1·5	0·7	1·0*	0·3
FEV_1 (post) (%)†	52·2	19·8	51·9	20·5	52·9	18·5
FEV_1:FVC (%)	44·9	11·8	43·9	11·8	47·1	11·6
PaO_2 (mmHg)	66·5	11·8	68·2	12·7	62·8	8·9
$PaCO_2$ (mmHg)	40·8	5·5	40·6	5·7	41·4	5·2

FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; PaO_2, arterial gas O_2 tension; $PaCO_2$, arterial gas CO_2 tension.
* Mean value was significantly different from that of the men ($P<0·0001$).
† Post-400 μg salbutamol inhalation.

significant difference between the mean ages of the two sexes. The BMI mean value for the group was considered to be normal, 24·5 (SD 4·5) kg/m^2, ranging from 13·7 to 34·5 kg/m^2. Of the patients, 49 % were eutrophic, 27·9 % were underweight and 26·2 % were obese. Concerning the bronchial obstruction, the group was moderately obstructed, with 34·4 % being classified as mild, 31·2 % as moderate and 34·4 % as severe. Individual analysis showed that 19·7 % of the patients were hypoxaemic and 24·6 % were hypercapnic.

Body composition obtained by anthropometry showed significantly higher values of FFM (kg and %) and FFMI (kg/m^2) in male than in female patients ($P<0·001$), as would be expected (Table 2). Relative values of fat mass (%) were significantly higher in women than in men ($P<0·001$). The same profile was observed when body composition was analysed by BIA and DEXA. Nutritional status related to the different degrees of bronchial obstruction is shown in Fig. 1.

The limits of agreement between FFM obtained by anthropometry and BIA, as compared with DEXA, are shown in Figs. 2 and 3. For the group as a whole, anthropometry overestimates FFM in comparison to DEXA (FFM anthropometry – DEXA) by 0·62 kg with limits of agreement between −5·05 and 6·28 kg. In contrast, BIA underestimates FFM compared with DEXA (FFM BIA – DEXA) by 0·61 kg, with limits of agreement between 4·90 and −6·15 kg. The percentage of patients with muscle depletion (FFMI) according to BMI analysed by different methods can be observed in Fig. 4.

The three methods were well correlated and showed good reliability for all variables of body composition, with α values ranging from 0·86 to 0·98 ($P<0·001$). The same pattern was observed regarding the correlation between FFM (kg) anthropometry *v.* BIA (*r* 0·94; $P<0·001$), anthropometry *v.* DEXA (*r* 0·96; $P<0·001$) and DEXA *v.* BIA (*r* 0·95; $P<0·001$). Anthropometry and BIA presented 92 and 87 % sensitivity and 97·8 and 91·3 % specificity respectively, to detect nutritional depletion using DEXA as the reference method.

Discussion

It is very common for COPD to be associated with a variety of nutritional and metabolic abnormalities, including protein–energy undernutrition. It is also common for patients with end-stage lung disease, including bronchitis and emphysema, to show intense changes in their body composition (Wouters & Schols, 1993). It is reported that 20 % of COPD out-patients and 35 % of COPD patients referred for pulmonary rehabilitation present some degree of malnutrition or of being underweight (Schols & Wouters, 2000). The present results are similar to those observed in the above-mentioned studies; approximately 50 % of the group exhibited weights within the normal range, with approximately 25 % underweight and 25 % obese patients. The largest concentration of underweight patients was observed among those with severe obstruction, which may represent an increased risk of morbidity and mortality (Fig. 1). Schols *et al.* (1993) found malnutrition in 50 % of their patients with chronic hypoxaemia, normal partial pressure of arterial CO_2 and severe bronchial obstruction (FEV_1 <35 %), but only in 25 % of those with moderate intensity of the disease. The nutritional and metabolic abnormalities found in COPD patients may play an important role in impaired performance of their respiratory muscles and in the low quality of life they present, with no relation to the severity

Table 2. Body composition and fat-free mass (FFM) depletion of sixty-one out-patients with chronic pulmonary obstructive disease (COPD) assessed by anthropometry, bioelectrical impedance (BIA) and dual-energy X-ray absorptiometry (DEXA)
(Mean values and standard deviations)

