

PHYSICAL ACTIVITY IN COPD PATIENTS: PATTERNS AND BOUTS

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ABSTRACT

The present study aims to describe the pattern of physical activity and the frequency, duration and intensity of physical activity bouts in patients with chronic obstructive pulmonary disease (COPD), to assess how these patterns differ according to COPD severity, and to explore whether these patients meet the general guidelines for physical activity for older adults.

One hundred seventy-seven patients (94% male, mean(SD) age 71(8) years, and FEV₁ 52(16)%) wore the SenseWear[®] Pro₂ Armband accelerometer for 8 consecutive days. Physical activity bouts were defined as periods of ≥ 10 min above 1.5 METs and classified according to their median intensity.

Patients engaged in activity a median of 86 min/d, and 57% of that time was spent in bouts. Median frequencies of bouts per day were 4 and 3 for all- and moderate-to-vigorous intensities, respectively. With increasing COPD severity, time in physical activity, proportion of time in bouts, and frequency of bouts decreased. Sixty-one percent of patients fulfilled the recommended physical activity guidelines.

In conclusion, COPD patients of all spirometric severity stages engage in physical activity bouts of moderate-to-vigorous intensities. Patients with severe and very severe COPD perform their daily activities in fewer and shorter bouts than those in mild and moderate stages.

Abstract word count: 200

Keywords: Activity Monitor; Epidemiology [MeSH Term]; Motor activity [MeSH Term]; Pulmonary Disease, Chronic Obstructive [MeSH Term]

INTRODUCTION

Among patients with chronic obstructive pulmonary disease (COPD), reduced levels of physical activity have been found to be related to an increased risk of hospital admissions and mortality [1–3]. In addition, research on the physical activity levels of COPD patients has consistently shown that COPD patients have lower physical activity levels than their healthy peers [4,5]. Most of the previous studies have reported accurate measurements of the physical activity level without addressing the pattern of activity. Indeed, physical activity is recognized as a multi-faceted behavior that involves frequency, intensity, time, and type (*FITT principle*) as modifiable components that are specifically used for guiding and testing interventions [6,7]. In alignment with this concept, the recommendation from the American College of Sports Medicine and the American Heart Association advise that older adults “should perform moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic activity for a minimum of 20 min on three days each week” [8]. Importantly, current physical activity guidances explicitly acknowledge that the recommendation should be used in the context of the subject’s needs, goals, and initial abilities; thus, the 30 consecutive minutes of activity could be replaced by two or three bouts of at least 10 min each [9]. This adaptation is especially useful for COPD patients, given their limitations to engage in more activity [10]. Unfortunately, the lack of information on the pattern of physical activity in COPD patients with respect to the bouts of activity may have limited our ability to design interventions with realistic goals for this population [11]. For patients with other diseases, such as arterial hypertension, information on bout frequency, duration, and intensity has enabled the development of recommendations for the primary prevention, treatment, and control of this condition [12]. The present study aims to describe the pattern of physical activity and the frequency, duration and intensity of

physical activity bouts in patients with COPD, to assess how these patterns differ according to COPD severity, and to explore whether these patients meet the general guidelines for physical activity for older adults.

METHODS

Participants

This study is part of the “Phenotype characterization and course of chronic obstructive pulmonary disease (PAC-COPD)” cohort. Patients with a diagnosis of COPD (ratio of the post-bronchodilator forced expiratory volume in the first second to the forced vital capacity (FEV_1/FVC) $<70\%$) [13] were recruited at 9 tertiary hospitals in Spain [14,15] and their spirometric severity was classified according to ATS/ERS criteria [13]. Of the 342 COPD patients included in the PAC-COPD cohort, 177 patients had physical activity data available and were therefore included in the present analysis. There were no differences between these patients and the remaining PAC-COPD patients, as previously reported [16]. The study was approved by the Ethics Committees of all of the participating hospitals, and written informed consent was obtained from all of the subjects.

