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.

177 patients (94% male, mean±SD age 71±8 years and forced expiratory volume in 1 s 52±16% predicted) wore the SenseWear Pro_2 Armband accelerometer for eight consecutive days. Physical activity bouts were defined as periods of ⩾10 min above 1.5 metabolic equivalent tasks and classified according to their median intensity.

Patients engaged in activity a median of 153 min·day^{-1} and 57% of that time was spent in bouts. Median frequencies of bouts per day were four and three 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. 61% 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.

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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 previous studies have reported accurate measurements of the physical activity level without addressing the pattern of activity. Indeed, physical activity is recognised as a multi-faceted behaviour that involves frequency, intensity, time and type (FITT principle) as modifiable components that are specifically used for guiding and testing interventions [6, 7]. Consistent with this concept, the recommendations 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 5 days each week or vigorous-intensity aerobic activity for a minimum of 20 min on 3 days each week'' [8]. Importantly, current physical activity guidelines explicitly acknowledge that the recommendations 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 engaging 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 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 1 s (FEV_1) to the forced vital capacity (FVC) $<70\%$) [13] were recruited at nine tertiary hospitals in Spain [14, 15] and their spirometric severity was classified according to American Thoracic Society/European Respiratory Society 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 3 months after the last recorded exacerbation. Physical activity levels and bouts, and adherence to recommendations were measured using the SenseWear Pro_2 Armband accelerometer (Body Media, Pittsburgh, PA, USA), which has proven a valid tool to measure physical activity in COPD patients [17]. The accelerometer was worn for eight consecutive days and the minimal time was defined, *a priori,* as at least 3 days recording more than 70% of daily time (08:00–22:00 h) [18]. The consistency of accelerometer data was tested by the intra-class correlation coefficient (ICC) of steps per day between all possible combinations of 3 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].

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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 characterised using energy expenditure (MET·min·day^{-1}), time (min·day^{-1}), intensity (METs), time spent in minutes with ⩾1.5 MET and steps (steps per day). Secondly, physical activity bouts were defined as any period of at least 10 min with an intensity ⩾1.5 MET and classified as light, moderate or vigorous according to their median intensity (in METs). The thresholds for moderate and vigorous physical activity were set at 50% and 65% 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 MET, respectively [19]. We computed the frequency (bouts per day), duration (minutes per bout), intensity (METs) and total time (min·day^{-1}) in bouts. To exemplify the latter, figure 1 shows a minute-by-minute METs report from the accelerometer in a sample day of a COPD patient, together with the graphical illustration of six physical activity bouts and their duration and median intensity. The ratio of time in physical activity bouts to time in physical activity was also obtained. Thirdly, the adherence to the recommendation for older adults was defined as spending ⩾30 min in moderate activity ⩾5 days per week or spending ⩾20 min in vigorous activity ⩾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