	Anthropometry				BIA				DEXA			
	Male (*n* 42)		Female (*n* 19)		Male (*n* 42)		Female (*n* 19)		Male (*n* 42)		Female (*n* 19)	
Body composition	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FFM (%)	74·3	6·6	67·4*	6·9	71·9	6·9	67·2*	7·8	75·4	6·6	69·0*	8·9
FFM (kg)	50·8	7·3	34·9*	5·8	49·2	7·8	34·6*	15·7	50·0	7·1	34·7*	4·6
FM (%)	25·7	6·6	32·6*	6·9	28·1	6·9	32·8*	7·8	24·6	6·6	31·0*	8·9
FM (kg)	18·4	7·5	17·7	6·6	20·0	7·7	17·9	7·0	17·3	7·3	16·8	7·4
FFMI (kg/m^2)	18·6	2·2	15·2*	2·3	18·0	2·4	15·1*	2·0	18·3	2·0	15·1*	1·5
No. subjects with depletion	6		9		7		10		5		10	
Subjects with depletion (%)	24·6				27·9				24·6			

FM, fat mass; FFM, fat free mass; FFMI, FFM index.
* Mean value was significantly different from that of the men ($P<0·001$).

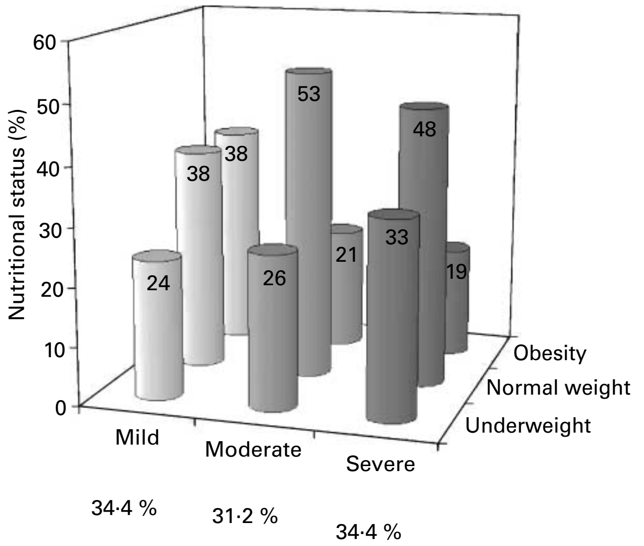

Fig. 1. Distribution of sixty-one out-patients with chronic pulmonary obstructive disease according to severity of obstruction and nutritional assessment.

of the bronchial obstruction. These aspects were observed by Schols *et al.* (1998) after comparing retrospectively 400 obese and overweight patients with normal and low-weight patients ($P < 0.0001$). They detected a clear tendency toward higher mortality in patients with a BMI $< 24\,kg/m^2$. Marquis *et al.* (2002) reached a similar conclusion after following up 142 patients for 5 years; they observed that patients with a mid-thigh muscle cross-sectional area of $< 70\,cm^2$ and $FEV_1 < 50\,\%$ of predicted had a lower chance of survival when compared with patients with a mid-thigh muscle cross-sectional area $\geq 70\,cm^2$ and $FEV_1 \geq 50\,\%$ of predicted. Recently Celli *et al.* (2004) developed a four-variable (including BMI) multi-systemic index (body-mass-index, airflow obstruction, dyspnoea, and exercise capacity index) to predict mortality in COPD patients that once again proves the importance of body composition for COPD patients. In contrast, the occurrence of normal weight in our sample is a positive factor for life prognosis (Fig. 1).

Concerning the cut-off point for undernutrition, as reported by BMI, we decided to utilise the values recommended by the American Academy of Family Physicians, the American Dietetic Association, the National Council on the Aging (Harmon-Weiss, 1999) and Lipschitz (1994), as they are specifically recommended for COPD patients ($22–27\,kg/m^2$). Cut-off points similar to the one we used have been reported in the literature for morbidity and mortality of COPD patients: Mostert *et al.* (2000), $21·0\,kg/m^2$; Vermeeren *et al.* (1997), $21·0\,kg/m^2$; Landbo *et al.* (1999), $20·0\,kg/m^2$ and, more recently, Celli *et al.* (2004), $21·0\,kg/m^2$.