Variables and instruments of measurement

All study tests were carried out on patients in clinically stable conditions at least three months after the last recorded exacerbation. Physical activity levels, bouts and adherence to recommendation was measured using SenseWear[®] Pro₂ Armband accelerometer (SWA; Body Media, Pittsburgh, PA), that has been proved a valid tool to measure physical activity in COPD patients [17]. The accelerometer was worn during 8 consecutive days, and the

minimal time was defined *a priori* as at least three days recording more than 70% of daily time (from 8:00 am to 22:00 pm) [18]. The consistency of accelerometer data was tested by intra-class correlation coefficient (ICC) of steps per day between all possible combination of three days (ICC=0.95, 95% CI 0.93-0.96). The accelerometer was worn on the right arm and recorded the subjects' movements from lower and upper body. More details on the accelerometer wearing time and recording have been previously published [16]. The accelerometer provided a minute-by-minute report for each subject with values for the number of steps and the Metabolic Equivalent Tasks (METs) that were used to compute the variables of interest.

First, the physical activity was characterized using energy expenditure (METs·min·day⁻¹), time (min·day⁻¹), and intensity (METs) spent in minutes with ≥ 1.5 MET, and steps (steps·day⁻¹). Second, physical activity bouts were defined as any period of at least 10 min with an intensity ≥ 1.5 METs and classified as light, moderate, and vigorous according to their median intensity (METs). The thresholds for moderate and vigorous physical activity were set at 50% and 65% out of the maximum oxygen consumption [19] from an incremental test (mean 16 ml·min⁻¹·kg⁻¹, reported elsewhere) [15] following the most recent recommendations on the best practices for the use of objective methods to assess physical activity in studies for adults with functional limitations [20], and resulted in 2.6, and 3.4 METs [19]. We computed the frequency (bouts·day⁻¹), duration (min·bout⁻¹), intensity (METs), and total time (min·day⁻¹) in bouts. To exemplify the later, Figure 1 shows a minute-by-minute METs report from the accelerometer in a sample day of a COPD patient together with the graphic illustration of six physical activity bouts and their duration and median intensity. The ratio of time in physical activity bouts out of time in physical activity was also obtained. Third, the adherence to the recommendation for older adults was defined as spending ≥ 30 minutes in moderate activity at

least 5 days per week or spending ≥ 20 minutes in vigorous activity at least 3 days per week [8]. For both definitions, we distinguished if the minimum time spent in activity was achieved through consecutive minutes or through the accumulation of bouts.

Self-reported physical activities were obtained with the Spanish version of the Yale Physical Activity Survey [21], as previously validated for our COPD population [16]. This questionnaire collects information (frequency and duration) on a wide range of activities performed in a typical week of the previous month. Other relevant variables included socio-demographic factors, smoking, Charlson co-morbidity index, dyspnea, the St. George Respiratory Questionnaire (SGRQ), lung function measurements (post-bronchodilator FEV₁, FVC, and FEV₁/FVC, residual volume (RV), total lung capacity (TLC), RV/TLC, and arterial oxygen partial pressure (PaO₂)), body mass index (BMI), fat-free mass index (FFMI), and the six-minute walking distance. Details about these procedures have been published previously [14,15].

Statistical analysis

Sample size calculations are available in the *ERJ* Online Depository. The subjects' characteristics and physical activity characteristics are presented as numbers (percentage) for categorical variables and means (SD) or medians (25th-75th percentile) for continuous variables with normal and non-normal distributions, respectively. Physical activity variables were modelled using Poisson regression. Tests for trends across COPD severity stages were obtained by treating the COPD severity stages as a continuous variable. For sensitivity analyses, we repeated all analyses (i) using standard cut-off points for intensity of physical activity (3 METs for moderate and 6 METs for vigorous physical activity [9]), and (ii) excluding subjects with extreme values (>95th percentile) in the number of daily steps

recorded by the accelerometer. All analyses were conducted using R 2.14.1 (2011 The R Foundation for Statistical Computing). The scripts for the calculation of bouts are available in the *ERJ* Online Depository.

