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Obesity and Physical Activity in the Daily Life of Patients with COPD

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Abstract

Background The aim of this study was to investigate the differences in body composition between physically active and inactive patients with chronic obstructive pulmonary disease (COPD) and the relationship of obesity [according to body mass index (BMI) and percentage of fat mass (%FM)] with physical activity in the daily life (PADL) in this population.

Methods Body composition (bioelectrical impedance analysis) and level of PADL (activity monitors DynaPort and SenseWear) were evaluated in 74 patients with COPD (45 men, 65 ± 9 years old, $FEV_1 = 40 \pm 15$%pred, BMI $= 27 \pm 6$ kg m^{-2}). Patients were divided in two groups: physically active (>30 min/day of physical activity of at least moderate intensity, or TPA > moderate) and inactive (did not achieve these recommendations). The sample was also classified according to BMI (underweight, normal weight, overweight, and obese) and their %FM (moderate obesity, high obesity, and morbid obesity).

Results In the whole group, TPA > moderate correlated weakly with BMI ($r = -0.28$; $p = 0.02$) and FM ($r = -0.30$; $p = 0.001$) but not with fat-free mass (FFM) ($r = -0.18$; $p = 0.13$). Physically inactive patients had higher body weight ($p = 0.002$), FM ($p = 0.0005$), and lower FFM as % of body weight ($p = 0.03$) than active patients. Obese patients (according to BMI) had a worse PADL level than underweight and normal-weight patients ($p < 0.0001$). A poorer PADL level occurred in morbidly obese patients ($p = 0.01$) despite the weak correlation between FM and TPA > moderate in the whole group.

Conclusion Physically active patients with COPD have proportionally more FFM and less FM than inactive patients. More pronounced physical inactivity occurs in obese patients, although body composition does not qualify as an important correlate factor of the level of PADL in patients with COPD.

Keywords Chronic obstructive pulmonary disease · Obesity · Body mass index · Body composition · Exercise · Physical activity

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Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by airflow limitation, dyspnea, and reduction in exercise capacity, muscle strength, and quality of life [1]. Patients with COPD are frequently characterized by abnormalities in their body composition such as weight loss and fat-free mass depletion, and it is known that reduced body mass index (BMI) and fat-free mass index (FFMI) are independent predictors of mortality in these patients [2–5].

However, recent studies indicate that obesity has become increasingly common in patients with COPD [6–8]. Physical activity in daily life (PADL) is also often reduced in patients with COPD [9, 10] and as described for the alterations in body composition, reduction in PADL is a modifiable risk factor for morbidity and mortality [11, 12]. Public health guidelines regarding physical activity published by the American College of Sports Medicine (ACSM) recommend that a minimum of 30 min of physical activity of moderate intensity (e.g., walking) is necessary for the maintenance or development of physical fitness [13].

In the general population, it is known that physical inactivity is strongly related to obesity [14]. However, this is not necessarily the same in patients with COPD due to the obesity paradox. Despite obesity being characterized by an increased ventilatory demand and work of breathing, respiratory muscle inefficiency, reduced respiratory compliance, and increased dyspnea [15], the literature show that obese patients with COPD have a better prognosis of the disease and less pronounced airway obstruction than patients with normal BMI [2, 4, 8]. Moreover, although previous studies have shown that obese patients with COPD have lower functional exercise capacity [6, 8], other studies found that obese and overweight patients with COPD have higher peak VO_2 and similar or reduced perception of dyspnea (due to reduced rest and dynamic hyperinflation) than their lean counterparts [16, 17]. Explanation for these apparently contradictory findings may be linked to the different characteristics of exercise assessment (walking versus cycling and submaximal versus maximal), among other factors. Therefore, taking into account the complex interaction between these conditions (obesity, exercise, and COPD), the relationship between obesity and PADL in these patients is unclear. New knowledge in this matter is relevant since obesity and physical inactivity are global phenomena, both associated with a worse prognosis in COPD.

Therefore, the present study had as its primary aim to determine if there are differences in body composition between active and inactive patients with COPD (according to the ACSM recommendations). It also aimed to verify whether obese patients have a lower level of PADL and worse functional exercise capacity than underweight, normal weight, and overweight patients and to investigate if there are differences in functional exercise capacity and PADL between levels of obesity, according to the percentage of fat mass.