The isolated use of a decreased BMI value or percentage of ideal weight cannot indicate which compartment, FFM or fat mass, is more affected. An excess of fat tissue may preserve the normal weight while the muscle compartment is depleted (Schols, 2002).

Hydrodensitometry is one of the methods considered to be the gold standard in the analysis of body composition. As this method requires the subjects to be submerged in water, it is not comfortable for COPD patients. There are methods considered to be reference standards, such as ^2H dilution, total ^{40}K count, magnetic resonance and others which are not feasible in clinical practice. Generally, they take a long time to be performed, are expensive and require specialised personnel, technological resources and supporting services; they are therefore not applicable in clinical practice.

We chose to analyse anthropometry, BIA and densitometry (DEXA) because of their easy clinical applicability and their validation for COPD patients. Additionally, the first two are particularly cost efficient.

Schols *et al.* (1991b) found a good correlation between FFM obtained by anthropometry and BIA in thirty-two stable patients with COPD (r 0·93; $P < 0·001$), but observed that the FFM values obtained by anthropometry were significantly higher than those of FFM estimated by BIA (4·4 (SD 0·8) kg; $P < 0·0001$). In the present study, the authors validated the use of BIA for body composition evaluation in patients with COPD, using the method of ^2H dilution as reference.

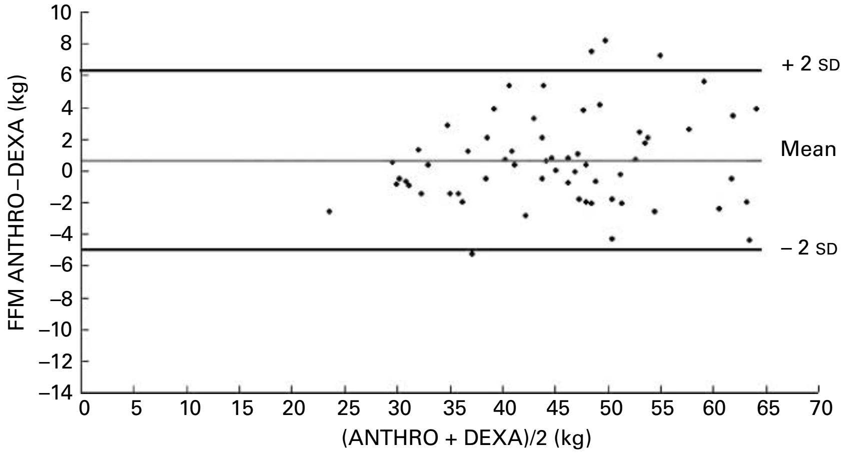

Fig. 2. Limits of agreement between fat-free mass (FFM; kg) body composition assessed by anthropometry (ANTHRO) and dual-energy X-ray absorptiometry (DEXA) of sixty-one out-patients with chronic pulmonary obstructive disease. Mean of differences was 0·62 (95 % CI −0·12, 1·36) kg; SD of the difference was 2·89 kg; lower limit was −5·05 (95 % CI −6·33, −3·76) kg; upper limit was 6·28 (95 % CI 5·00, 7·56) kg.

Studies by Hugli *et al.* (1996) on sixteen patients with COPD and twelve controls also showed a good correlation of FFM in absolute values as analysed by anthropometry and by BIA (control r 0·604, $P<0·05$; COPD r 0·86, $P<0·001$), although the values obtained by anthropometry were significantly lower than those obtained by BIA (4·2 (SD 3·1) kg) in COPD patients ($P<0·001$) and in the control group (5·3 (SD 2·7) kg; $P<0·001$). The equation used in the present study was developed based on anthropometry as a reference method, although it is not considered to be a standard. We also found a good correlation for FFM (kg) analysed by anthropometry and BIA (r 0·94; $P<0·001$). Baarends *et al.* (1997) analysed the water compartment by ^{2}H-labelled water regarding muscle depletion in thirty-eight patients with moderate COPD (FEV_1 40·3 (SD 11·6) % for women and 36·2 (SD 14·7) % for men), and observed that 44·7 % presented muscle depletion (FFMI $\leq 15·0\,kg/m^2$). Through the use of FFMI, we observed that 24·6 % of our patients had muscle depletion when anthropometry was the assessment method of body composition, 27·9 % with BIA and 24·6 % with DEXA; women exhibited more muscle depletion than men in all three methods of analysis (Table 2). Steiner *et al.* (2002) also showed that women present more muscle depletion than men when the three methods are used (FFMI by DEXA, 72 %; FFMI by BIA, 59 %; FFMI by anthropometry, 53 %) and that BIA underestimates FFM while anthropometry overestimates it in relation to DEXA. We also found these relationships in the present study, but saw a better sensitivity of BIA in relation to DEXA. Despite FFMI having gained recognition as a good index for depletion in body composition evaluation of COPD patients (Bareends *et al.* 1997; Mostert *et al.* 2000; Steiner *et al.* 2002), its use is not yet widespread.