RESULTS

Table 1 shows main characteristics of the patients. Patients wore the accelerometer a mean of six days, and recorded a mean of 95% of daily time (13.5 h of 14 h maximum). Almost all COPD patients (98%) participated in physical activity bouts on a daily basis, and 57% of their physical activity was performed in bouts (Table 2). Median number of daily bouts was 4.4 and 2.6 for all intensities and moderate-to-vigorous intensities, respectively. The median duration of the bouts was around 20 minutes, irrespective of their intensity. Overall, our patients exhibited moderate exercise limitation and were reasonably active. Exercise capacity and physical activity were moderately correlated (Spearman $r=0.54$, $p<0.001$) (Figure S1).

Figure 2 shows that the number of steps, time in physical activity, and proportion of time in bouts out of total time in physical activity exhibited a significant, steady decrease with increasing COPD severity, but no differences in intensity were found. The frequency of the bouts, as well as the total time spent in bouts, decreased with increasing COPD severity (Figure 3). Patients with severe-to-very severe COPD reported lower participation and less time spent in some of the leisure time activities (gardening and exercising) compared to mild-to-moderate COPD, while there were no differences in participation and time spent in household activities or recreational activities (Table S1).

Figure 4 shows that at about 25% of the COPD patients fulfilled the recommendation of engaging in ≥ 30 consecutive minutes of moderate physical activity 5 or more days per week. The latter proportion increased to almost 60% when the duration of ≥ 30 min per day was achieved through the accumulation of bouts of at least 10 min duration. Overall, 61% COPD patients fulfilled the physical activity recommendation for older adults. Table 3 shows that the patients who adhered to this recommendation had reported higher time in leisure activity, primarily yard-work/gardening and recreational activities.

All analyses were repeated using standard cut-off points for the definition of moderate and vigorous intensities of physical activity (Tables S2 and S3 and Figures S2 and S3 in the *ERJ* Online Depository). Results about participation, frequency, duration and intensity of bouts were very similar. The proportion of COPD patients fulfilling the physical activity recommendation was reduced from 61% to 50% (Figure S3). Sensitivity analysis excluding subjects with extreme values yielded notably similar results.

DISCUSSION

This report is the first assessing bouts of physical activity in COPD patients. It shows that these subjects are able to perform bouts of moderate-to-vigorous physical activity. The severity of COPD is inversely associated with the frequency of bouts. More than 60% of our COPD patients fulfill the physical activity recommendation for older adults.

Comparison with previous studies

Our results on the patterns of physical activity can be compared with previous research. The COPD patients included in our study walked more (according to steps per day or walking time measures) than COPD patients who participated in previous studies from four different geographic locations [18,22,23]. Our patients were older and had similar airflow limitation and exercise capacity than patients in these former studies. Interestingly, the time spent in activity was similar across studies, suggesting a higher participation, duration or speed during walking activities in our population. In fact, a previous study found that COPD patients walk 25% slower than healthy age-matched controls [23]. Akin to this finding, only 7% of the walking time in our patients was reported as brisk walking, as compared to a 75% in a study with healthy subjects of similar age and geographical location using identical physical activity questionnaire [24]. Another differential trait between previous studies and ours is that the latter studies recruited patients with an established diagnosis of COPD from outpatient clinics, whereas our sample was made up of patients who were recruited after their first COPD admission, one-third of whom under-diagnosed as COPD [14]. Thus, the limiting effects of COPD on activity may be more related to the specific time-point in the course of the disease, rather than to its spirometric severity.