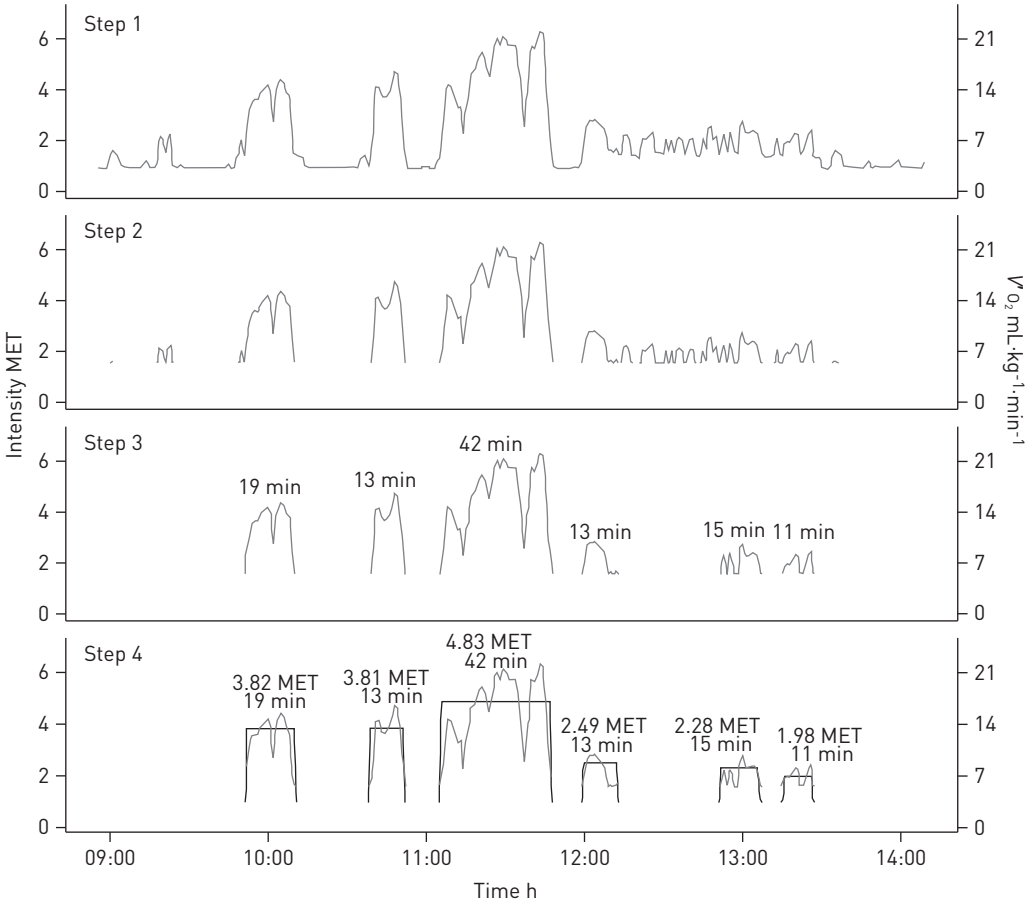

FIGURE 1 Graphical illustration of the process to identify physical activity bouts from the minute-by-minute metabolic equivalent tasks (METs) report of the accelerometer during a sample day in a chronic obstructive pulmonary disease patient. The continuous grey line represents the minute-by-minute MET values recorded by the accelerometer. Step 1 (if required): to format data into the minute-by-minute report of MET values; step 2: to keep minutes in which activity is ⩾1.5 MET; step 3: to calculate the duration of consecutive minutes and keep periods ⩾10 min; step 4: to calculate the average intensity of each bout, to be classified into light, moderate or vigorous according to each population threshold. V'_{O_2}: oxygen uptake.

(frequency and duration) on a wide range of activities performed in a typical week of the previous month. Other relevant variables included sociodemographic factors, smoking, Charlson comorbidity index, dyspnoea, the St George's Respiratory Questionnaire, lung function measurements (post-bronchodilator FEV_1, FVC and FEV_1/FVC, residual volume (RV), total lung capacity (TLC), RV/TLC, and arterial oxygen tension, body mass index, fat-free mass index and the 6-min walking distance. Details of these procedures have been published previously [14, 15].

Statistical analysis

Sample size calculations are available in the online supplementary material. The subjects' characteristics and physical activity characteristics are presented as n (%) for categorical variables and mean±SD or median (interquartile range) 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: 1) using standard cut-off points for intensity of physical activity (3 MET for moderate and 6 MET for vigorous physical activity [9]); and 2) excluding subjects with extreme values (above the 95th percentile) in the number of daily steps recorded by the accelerometer. All analyses were conducted using R 2.14.1 (the R Project for Statistical Computing, www.r-project.org). The scripts for the calculation of bouts are available in the online supplementary material.

Results

Table 1 shows the main characteristics of the patients. Patients wore the accelerometer for a mean of 6 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 ~20 min, 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) (online supplementary fig. S1).

TABLE 1 Sociodemographic and clinical characteristics according to levels of chronic obstructive pulmonary disease (COPD) severity