Methods

Sample and Inclusion and Exclusion Criteria

Seventy-four patients with COPD (45 men, 65 ± 9 years old, $FEV_1 = 40 \pm 15$%pred, $BMI = 27 \pm 6$ kg m^{-2}) were included in this cross-sectional study. Patients were enrolled at the Pulmonary Outpatient Clinic of a university hospital (State University of Londrina, Brazil). Diagnosis of COPD was based on the Global Initiative for Chronic Obstructive Lung Disease criteria [1]. As inclusion criteria, patients had to be in stable condition (no exacerbations in the last 3 months that required a change in medication or hospital admission), had not participated in any exercise training program in the last year before admission to the study, and did not have other pathological conditions that could impair their performance, such as cerebrovascular, orthopedic, or rheumatic disease. Exclusion criteria were the occurrence of severe acute exacerbation requiring hospitalization during the assessment period and the inability to understand or cooperate with the assessment methods. The ethics committee of Londrina University Hospital approved the research protocol and a signed consent form was obtained from each patient.

Assessments

Pulmonary function (spirometry) was performed using a Pony Graphics® spirometer (Cosmed, Rome, Italy) according to international recommendations [18]. Reference values used were those of Pereira et al. [19].

Functional exercise capacity was evaluated by the 6-minute walking test (6MWT). Standards used were those recommended by the American Thoracic Society [20]. Two tests were performed (with at least a 30-min interval) and the best distance of the two tests was used. Reference values were those described by Troosters et al. [21].

Body composition analysis was performed by bioelectrical impedance (Biodynamics 310™, Biodynamics Corp., Seattle, WA, USA) (BIA), using the technique described by Lukaski et al. [22]. Reference values used were those described by Kyle et al. [23] specifically for patients with chronic lung disease. BMI was calculated by dividing weight by height squared, and FFMI was calculated by dividing the weight of FFM (obtained by BIA) by height squared.

Assessment of PADL was performed simultaneously by two activity monitors: the accelerometer-based DynaPort Activity Monitor (DAM) (McRoberts BV, The Hague, the Netherlands) and the multisensor SenseWear Armband (SAB) (BodyMedia Inc., Pittsburgh, PA, USA). The DAM consists of a small, lightweight box enclosed in a belt worn around the waist and a leg sensor (total weight = 375 g). The DAM was shown to be as accurate as video recordings (criterion method) in order to assess time spent in different activities by patients with COPD, such as the time spent walking/day (TW) [24]. Technical specifications about the DAM can be found elsewhere [24]. The SAB is a lightweight (80 g) activity monitor worn on the triceps brachial bulk of the right arm. The device estimates energy expenditure based on a biaxial accelerometer and physiologic sensors that detect galvanic skin response, heat flux, and skin temperature in a manufacturer's algorithm. It also provides the duration of activities performed above a determined level of intensity (e.g., time spent per day in activities of at least moderate intensity, or TPA > moderate). The SAB was already validated for the estimate of energy expenditure in patients with COPD [25–28].

The main outcomes of the PADL assessment were TW (from the DynaPort) and TPA > moderate (from the SenseWear). Assessments with both activity monitors were performed over two consecutive weekdays, for 12 h per day (from wake-up time to 12 h after waking). The mean of the two assessment days was used for statistical analysis, and the minimal number of days needed to obtain a reliable assessment of daily physical activity was determined in a previous study [9].