Our results, consistent with previous data that showed that the severity of airflow limitation is related to the level of physical activity [4,5], provide, for the first time, information on the activity pattern that is behind the differences in levels. Our very severe COPD patients spent a lower proportion of their activity time in bouts, at the expenses of reducing bouts frequency (see Figure 2). The lack of differences in bouts duration across severity stages needs to be interpreted with caution; the very severe patients perform bouts which have similar duration than those of patients in other severity stages. However, the lower proportion of time spent in

bouts implies that their physical activity is performed in episodes of less than 10 minutes duration. It is also notorious the lack of differences in intensity of physical activity across severity stages. It has been hypothesized that COPD patients increase the intensity of their daily physical activities as a result of “trying to perform activities as fast as possible so as to alleviate the unease caused by physical activity” [5]. In our study, patients kept doing both household and recreational activities; the former are likely practiced despite disease severity because they are compulsory for daily living, while the latter, and more specifically in the case of leisure walking, because they are perceived as healthy, social or simply pleasant. Altogether our findings suggest that the exercise limitation in COPD primarily affects the way patients distribute their periods of activity over time, towards less and shorter episodes of uninterrupted activity.

The proportion of COPD patients meeting the physical activity recommendation has been reported to be an important subject for COPD research [10] that had not previously been assessed. We approached this subject by using an objective tool for defining bouts in agreement with the definitions of the international physical activity guidelines, which are widely known, disseminated and implemented in Spain. The comparison with findings from other studies [25,26] should consider the current evidence that geographical, cultural, and lifestyle factors affect the practice of physical activity.

Applicability of the results

There is an emerging need for interventions that aim to increase the physical activity level of COPD patients [10,27]. These interventions include, but are not restricted to, pulmonary rehabilitation and/or community health promotion programs and should be considered in addition to the promotion of the light intensity activities frequently performed during daily

life [8]. Our detailed assessment of physical activity patterns provides important insight into the design of such interventions. First, the proportion of patients achieving the recommended physical activity levels is elevated when shorter bouts are grouped together, rather than when definitions are restricted to consecutive minutes. Thus, fulfilling the recommendation with short bouts may be more feasible and not necessarily less effective because several clinical trials have demonstrated similar effects in aerobic fitness, weight loss, and other cardiovascular risk factors with either long-bout (≥ 20 min) or short-bout (≥ 10 min) interventions [28–30]. Interestingly, in our study, patients fulfilling the recommendation also reported more time engaged in recreational activities. Second, it is interesting to note that the way COPD patients seem to adapt to exercise limitation (towards less and shorter periods of activity, as discussed above), matches with the strategy of interval training that is used in pulmonary rehabilitation, specifically in the most severe patients. We suggest that a meaningful focus of rehabilitation programs is increasing the frequency of bouts rather than prolonging the duration of current bouts. This is supported by a previous 6-months pulmonary rehabilitation program which found that the increase in time spent walking after the intervention was due to an increase in the frequency of short activity blocks (< 1 min) rather than to lengthening of existing periods [31]. Finally, the differing physical activity levels observed between the patients in the current study and the patients from other studies with similar COPD severities or other populations suggest that interventions designed for COPD patients should not only be based on pathophysiology-related limitations but also on the “subjects’ needs, goals, and initial abilities”, as advocated by the recommendations [8,9].

Limitations and strengths

The current study has several limitations. The cross-sectional design does not allow for the differences to be interpreted across COPD severity stages such as the evolution of physical

activity over time. The lack of a control (non-COPD) group may be seen as a limitation. However, because the aim of the project was to describe the characteristics of physical activity in COPD patients, we believe that the population addresses the needs of the research question. Unfortunately, the small number of patients in the mild and very severe COPD groups could have led to reduced statistical power to identify as statistically significant the observed differences in physical activity. Despite this fact, our study still includes a considerable number of patients with moderate and severe COPD, which is more than in previous COPD studies [5]. We defined a bout as a minimum of 10 consecutive minutes in activity, according to Public Health recommendations [32,33], a definition that has not been consistently applied as yet such that the comparison of our results with existing research is currently limited. Finally, our findings on physical activity levels and patterns may not be applicable to other COPD groups with more impaired exercise capacity or belonging to other geographical areas, which may differ with respect to climate or lifestyle. However, the relation of activity levels and patterns with disease severity is still valid and original.