	All COPD patients	Mild COPD	Moderate COPD	Severe COPD	Very Severe COPD
Subjects	177 (100)	9 (5)	87 (49)	64 (36)	17 (10)
Male	166 (94)	6 (67)	82 (94)	63 (98)	15 (88)
Age years	71±8	69±10	71±8	72±7	66±8
Working status: active	15 (8)	0 (0)	10 (11)	4 (6)	1 (6)
Low (IV, V) socioeconomic status#	130 (80)	7 (78)	64 (82)	47 (80)	12 (75)
Current smokers	57 (32)	3 (33)	28 (32)	18 (28)	8 (47)
BMI kg·m^{-2}	29±5	28±4	30±5	28±4	25±5
FFMI kg·m^{-2} #	20±3	18±3	20±3	19±3	18±3
Dyspnoea mMRC score¶	2.5±1.6	1.3±1.2	2.1±1.5	3.0±1.5	3.5±1.3
Charlson index score+	2.2±1.4	1.7±0.7	2.3±1.5	2.0±1.3	2.2±1.4
SGRQ total score§	32±18	16±12	25±16	37±16	51±17
FEV_1 % pred	52±16	87±7	61±8	41±5	25±4
FEV_1/FVC %#	54±13	67±7	60±9	47±11	35±8
RV/TLC %#	58±10	46±5	54±8	62±8	69±7
P_{aO_2} mmHg#	74±10	81±8	76±10	72±10	69±9
6-min walking distance m#	407±96	450±91	423±86	395±102	349±103
V'_{O_2max} mL·kg^{-1}·min^{-1} #	16±4	19±4	16±4	16±5	15±4
V'_{O_2max} MET#	5±1	5±1	5±1	4±1	4±1

Data are presented as n (%) or mean±SD. BMI: body mass index; FFMI: fat-free mass index; mMRC: modified Medical Research Council; SGRQ: St George's Respiratory Questionnaire; FEV_1: forced expiratory volume in 1 s; % pred: % predicted; FVC: forced vital capacity; RV: residual volume; TLC: total lung capacity; P_{aO_2}: arterial oxygen tension; V'_{O_2max}: maximal oxygen uptake; MET: metabolic equivalent task. #: some values are missing for certain variables (15 in socioeconomic status, 13 in FFMI, one in FEV_1/FVC, 11 in RV/TLC, six in P_{aO_2}, 10 in 6-min walking distance and 66 in V'_{O_2max}); missing values were distributed at random and were mainly due to the hospital logistics and patients' availability, as previously published [15]. ¶: out of five; +: out of 30; §: out of 100.

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TABLE 2 Characteristics of physical activity and physical activity bouts in chronic obstructive pulmonary disease patients

	All intensities (⩾1.5 MET)	Moderate-to-vigorous intensities (⩾2.6 MET)#
Characteristics of physical activity		
Steps per day	5876 (3316–9571)	
Energy expenditure in physical activity MET·min·day^{-1}	424 (234–724)	
Time in physical activity min·day^{-1}	153 (88–232)	
Intensity of physical activity MET	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 MET¶	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)

Data are presented as median (interquartile range), unless otherwise stated. n=177 patients. MET: metabolic equivalent task; #: 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.