For analysis, patients were first divided into two groups according to the minimum recommended daily physical activity determined by the ACSM [13]: active (performed more than 30 min/day of TPA > moderate) and inactive (did not achieve this recommendation). The threshold of metabolic equivalents (METs) to characterize an activity as at least of moderate intensity was also suggested by the ACSM as between 4.0 and 5.9 METs for subjects 40–64 years old and between 3.2 and 4.7 METs for subjects ≥65 years old [13]. Data obtained from the SAB were reanalyzed for every patient using these customized ACSM thresholds instead of the three METs threshold usually given by the SAB software. Secondarily, the same group was divided according to the BMI classification suggested for patients with COPD by the ATS-ERS Statement of Pulmonary Rehabilitation [29] into underweight [UW] ($BMI < 21\ kg\ m^{-2}$), normal weight [NW] ($21 \leq BMI < 25\ kg\ m^{-2}$), overweight [OW] ($25 \leq BMI < 30\ kg\ m^{-2}$), and obese [OB] ($BMI > 30\ kg\ m^{-2}$). Finally, the group was divided according to the percentage of fat mass (%FM) into nonobese (women [W]: < 25%FM; men [M]: < 15%FM); mild obesity (W: 25 ≤ %FM < 30; M: 15 ≤ %FM < 20); moderate obesity [MO] (W: 30 ≤ %FM < 35; M: 20 ≤ %FM < 25), high obesity [HO] (W: 35 ≤ %FM < 40; M: 25 ≤ %FM < 30) and morbid obesity [MbO] (W: %FM ≥ 40; M: %FM ≥ 30) [30].

Statistical Analysis

Statistical analysis was performed using the SPSS statistical package software ver. 17.0 (SPSS Inc., Chicago, IL, USA) and GraphPad Prism 3.0 (GraphPad Software, San Diego, CA, USA) programs. The Kolmogorov–Smirnov test was used to check for normal distribution. Comparisons between groups were performed using Student's *t*-test or the Mann–Whitney test, and one-way ANOVA or Kruskal–Wallis, followed by a post-hoc test (Bonferroni or Dunns, respectively). Correlations were studied using the Pearson or Spearman coefficient, according to the normality in data distribution. To verify the similarity in gender between the groups, the χ^2 test was used. A significance level of $p \leq 0.05$ was adopted.

Results

Body Composition and Patients' Characteristics (Active vs. Inactive)

According to the ACSM guidelines, 70% of the 74 patients included in the study were classified as physically inactive (52 vs. 22 physically active). Results of the whole group and differences in body composition between physically active and inactive subgroups are given in Table 1. Physically active and inactive patients with COPD had important differences in their body composition. Inactive patients had higher body weight ($p = 0.002$), BMI ($p = 0.001$), and FM ($p = 0.004$). Because of the higher body weight, the inactive group had higher absolute values of FFM ($p = 0.05$). However, when analyzing FFM as % of body weight, the inactive group had significantly lower values ($p = 0.03$).

In the whole group, TPA > moderate correlated weakly and significantly with weight ($r = -0.29$; $p = 0.02$), BMI ($r = -0.28$; $p = 0.02$), and FM ($r = -0.30$; $p = 0.001$), but not with FFM ($r = -0.18$; $p = 0.13$). Correlation between BMI and %FM was $r = 0.47$; $p < 0.0001$. The 6MWT was significantly lower in inactive patients, whereas the active and inactive subgroups did not differ in their airway obstruction (Table 1).

Classification According to BMI

When the whole group was divided according to BMI, 19% of the patients were UW, 23% were NW, 30% were OW, and 28% were OB. Table 2 shows that when comparing the four groups with respect to level of PADL, the OB group had significantly lower TW than the UW group and the NW group, and significantly lower TPA > moderate than the UW group ($p < 0.05$ for all). No differences were found between the OW group and the other three groups (UW, NW, and OB). Despite the differences in PADL between the OB group vs. the UW and NW groups, the groups did not differ significantly in the 6MWT, although there was an average difference of 54 m between the OB group and the UW group and 41 m between the OB group and the NW group.

Table 1 Results from the general group of patients with chronic obstructive pulmonary disease (COPD) and the physically active and inactive subgroups according to American College of Sports Medicine (ACSM) minimum recommendations of daily physical activity