One strength of our study is the large number of patients who were assessed using accelerometry during a period of eight consecutive days. Other physical activity instruments or shorter recording periods would have not allowed for the calculation of weekly patterns of physical activity bouts. The fact that all patients were recruited at the same time-point during the clinical course of COPD allows for the avoidance of the potential confounding factors produced by changes during the course of disease. Finally, we defined the MET cut-off points for moderate and vigorous physical activity according to the mean maximal oxygen uptake during cardiopulmonary incremental exercise test in the same patients [15,19]. Setting the cut-off points in this manner is a clear advantage in comparison with previous COPD

research that used only the standard intensity cut-offs for the general population, which results in higher relative intensities when applied to older and less fit individuals [19,20].

Conclusions

In conclusion, COPD patients of all spirometric severity stages engage in physical activity bouts of moderate-to-vigorous intensities. Patients with severe and very severe COPD perform their daily activities in fewer and shorter bouts than those in mild and moderate stages. Interventions that aim to increase the physical activity levels of COPD patients, including physical activity advice and pulmonary rehabilitation programs, should focus on maximizing endurance capacity of the patients.

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Figure 1. Graphic illustration of the process to identify physical activity bouts from the minute-by-minute METs report of the accelerometer during a sample day in a COPD patient.

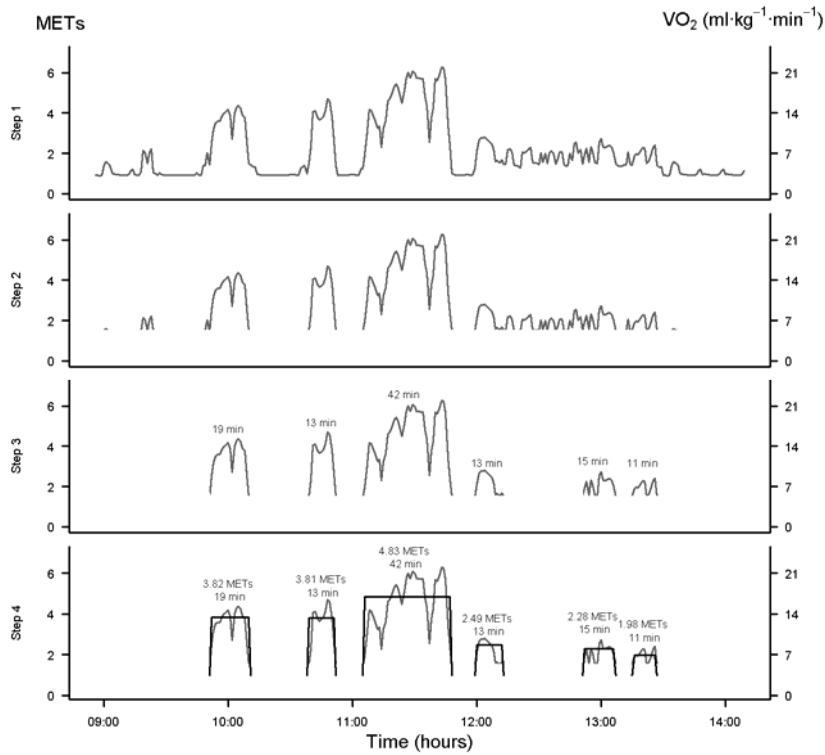


Figure footnote:

Continuous grey line represents the minute by minute METs values recorded by the accelerometer. *Step 1 (only when needed):* to format data in the minute by minute report of MET values. *Step 2:* to keep $\min \geq 1.5$ METs. *Step 3:* to calculate duration of consecutive minutes and keep periods ≥ 10 min. *Step 4:* to calculate average intensity of each bout to be classified in light, moderate or vigorous according to each population thresholds.

Figure 2. Characteristics of physical activity across levels of COPD severity.