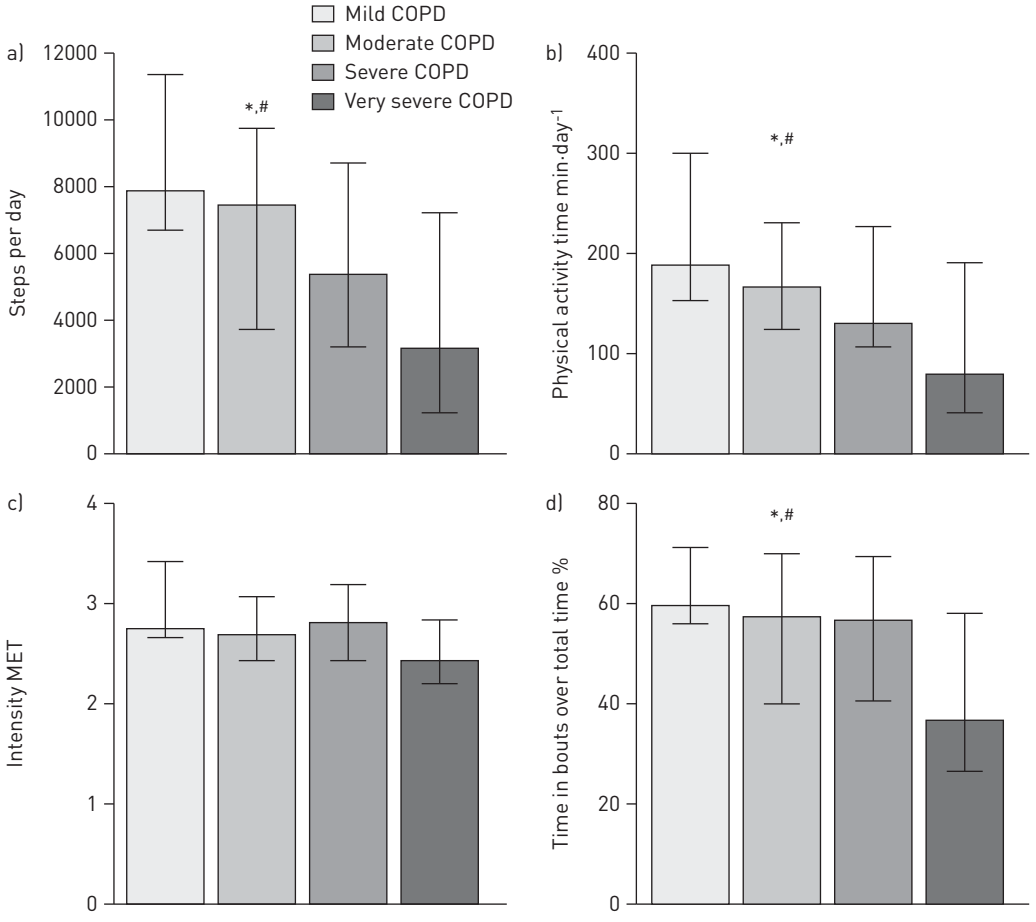

FIGURE 2 Characteristics of physical activity across levels of chronic obstructive pulmonary disease (COPD) severity. Bar plots represent the medians and error bars the interquartile range. a) Total number of steps per day, b) total time in physical activity ⩾1.5 metabolic equivalent tasks (METs), c) mean intensity in physical activity and d) percentage 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 2 shows that the number of steps, time in physical activity and proportion of time in bouts over 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 (fig. 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 those with mild-to-moderate COPD, while there were no differences in participation and time spent in household activities or recreational activities (online supplementary table S1).