Characteristics	Total ($n = 74$)	Active ($n = 22$)	Inactive ($n = 52$)	p (act vs. inact)
Age (years)	65 ± 9	65 ± 12	65 ± 7	0.90
Gender (M/F)	45/29	15/7	30/22	0.86
Weight (kg)	69 ± 16	61 ± 12	73 ± 16	0.002
Height (cm)	160 ± 9	161 ± 10	160 ± 7	0.82
FEV_1 (%pred)	40 ± 15	44 ± 15	39 ± 14	0.18
BMI (kg m^{-2})	27 ± 6	23 ± 4	28 ± 6	0.001
FFMI (kg m^{-2})	18 ± 3	16 ± 2	18 ± 4	0.009
FFM (kg)	46 ± 11	42 ± 11	47 ± 10	0.05
FM (kg)	23 ± 8	18 ± 6	25 ± 8	0.0005
FFM (%)	67 ± 8	70 ± 8	65 ± 7	0.03
FM (%)	33 ± 8	30 ± 8	35 ± 7	0.03
Metabolic rate (kcal)	1,396 ± 322	1,285 ± 308	1,442 ± 319	0.05
6MWD (m)	428 ± 94	454 ± 113	416 ± 84	0.04
6MWD (%pred)	72 ± 16	74 ± 18	71 ± 15	0.21

Data are expressed as mean ± standard deviation

Subgroup active achieves at least 30 min per day of physical activity of at least moderate intensity, in accordance with the ACSM recommendations. Subgroup inactive does not achieve these minimum recommendations

FEV_1 forced expiratory volume in 1 s, *BMI* body mass index, *FFMI* fat-free mass index, *FFM* fat-free mass, *FM* fat mass, *6MWD* 6-minute walking distance

Table 2 Comparison of patients with chronic obstructive pulmonary disease (COPD) classified according to the body composition based on the body mass index (BMI)

	Underweight ($n = 14$)	Normal weight ($n = 17$)	Overweight ($n = 22$)	Obese ($n = 21$)
Age (years)	65 ± 11	66 ± 11	66 ± 8	65 ± 6
Gender (M/F)	10/4	11/7	14/8	10/11
FEV_1 (%pred)	36 ± 14	35 ± 15	40 ± 14	47 ± 13*
6MWT (m)	460 ± 61	447 ± 95	410 ± 115	406 ± 83
TPA > moderate (min/day)	42 ± 43	31 ± 33	23 ± 36	11 ± 12*
TW (min/day)	73 ± 31	69 ± 34	53 ± 30	46 ± 26*$^{+}$

Data are expressed as mean ± standard deviation

FEV_1 forced expiratory volume in 1 s; *6MWT* 6-minute walking test; *TPA > moderate* time spent per day in physical activities of at least moderate intensity; *TW* time spent walking per day; *Underweight* BMI < 21 kg m^{-2}; *Normal weight* 21 ≤ BMI < 25 kg m^{-2}; *Overweight* 25 ≤ BMI < 30 kg m^{-2}; *Obese* BMI > 30 kg m^{-2}

* $p < 0.05$ versus underweight; $^{+}$ $p < 0.05$ versus normal weight

Classification According to %FM

As for the classification according to the %FM, no subject in the present sample could be classified as nonobese. Three patients had mild obesity and were therefore excluded from subsequent analysis. Table 3 offers a detailed overview of the differences between MO, HO, and MbO in patients with COPD. Concerning PADL, significant differences were found in TW (MbO vs. MO and vs. HO) and TPA > moderate (MO vs. MbO and vs. HO). A poorer 6MWT occurred with morbidly obese patients (Table 3).

Discussion

This study showed that despite physically active and inactive patients with COPD having similar age, level of airway obstruction, and gender proportion, inactive patients have less FFM and more FM (in % of body weight) than their active counterparts. In addition, time spent in activities of at least moderate intensity (as classified by the ACSM) has weak correlation with BMI and absolute values of FM but no correlation with FFM. Almost 30% of the patients were obese according to the

Table 3 Comparison of patients with chronic obstructive pulmonary disease (COPD) classified according to the body composition based on the percentage of fat mass (FM%)

	Moderate obesity ($n = 11$)	High obesity ($n = 30$)	Morbid obesity ($n = 30$)
Age (years)	65 ± 10	62 ± 7	69 ± 8$^+$
Gender (M/F)	7/4	15/15	20/10
FEV_1 (%pred)	35 ± 14	44 ± 14	38 ± 14
6MWT (m)	475 ± 75	445 ± 88	389 ± 98*
TPA > moderate (min/day)	47 ± 45	19 ± 20*	20 ± 26*
TW (min/day)	72 ± 36	62 ± 29	43 ± 27*$^+$