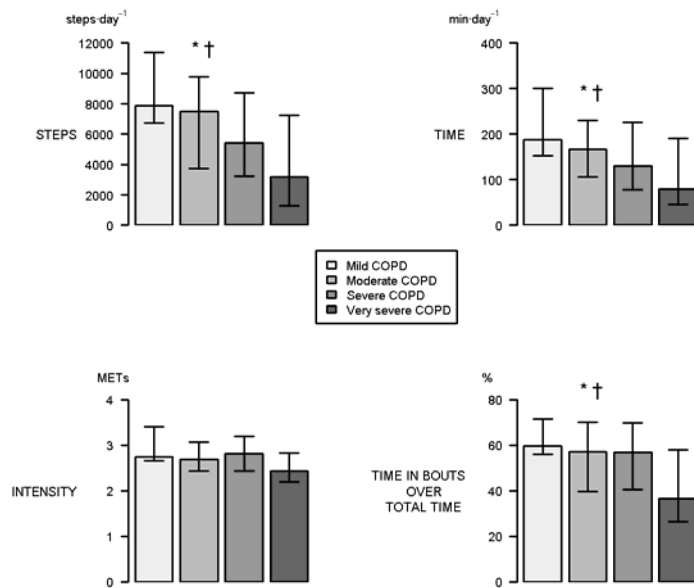


Figure footnote:

Bar plots represent median and P25th-P75th values. Steps: Total number of steps per day. Time: Total time in physical activity ≥ 1.5 METs. Intensity: Mean intensity in physical activity. Time in bouts out of total time: Percent of time in physical activity bouts out of the total time in physical activity.

* p-trend across COPD severity stages <0.05 .

† p-value comparing mild-to-moderate *versus* severe-to-very severe COPD <0.05 .

Figure 3. Frequency, duration, and time in physical activity bouts of all- and moderate-to-vigorous intensities, across levels of COPD severity

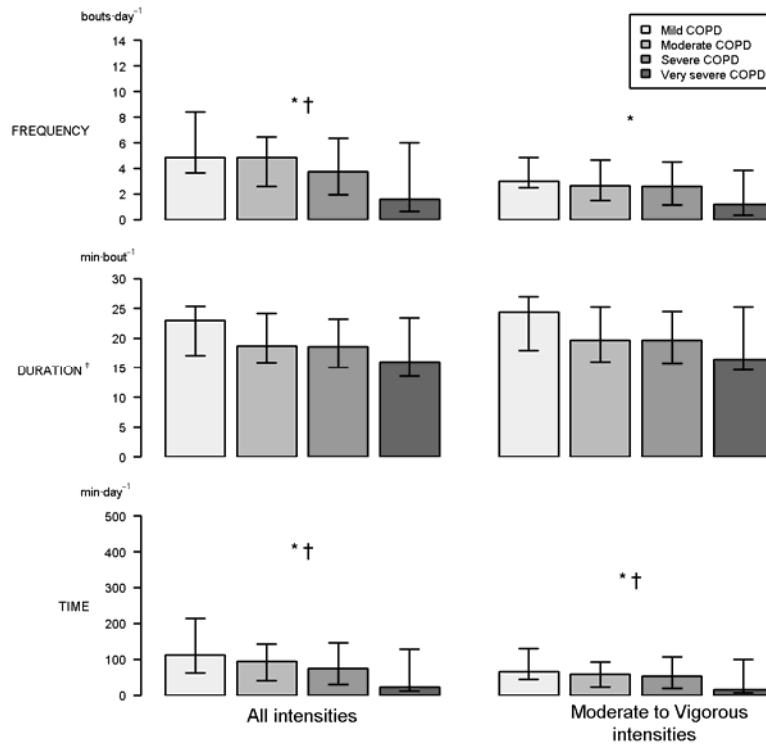


Figure footnote:

Bar plots represent median and P25th-P75th values. Frequency: Number of physical activity bouts per day.

Duration: Mean duration of the physical activity bouts. Time: Total amount of time in physical activity bouts.

* p-trend across COPD severity stages <0.05.

† p-value comparing mild-to-moderate *versus* severe-to-very severe COPD <0.05.

‡ Only patients who participated in bouts.

Figure 4. COPD patients adherence to physical activity recommendation for older adults*.