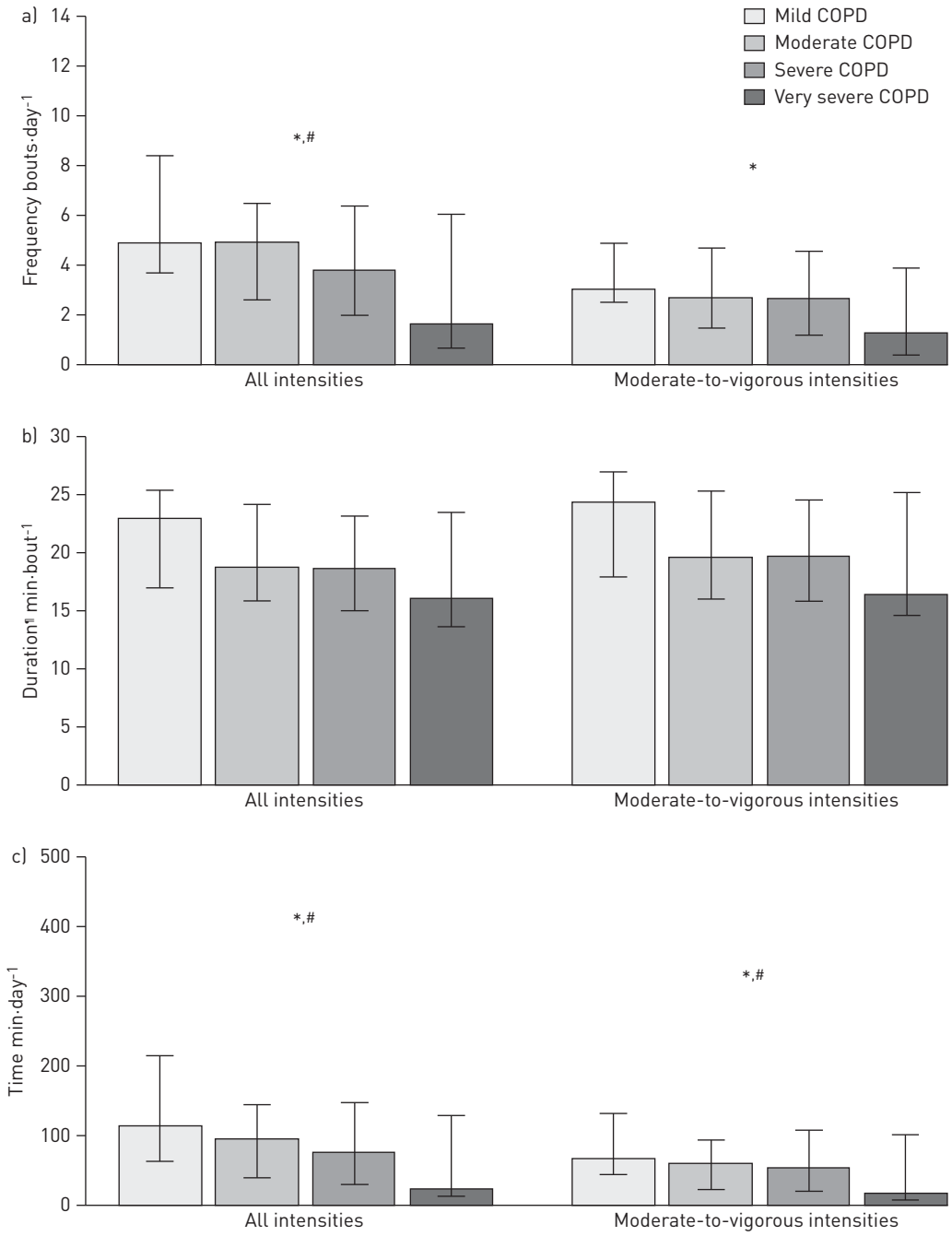

FIGURE 3 Frequency, duration and time in physical activity bouts of all and moderate-to-vigorous intensities, across levels of chronic obstructive pulmonary disease (COPD) severity. Bar plots represent the medians and error bars the interquartile range. a) Number of physical activity bouts per day, b) mean duration of the physical activity bouts and c) 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.

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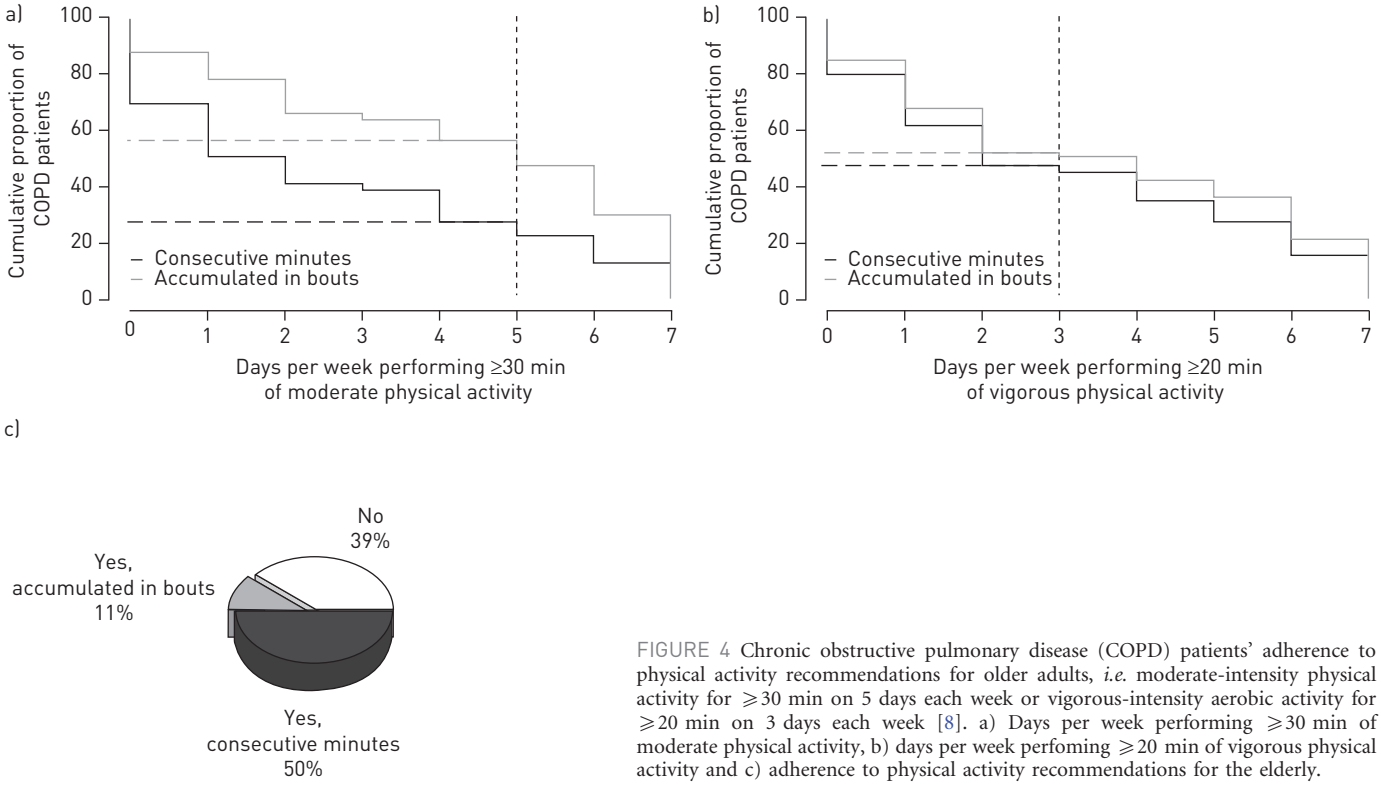