Pichard *et al.* (1997) analysed several equations to predict body composition. All the correlation coefficients between BIA formulas and DEXA measurements were highly significant ($r>0·77$; $P<0·001$). However, there were differences in the predictive capacity of each formula. Although they concluded that the equation developed by Schols *et al.* (1991*a*,*b*) could present inaccurate results, in view of the differences of FFM of 5·1 (SD 3·1) kg for women and 3·8 (SD 3·1) kg for men observed in the comparison of BIA and DEXA, it is the only validated equation for COPD patients. The present results are better than those of Schols *et al.* (1991*b*), according to our more narrow range of variation: −0·61 (SD of the difference 2·82) kg for the whole group (Fig. 3); −0·10 (SD of the difference 2·04) kg for women; −0·85 (SD of the difference 3·10) kg for men. Our more favourable results may be attributable to our sample being more homogeneous than that of Schols *et al.* (1991*b*), as they included restrictive patients in their study.

Kyle *et al.* (1998) compared the results obtained from BIA and DEXA in patients with pulmonary diseases and developed a new equation for the calculation of body composition. They observed that the value of the means of the differences for the group in relation to FFM was 0·2 (SD 1·8) kg.

The reliability and correlation analysis of our three methods clearly showed a large degree of similarity. From the means and standard deviations analysis perspective, it can be observed that the use of BIA was advantageous in comparison with anthropometry and DEXA because it presented the lowest value of means of differences, lower standard deviation and lower dispersion value (Bland & Altman, 1986). According to our findings, anthropometry overestimated FFM values, compared with DEXA, while BIA underestimated these values. Although the difference found between the two methods was not large compared with DEXA, the choice of an assessment method for body composition in patients with COPD cannot be based solely on differences of means, but must also take into regard dispersion of values within the 95 % CI, with upper and lower limits. In the present study, we observed that BIA and anthropometry are good choices to assess FFM in patients with COPD.

Anthropometry has been criticised due to its low reproducibility. In the present study, however, it was shown to be as reliable as the other methods. It is the least expensive method, but presents some disadvantages: it requires specialised personnel and is based upon the principle of a constant body-fat fraction. However, localised subcutaneous fat tissue may cause

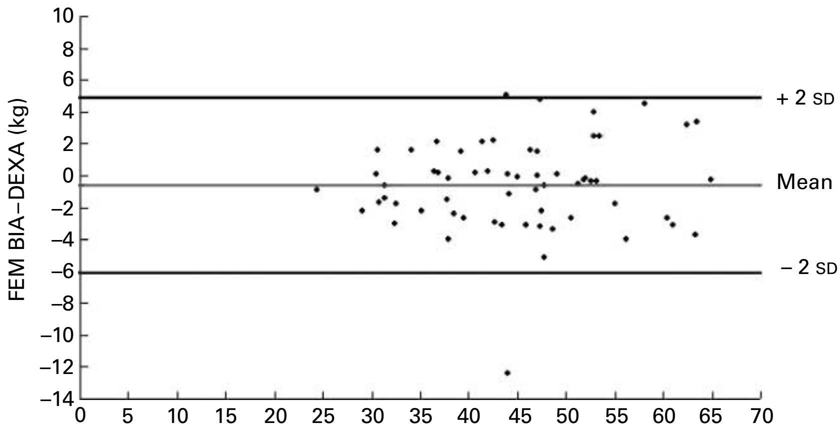

Fig. 3. Limits of agreement between fat-free mass (FFM; kg) body composition assessed by bioelectrical impedance (BIA) and dual-energy X-ray absorptiometry (DEXA) of sixty-one out-patients with chronic pulmonary obstructive disease. Mean of differences was −0·61 (95 % CI −1·34, 0·11) kg; SD of the difference was 2·82 kg; lower limit was −6·13 (95 % CI −7·38, −4·88) kg; upper limit was 4·90 (95 % CI 3·65, 6·15) kg.