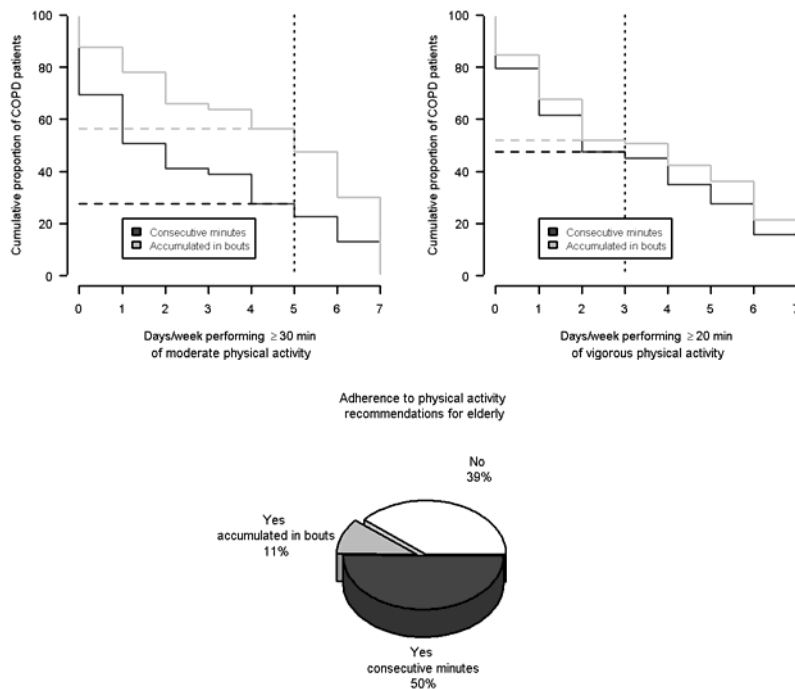


Figure footnote:

* Moderate-intensity physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic activity for a minimum of 20 min on three days each week [8].

Table 1. Socio-demographic and clinical characteristics according to levels of COPD severity.

	All COPD patients n=177	Mild COPD n=9 (5%)	Moderate COPD n=87 (49%)	Severe COPD n=64 (36%)	Very Severe COPD n=17 (10%)
Sex: Male, n (%)	166 (94)	6 (67)	82 (94)	63 (98)	15 (88)
Age (years), m (SD)	71 (8)	69 (10)	71 (8)	72 (7)	66 (8)
Working status: active, n (%)	15 (8)	0 (0)	10 (11)	4 (6)	1 (6)
Low (IV, V) socioeconomic status, n (%)	130 (80)	7 (78)	64 (82)	47 (80)	12 (75)
Smoking status: current smokers, n (%)	57 (32)	3 (33)	28 (32)	18 (28)	8 (47)
BMI (kg·m ⁻²), m (SD)	29 (5)	28 (4)	30 (5)	28 (4)	25 (5)
FFMI (kg·m ⁻²), m (SD)	20 (3)	18 (3)	20 (3)	19 (3)	18 (3)
Dyspnea (mMRC, 0-5), m (SD)	2.5 (1.6)	1.3 (1.2)	2.1 (1.5)	3.0 (1.5)	3.5 (1.3)
Charlson index (score 0-30), m (SD)	2.2 (1.4)	1.7 (0.7)	2.3 (1.5)	2.0 (1.3)	2.2 (1.4)
SGRQ-total score (0-100), m (SD)	32 (18)	16 (12)	25 (16)	37 (16)	51 (17)
FEV ₁ (% predicted), m (SD)	52 (16)	87 (7)	61 (8)	41 (5)	25 (4)
FEV ₁ /FVC (%), m (SD)	54 (13)	67 (7)	60 (9)	47 (11)	35 (8)
RV/TLC (%), m (SD)	58 (10)	46 (5)	54 (8)	62 (8)	69 (7)
PaO ₂ (mmHg), m (SD)	74 (10)	81 (8)	76 (10)	72 (10)	69 (9)
6-min walking distance (m), m (SD)	407 (96)	450 (91)	423 (86)	395 (102)	349 (103)
VO ₂ max (ml·kg ⁻¹ ·min ⁻¹), m(SD)	16 (4)	19 (4)	16 (4)	16 (5)	15 (4)
VO ₂ max (METs), m(SD)	5 (1)	5 (1)	5 (1)	4 (1)	4 (1)

n: number; m: mean; SD: standard deviation; BMI: body mass index; FFMI: fat-free mass index; mMRC: modified Medical Research Council; SGRQ: St George Respiratory Questionnaire; FEV₁: forced expiratory volume in the first second; FVC: forced vital capacity; RV: residual volume; TLC: total lung capacity; PaO₂: arterial oxygen partial pressure.