Data are expressed as mean ± standard deviation

FEV_1 forced expiratory volume in 1 s; *6MWT* 6-minute walking test; *TPA > moderate* time spent per day in physical activities of at least moderate intensity; *TW* time spent walking per day; *Moderate obesity* women, $30 \leq$ %FM < 35; men, $20 \leq$ %FM < 25; *High obesity* women, $35 \leq$ %FM < 40; men, $25 \leq$ %FM < 30; *Morbid obesity* women, %FM ≥ 40; men, %FM ≥ 30

* $p < 0.05$ versus moderate obesity; $^+$ $p < 0.05$ versus high obesity

classification based on the BMI. On the other hand, when using percentage of fat mass to classify obesity, 100% of patients were classified as obese, either mildly, moderately, highly, or morbidly. Obese patients had a worse level of daily physical activity than underweight and normal-weight patients. Moreover, higher degrees of obesity (according to %FM) are related to more impaired PADL and worse functional exercise capacity.

It is widely known that patients with COPD have important alterations in body composition and this is an independent predictor of mortality [4]. We now observed that inactive patients with COPD have higher body weight and BMI, and this was mainly caused by higher weight of fat mass. The inactive subgroup had higher absolute values of FFM, but this was due to the fact that these subjects had higher body weight, since FFM as % of body weight was significantly lower in this group. Moreover, although weakly, FM was significantly correlated with the level of PADL, which was not the case regarding FFM. These results suggest that in COPD, obesity is somewhat better linked to physical inactivity than loss of FFM, although none of the two factors appear to be a strong correlate of the level of PADL in this population. This corroborates previous findings by Watz et al. [31], who studied the determinants of objectively measured physical activity in patients with COPD. These authors also concluded that BMI was not a determining factor for PADL level. Other studies also did not find BMI to be a strong correlate of the level of physical activity in daily life in patients with COPD [9, 32, 33].

Obesity is known as an important issue in COPD and BMI is the most used variable to identify obesity in these patients. The literature reports obesity prevalence (according to BMI) in COPD as ranging between 18% [34] and 54% [35]. In the present study, 28% of the patients were obese according to their BMI. Our results showed that obese patients (BMI ≥ 30 kg m^{-2}) are less active than underweight and normal-weight patients with COPD but not in comparison to overweight patients. Similar results were found in a study of older healthy adults in whom obesity but not being overweight was associated with lower levels of physical activity [36].

Although differences in the 6MWT between the groups classified according to BMI did not reach statistical significance, our data showed that obese patients walked an average of 54 m less than underweight patients and 41 m less than normal-weight patients, values that are well above the two values for minimal clinically important difference recently suggested for the 6MWT in the literature (25 and 35 m) [37, 38]. Therefore, despite not reaching statistical significance, a worse functional exercise capacity in obese patients appears to be clinically relevant. The previous literature has shown that higher BMI is associated with lower functional exercise capacity [8, 15, 39] and this is likely the result of the increase in energy expenditure associated with weight-bearing exercise [40]. Furthermore, previous studies showed that the combined mechanical effects of obesity and COPD increase peak oxygen uptake and reduce the dyspnea perception during exercise (cycle ergometry) [16, 17]. These favorable effects caused by obesity are explained by the less pronounced dynamic hyperinflation that is commonly found in obese patients with COPD.