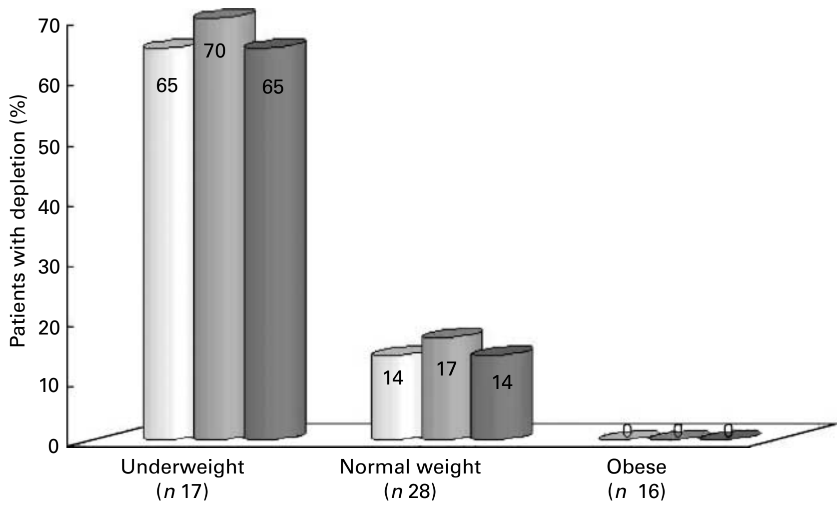

Fig. 4. Percentage of patients with muscle depletion (by fat-free mass index; see p. 90) by three methods according to classification by BMI: anthropometry ( ); bioelectrical impedance ( ); dual-energy X-ray absorptiometry ( ).

underestimation of the whole fat-mass in the elderly, who characteristically present body changes with greater fat centralisation and internalisation (Schols *et al.* 1991*b*). According to Heyward & Stolarczyk (1996), the reproducibility of anthropometry may be altered according to the technician's experience, the type of calliper used for the measurement, the individual characteristics and the equation used for calculation. It is possible that the major source of error in the anthropometry measurements is the variability among those who carry out the assessment, a fact that did not occur in the present study because all measurements were performed by the same researcher (M. C. L.). In addition to high reproducibility, anthropometry showed a high correlation coefficient when compared with DEXA (r 0·96).

BIA, in spite of a higher initial cost than anthropometry, does not depend on experienced technical personnel, is simple, and does not cause discomfort to the patient. It can be performed while the patient is fully clothed, which makes it more convenient for a patient seen at an out-patient clinic. The greatest source of error is the hydration status, because the impedance value is obtained as a function of the resistance of the electric current against water flow. Therefore, in oedematous patients, the results may be masked by the water content. According to Schols *et al.* (1991*b*), the use of diuretics does not interfere with the final result.

Both anthropometry and BIA are methods that allow us to obtain FFM and fat-mass values. DEXA has an advantage because, in addition to those two variables, it also allows the determination of mineral content and its density. In this case, assessments of nutritional status in COPD patients would be enriched by the possibility of knowing their bone density, as many of them present with osteoporosis (Engelen *et al.* 1998). DEXA also has the advantage of evaluating body composition by segments (upper and lower limbs and trunk), making follow-up easier after any intervention. Additionally, it is easy to perform, does not require any special preparation and has recently become recognised as a reference method for assessment of body composition. However, DEXA is the most costly method among the three and not all health services have the equipment. Although DEXA is still not considered a gold-standard method, it has been used as a reference method despite variables that may hinder the results, such as the hydration factor (about 73·2 % water).

The present study has shown the importance of adequate assessment of body composition in patients with COPD. The method used for measurement of body composition is very important, but undoubtedly the criteria for this choice will depend not only on the advantages and disadvantages offered by each one, but also on the patient's limitations, the conditions of the health system and the purpose of the study. Pichard *et al.* (1997) and Steiner *et al.* (2002) suggest that the equations for the evaluation of body composition of COPD patients should be improved and caution should be exercised when using them. We obtained good results with the equation developed by Schols *et al.* (1991*a*). It is possible that ethnic differences among all the populations evaluated may be implicated in the different results found by the different authors.