* Some values are missing for certain variables: 15 in socioeconomic status, 13 in FFMI, 1 in FEV₁/FVC, 6 in PaO₂, 11 in RV/TLC, 10 in 6-min walking distance, and 66 in VO₂max. Missing values were distributed at random and were mainly due to the hospital logistics and patients availability, as previously published (15).

Table 2. Characteristics of physical activity and physical activity bouts in COPD patients.

	All intensities (≥ 1.5 METs)	Moderate-to-vigorous intensities (≥ 2.6 METs)*
	median (25th-75th percentile)	median (25th-75th percentile)
Characteristics of physical activity	n=177 (100%)	
Steps (steps·day ⁻¹)	5876 (3316-9571)	
Energy expenditure in physical activity (METs·min·day ⁻¹)	424 (234-724)	
Time in physical activity (min·day ⁻¹)	153 (88-232)	
Intensity of physical activity (METs)	2.7 (2.4-3.1)	
Characteristics of physical activity bouts		
Participation in physical activity bouts, n (%)	174 (98%)	172 (97%)
Frequency (bouts·day ⁻¹) [†]	4.4 (2-6.5)	2.6 (1.2-4.8)
Duration (min·bout ⁻¹) [†]	19 (15-24)	20 (16-25)
Intensity (METs) [†]	3.1 (2.8-3.5)	3.6 (3.4-3.8)
Time in bouts (min·day ⁻¹) [†]	86 (34-145)	57 (20-106)
Time in bouts out of total time in activity (%) [†]	57 (39-70)	37 (19-52)

n: number; m: mean; SD: standard deviation; MET: metabolic equivalent tasks.

* Cut-off points for definition of intensity of physical activity are based on the mean values of maximal oxygen uptake at cardiopulmonary incremental exercise test peak in this population (see methods).

[†] The frequency, duration, intensity, time in bouts, and time in bouts out of total time in activity were only computed for subjects that had at least one bout in the whole recording period

Table 3. Self-reported (Yale Physical Activity Survey) time spent weekly in physical activities, according to the adherence to physical activity recommendation for older adults*

	Adherence to physical activity recommendation			p-value [†]
	No	Yes, accumulated in bouts ≥ 10 min	Yes, in consecutive min	
	n= 66 (39%)	n= 17 (10%)	n= 86 (51%)	
	m (SD)	m (SD)	m (SD)	
Household activities (h·week ⁻¹)	8.1 (8.1)	6.3 (7.1)	11.5 (12.1)	0.054
Work activities (h·week ⁻¹)	3.7 (11.8)	2.4 (9.7)	5.7 (15.2)	0.411
Leisure time activities (h·week ⁻¹)	11.6 (11)	16.2 (13.4)	16.4 (12.3)	0.007
Yard work/gardening (h·week ⁻¹)	1.1 (4.3)	4.1 (6.9)	3 (10.2)	0.035
Caretaking (h·week ⁻¹)	0.9 (4.5)	0 (0)	0.9 (3.5)	0.266
Exercise (h·week ⁻¹)	0.7 (1.5)	2.5 (7.6)	1.5 (3.5)	0.217
Recreational activities (h·week ⁻¹)	9 (10)	9.6 (9.6)	10.9 (7.3)	0.017

* Moderate-intensity physical activity for a minimum of 30 min on five days each week or vigorous-intensity aerobic activity for a minimum of 20 min on three days each week [8].

[†] p-value using Kruskal Wallis test to compare the three groups of adherence to recommendation.