BMI is the most used outcome to classify obesity, although it does not provide clear information about the distribution of FM and FFM. Patients with COPD commonly develop cachexia which is caused by different factors such as increased metabolic rate, hypoxemia, sympathetic upregulation, inactivity, oxidative stress, inflammation, and anabolic hormone insufficiency [41]. This reduction in percentage of FFM leads to a higher proportion of fat mass, even though the patient's weight is not necessarily high. This explains the fact that 100% of the present sample was classified as obese based on the %FM, with 42% classified as morbidly obese. A study by Park et al. [42], which verified the relationship of body composition with PADL in adult women, suggested that the relationship between obesity and daily physical activity should be discussed using not only BMI but also fat mass index or %FM since these two variables were related to the physical activity level, which was corroborated by the present results. Obesity is defined as excessive accumulation of fat mass, and patients with COPD present high %FM despite not having high body weight. In addition, our data showed that more pronounced levels of obesity (i.e., morbid obesity) denote lower levels of PADL and lower exercise capacity in comparison to moderate obesity. Corroborating these results, the study by Park et al. [42] in older women showed that those with more pronounced obesity (according to %FM) had taken fewer steps per day and performed less moderate and vigorous physical activity. We believe that this is not necessarily caused only by changes due to excessive weight but also by a reduction in the percentage of muscle mass.

It was interesting to observe that as with BMI, the correlation between %FM and PADL in our sample of patients with COPD was weak. Studies of other populations already reported that PADL appears to be negatively associated with FM [43, 44]. On the other hand, classification of obesity according to %FM showed that all subjects with COPD in our sample were obese, which might be misinterpreted as an indication that patients with COPD do not present cachexia. In fact, the FFMI value was indicative of depletion in 23 patients (32%) from the present sample (FFMI < 16 kg m^{-2} for men and FFMI < 15 kg m^{-2} for women) [45]. A study by Furutate el al. [46] showed that the prevalence of abdominal obesity in patients with COPD according to visceral fat area was 52.5% in contrast to 38.7% in a matched control group. In addition, they showed that patients with COPD retained visceral fat despite the absence of obesity (i.e., their visceral fat area was significantly greater regardless if they had the same BMI as the control group), and this finding was more evident in more advanced stages of COPD. Therefore, although BMI does not correctly classify obesity, specific cutoff points of %FM for the COPD population are needed since they present specific changes in body composition. Thus, both options (BMI and %FM) present clear limitations when used to reflect body composition in this population as well as their level of physical activity.

Limitations

One may argue that assessment of body composition should ideally be performed with DEXA and not with bioimpedance; use of bioimpedance can be considered a limitation of the present study. However, electrical bioimpedance has been widely and successfully used in this population and has provided useful and reliable information concerning body composition of patients with COPD, especially when a specific formula for these patients is used [23, 47, 48]. Furthermore, although the study had power enough to yield significant differences between the obese and underweight groups concerning the main outcomes, a prospective sample size calculation was not performed and a larger sample could have provided higher power to detect other potentially significant differences in PADL, such as between the obese and normal-weight groups (see Table 2). Moreover, the relatively small sample size of the present study for an investigation of such nature could lead to lack of power in certain secondary variables such as the 6MWT (see Table 2). A larger sample could have yielded more solid results, although this would not interfere directly in the main conclusions of the study.

Clinical Implications and Conclusions

The findings of this study highlight the need for specific interventions for patients with COPD who are classified as obese. Our data showed that according to the ACSM recommendations, patients with higher BMI or %FM present more marked inactivity in daily life, whereas patients with low BMI and %FM are more likely to achieve the recommendations and therefore are better able to maintain or improve their physical fitness. Hence, these results show that although the literature suggests that obesity might be a protecting factor in patients with COPD, special attention must be given to making obese patients a preferential target for interventions aimed at increasing their physical activity in daily life, since obesity in COPD is clearly linked to physical inactivity.

In conclusion, despite the high prevalence of physical inactivity in patients with COPD, those who are active in daily life have proportionally more fat-free mass and less fat mass than inactive patients. Classification of obesity according to body mass index or percentage of fat mass leads to completely different obesity prevalence rates in this population. More pronounced physical inactivity occurs in obese patients, although in general the correlations between body composition and PADL are weak. This suggests that body composition does not qualify as a determining factor of the objectively assessed level of PADL in patients with COPD.

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Conflict of interest The authors have no conflicts of interest to disclose.