Conclusions

Analysis of the nutritional status of COPD patients showed that 45·9 % of them were of normal weight, with the obese and malnourished patients being split into equal percentages. More female patients presented as underweight, exhibited more muscle depletion and showed higher fat mass (%) and less FFM (kg) than male patients. Body composition estimated by BIA and anthropometry had clinically satisfactory accuracy despite the great disparity of the limits of agreement. Longitudinal studies may contribute to a better understanding of methodological differences.

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References

Anonymous (1995) Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. American Thoracic Society. *Am J Respir Crit Care Med* **152**, Suppl., 77–120.

Baarends EM, Schols AM, van Marken Lichtenbelt WD & Wouters EF (1997) Analysis of body water compartments in relation to tissue depletion in clinically stable patients with chronic obstructive pulmonary disease. *Am J Clin Nutr* **65**, 88–94.

Bland MJ & Altman GD (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **i**, 307–310.

Celli BR, Cote CG, Marin JM, Casanova C, Oca MM, Mendez RA, Plata VP & Cabral JH (2004) The body-mass-index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. *N Engl Med* **350**, 1005–1012.

Consenso Nacional de Saúde (1996) Resolução CNS 196/96. Normas de pesquisa envolvendo seres humanos (Resolution CNS 196/96. Norms of research involving human beings). *Bioética* **4**, Suppl., 7–27.

Donahoe M (1997) Nutritional support in advanced lung disease. The pulmonary cachexia syndrome. *Clin Chest Med* **18**, 547–561.

Douglas NJ, Calverley PM, Leggett RG, Brash HM, Flenley DC & Brezinova V (1979) Transenient hypoxemia during sleep in chronic bronchitis and emphysema. *Lancet* **i**, 1–4.

Durnin JVGA & Wormersley J (1974) Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr* **32**, 77–97.

Engelen MPKJ, Schols AMWJ, Baken WC, Wesseling GJ & Wouters EFM (1994) Nutritional depletion in relation to respiratory and peripheral skeletal muscle function in out patients with COPD. *Eur Respir J* **7**, 1793–1797.

Engelen MPKJ, Schols AMWJ, Heidendal GAK & Wouters EFM (1998) Dual-energy X-ray absorptiometry in the clinical evaluation of body composition and bone mineral density in patients with chronic obstructive pulmonary disease. *Am J Clin Nutr* **68**, 1298–1303.

Gosker HR, Wouters EFM, van de Vusse GJ & Schols AMWJ (2000) Skeletal muscle dysfunction in chronic failure: underlying mechanisms and therapy perspectives. *Am J Clin Nutr* **71**, 1033–1047.

Harmon-Weiss, S (1999) Nutritional strategies efficacious in the prevention or treatment of chronic obstructive pulmonary disease. In *The Role of Nutrition in Chronic Disease Care*. *Nutrition Screening Initiative Project*. American Academy of Family Physicians, pp 22–31, Washington, DC.

Heyward VH & Stolarczyk LM (1996) *Applied Body Composition Assessment*. Champaign, IL: Human Kinetics Publishers.

Hugli O, Schutz Y & Fitting J-W (1996) The daily energy expenditure in stable chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **153**, 294–300.

Jardim JR, Farkas G, Prefaut C, Thomas D, Macklem PT & Roussos C (1981) The failing inspiratory muscles under normoxic and hypoxic conditions. *Am Rev Respir Dis* **124**, 274–279.

Kyle UG, Pichard C, Rochat T, Slosman DO, Fitting WJ & Thiebaud D (1998) New bioelectrical impedance formula for patients with respiratory insufficiency: comparison to dual-energy X-ray absorptiometry. *Eur Respir J* **12**, 960–966.

Landbo C, Prescott E, Lange P, Vestbo J & Almdal PT (1999) Prognostic value of nutritional status in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **160**, 1856–1861.

Lipschitz DA (1994) Screening for nutritional status in the elderly. *Primary Care* **21**, 55–67.