References

1. Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P et al (2007) Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med 176:532–555
2. Landbo C, Prescott E, Lange P, Vestbo J, Almdal TP (1999) Prognostic value of nutritional status in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 160:1856–1861
3. Prescott E, Almdal T, Mikkelsen KL, Tofteng CL, Vestbo J, Lange P (2002) Prognostic value of weight change in chronic obstructive pulmonary disease: results from the Copenhagen City Heart Study. Eur Respir J 20:539–544
4. Schols AM, Slangen J, Volovics L, Wouters EF (1998) Weight loss is a reversible factor in the prognosis of chronic obstructive pulmonary disease. Am J Respir Crit Care Med 157:1791–1797
5. Slinde F, Gronberg A, Engstrom CP, Rossander-Hulthen L, Larsson S (2005) Body composition by bioelectrical impedance predicts mortality in chronic obstructive pulmonary disease patients. Respir Med 99:1004–1009
6. Ramachandran K, McCusker C, Connors M, Zuwallack R, Lahiri B (2008) The influence of obesity on pulmonary rehabilitation outcomes in patients with COPD. Chronic Respir Dis 5:205–209
7. Poulain M, Doucet M, Major GC, Drapeau V, Series F, Boulet LP et al (2006) The effect of obesity on chronic respiratory diseases: pathophysiology and therapeutic strategies. CMAJ 174:1293–1299
8. Sava F, Laviolette L, Bernard S, Breton MJ, Bourbeau J, Maltais F (2010) The impact of obesity on walking and cycling performance and response to pulmonary rehabilitation in COPD. BMC Pulm Med 10:55
9. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R (2005) Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 171:972–977
10. Hernandes NA, Teixeira DC, Probst VS, Brunetto AF, Ramos EM, Pitta F (2009) Profile of the level of physical activity in the daily lives of patients with COPD in Brazil. J Bras Pneumol 35:949–956
11. Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Anto JM (2006) Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. Thorax 61:772–778
12. Yohannes AM, Baldwin RC, Connolly M (2002) Mortality predictors in disabling chronic obstructive pulmonary disease in old age. Age Ageing 31:137–140
13. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP, American College of Sports Medicine (2011) American College of Sports Medicine Position Stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 43(7):1334–1359
14. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK (2009) American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. Med Sci Sports Exerc 41:459–471
15. Parameswaran K, Todd DC, Soth M (2006) Altered respiratory physiology in obesity. Can Respir J 13:203–210
16. Laviolette L, Sava F, O'Donnell DE, Webb KA, Hamilton AL, Kesten S et al (2010) Effect of obesity on constant workrate exercise in hyperinflated men with COPD. BMC Pulm Med 10:33
17. Ora J, Laveneziana P, Ofir D, Deesomchok A, Webb KA, O'Donnell DE (2009) Combined effects of obesity and COPD on dyspnea and exercise tolerance. Am J Respir Crit Care Med 180(10):964–971
18. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A et al (2005) Standardisation of spirometry. Eur Respir J 26:319–338
19. Pereira CA, Sato T, Rodrigues SC (2007) New reference values for forced spirometry in white adults in Brazil. J Bras Pneumol 33:397–406
20. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories (2002) ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 166:111–117
21. Troosters T, Gosselink R, Decramer M (1999) Six minute walking distance in healthy elderly subjects. Eur Respir J 14: 270–274
22. Lukaski HC, Bolonchuk WW, Hall CB, Siders WA (1986) Validation of tetrapolar bioelectrical impedance method to assess human body composition. J Appl Physiol 60:1327–1332
23. Kyle UG, Pichard C, Rochat T, Slosman DO, Fitting JW, 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
24. Pitta F, Troosters T, Spruit MA, Decramer M, Gosselink R (2005) Activity monitoring for assessment of physical activities in daily life in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 86:1979–1985
25. Langer D, Pitta F, Troosters T, Burtin C, Decramer M, Gosselink R (2009) Quantifying physical activity in COPD: different measures for different purposes. Thorax 64:458–459
26. Furlanetto KC, Bisca GW, Oldemberg N, Sant'Anna TJ, Morakami FK, Camillo CA et al (2010) Step counting and energy expenditure estimation in patients with chronic obstructive pulmonary disease and healthy elderly: accuracy of 2 motion sensors. Arch Phys Med Rehabil 91:261–267
27. Cavalheri V, Donaria L, Ferreira T, Finatti M, Camillo CA, Cipulo Ramos EM et al (2011) Energy expenditure during daily activities as measured by two motion sensors in patients with COPD. Respir Med 105:922–929
28. Patel SA, Benzo RP, Slivka WA, Sciurba FC (2007) Activity monitoring and energy expenditure in COPD patients: a validation study. COPD 4:107–112
29. Nici L, Donner C, Wouters E, Zuwallack R, Ambrosino N, Bourbeau J et al (2006) American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. Am J Respir Crit Care Med 173:1390–1413
30. Harrison B, Hubbard VS (1994) NIDDK role in obesity research. Obes Res 2:585–586
31. Watz H, Waschki B, Meyer T, Magnussen H (2009) Physical activity in patients with COPD. Eur Respir J 33:262–272
32. Mantoani LC, Hernandes NA, Guimaraes MM, Vitorasso RL, Probst VS, Pitta F (2011) Does the BODE index reflect the level of physical activity in daily life in patients with COPD? Rev Bras Fisioter 15:131–137
33. Garcia-Aymerich J, Felez MA, Escarrabill J, Marrades RM, Morera J, Elosua R et al (2004) Physical activity and its determinants in severe chronic obstructive pulmonary disease. Med Sci Sports Exerc 36:1667–1673
34. Steuten LM, Creutzberg EC, Vrijhoef HJ, Wouters EF (2006) COPD as a multicomponent disease: inventory of dyspnoea,

underweight, obesity and fat free mass depletion in primary care. Prim Care Respir J 15:84–91
35. Eisner MD, Blanc PD, Sidney S, Yelin EH, Lathon PV, Katz PP et al (2007) Body composition and functional limitation in COPD. Respir Res 8:7
36. Riebe D, Blissmer BJ, Greaney ML, Garber CE, Lees FD, Clark PG (2009) The relationship between obesity, physical activity, and physical function in older adults. J Aging Health 21:1159–1178
37. Puhan MA, Mador MJ, Held U, Goldstein R, Guyatt GH, Schunemann HJ (2008) Interpretation of treatment changes in 6-minute walk distance in patients with COPD. Eur Respir J 32:637–643
38. Holland AE, Hill CJ, Rasekaba T, Lee A, Naughton MT, McDonald CF (2010) Updating the minimal important difference for six-minute walk distance in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 91:221–225
39. Swinburn CR, Cooper BG, Mould H, Corris PA, Gibson GJ (1989) Adverse effect of additional weight on exercise against gravity in patients with chronic obstructive airways disease. Thorax 44:716–720
40. Ofir D, Laveneziana P, Webb KA, O'Donnell DE (2007) Ventilatory and perceptual responses to cycle exercise in obese women. J Appl Physiol 102:2217–2226
41. Wagner PD (2008) Possible mechanisms underlying the development of cachexia in COPD. Eur Respir J 31:492–501
42. Park J, Ishikawa-Takata K, Tanaka S, Hikihara Y, Ohkawara K, Watanabe S et al (2011) Relation of body composition to daily physical activity in free-living Japanese adult women. Br J Nutr 106(7):1117–1127
43. Schulz LO, Schoeller DA (1994) A compilation of total daily energy expenditures and body weights in healthy adults. Am J Clin Nutr 60:676–681
44. Yao M, McCrory MA, Ma G, Tucker KL, Gao S, Fuss P et al (2003) Relative influence of diet and physical activity on body composition in urban Chinese adults. Am J Clin Nutr 77:1409–1416
45. Schols AM, Broekhuizen R, Weling-Scheepers CA, Wouters EF (2005) Body composition and mortality in chronic obstructive pulmonary disease. Am J Clin Nutr 82:53–59
46. Furutate R, Ishii T, Wakabayashi R, Motegi T, Yamada K, Gemma A et al (2011) Excessive visceral fat accumulation in advanced chronic obstructive pulmonary disease. Int J Chronic Obstruct Pulmon Dis 6:423–430
47. Rutten EP, Spruit MA, Wouters EF (2010) Critical view on diagnosing muscle wasting by single-frequency bio-electrical impedance in COPD. Respir Med 104:91–98
48. Schols AM, Wouters EF, Soeters PB, Westerterp KR (1991) 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