Lohman TG, Roche AF & Martorell R (1988) *Anthropometric Standardization – Reference Manual*. Champaign, IL: Human Kinetics Publishers.

Marquis K, Debigaré R, Lacasse Y, LeBlanc P, Jobin J, Carrier G & Maltais F (2002) Midthigh muscle cross-sectional area is a better predictor of mortality than body mass index in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **166**, 809–813.

Mostert R, Goris A, Weling-Scheepers C, Wouters EFM & Schols AMWJ (2000) Tissue depletion and health related quality of life in patients with chronic obstructive pulmonary disease. *Respir Med* **94**, 859–867.

Neder JA, Andreoni S, Lerario MC & Nery LE (1999*a*) Reference values for lung function test. II Maximal respiratory pressures and voluntary ventilation. *Braz J Med Biol Res* **32**, 719–727.

Neder JA, Lerario MC, Castro ML, Sachs A & Nery LE (2001) Peak VO2 correction for fat-free mass estimated by anthropometry and DEXA. *Med Sci Sports Exerc* **33**, 1968–1975.

Neder JA, Nery LE, Castelo A, Lerario MC, Sachs A, Silva AC & Whipp BJ (1999*b*) Prediction of metabolic and cardiopulmonary responses to maximum cycle ergometry: a randomised study. *Eur Respir J* **14**, 1304–1313.

Paiva SAR, Campana AO & Godoy I (2000) Nutrition support for the patient with chronic obstructive pulmonary disease. *Nutr Clin Care* **3**, 44–50.

Pichard C, Kyle GU, Janssens JP, *et al.* (1997) Body composition by X-ray absorptiometry and bioelectrical impedance in chronic respiratory insufficiency patients. *Nutrition* **13**, 952–958.

Rochester DF (1993) Respiratory muscles and ventilatory failure: 1993 perspective. *Am J Med Sci* **305**, 394–402.

Schols AMWJ (2002) Pulmonary cachexia. *Int J Cardiol* **85**, 101–110.

Schols AMWJ, Slangen J, Volovics L & Wouters EFM (1998) Weight loss is a reversible factor in the prognosis of chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* **157**, 1791–1797.

Schols AMWJ, Soeters PB, Dingemans AMC, Mostert R, Frantzen PJ & Wouters EFM (1993) Prevalence and characteristics of nutritional depletion in patients with stable COPD eligible for pulmonary rehabilitation. *Am Rev Respir Dis* **147**, 1151–1156.

Schols AMWJ, Soeters PB, Mostert R, Saris WHM & Wouters EFM (1991*a*) Energy balance in patients with chronic obstructive pulmonary disease. *Am Rev Respir Dis* **143**, 1248–1252.

Schols AMWJ & Wouters EFM (2000) Nutritional abnormalities and supplementation in chronic obstructive pulmonary disease. *Clin Chest Med* **21**, 753–762.

Schols AMWJ, Wouters EFM, Soeters PB & Westertep KR (1991*b*) Body composition by bioelectrical-impedance analysis compared with deuterium dilution and skinfold anthropometry in patients with chronic obstructive pulmonary disease. *Am J Clin Nutr* **53**, 421–424.

Serres I, Hayot M, Préfaut C & Mercier J (1998) Skeletal muscle abnormalities in patients with COPD: contribution to exercise intolerance. *Med Sci Sports Exerc* **7**, 1019–1027.

Steiner MC, Barton RL, Singh SJ & Morgan MDL (2002) Bedside methods versus dual energy X-ray absorptiometry for body composition measurement in COPD. *Eur Respir J* **19**, 626–631.

van Loan MD (1998) Is dual-energy X-ray absorptiometry ready for prime time in the clinical evaluation of body composition? *Am J Clin Nutr* **68**, 1155–1156.

Vermeeren MAP, Schols AMWJ & Wouters EFM (1997) Effects of an acute exacerbation on nutritional metabolic profile of patients with COPD. *Eur Respir J* **10**, 2264–2269.

Wouters EFM (2000) Nutrition and metabolism. *Chest* **117**, Suppl., S274–S280.

Wouters EFM & Schols AMWJ (1993) Prevalence and pathophysiology of nutritional depletion in chronic obstructive pulmonary disease. *Respir Med* **87**, Suppl. B, S45–S47.