FIGURE 4 Chronic obstructive pulmonary disease (COPD) patients' adherence to physical activity recommendations for older adults, *i.e.* moderate-intensity physical activity for ⩾30 min on 5 days each week or vigorous-intensity aerobic activity for ⩾20 min on 3 days each week [8]. a) Days per week performing ⩾30 min of moderate physical activity, b) days per week perfoming ⩾20 min of vigorous physical activity and c) adherence to physical activity recommendations for the elderly.

Figure 4 shows that about 25% of the COPD patients fulfilled the recommendation of engaging in ⩾30 consecutive minutes of moderate physical activity five or more days per week. The proportion increased to almost 60% when the duration of ⩾30 min per day was achieved through the accumulation of bouts of ⩾10 min duration. Overall, 61% of 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 or gardening and recreational activities.

All analyses were repeated using standard cut-off points for the definition of moderate and vigorous intensities of physical activity (online supplementary tables S2 and S3 and figs S2 and S3). Results for participation, frequency, duration and intensity of bouts were very similar. The proportion of COPD

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 minutes	
Subjects n (%)	66 (39)	17 (10)	86 (51)	
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

Data are presented as mean±SD, unless otherwise stated. [#]: moderate-intensity physical activity for ⩾30 min on 5 days each week or vigorous-intensity aerobic activity for ⩾20 min on 3 days each week [8]; [¶]: Kruskal–Wallis test to compare the three groups of adherence to recommendations.

patients fulfilling the physical activity recommendation was reduced from 61% to 50% (online supplementary fig. 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 fulfilled 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 than, and had similar airflow limitation and exercise capacity to 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 75% in a study with healthy subjects of similar age and geographical location using an identical physical activity questionnaire [24]. Another difference between previous studies and ours is that the earlier 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 were undiagnosed 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 expense of reducing bout frequency (fig. 2). The lack of differences in bout duration across severity stages needs to be interpreted with caution; the very severe COPD patients perform bouts that have similar duration to 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 $<$10 min duration. The lack of differences in intensity of physical activity across severity stages is well known. It has been hypothesised 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 practised despite disease severity because they are compulsory for daily living, while the latter, 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 fewer 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 programmes 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 ($\geqslant$20 min) or short-bout ($\geqslant$10 min) interventions [28–30]. Interestingly, in our study, patients fulfilling the recommendation also reported more time engaged in recreational activities. Secondly, it is interesting to note that the way COPD patients seem to adapt to exercise limitation (towards less and shorter periods of

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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 programmes is increasing the frequency of bouts rather than prolonging the duration of current bouts. This is supported by a previous 6-month pulmonary rehabilitation programme, 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 a 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 in other geographical areas, which may differ with respect to climate or lifestyle. However, the relationship between 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 a 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 programmes, should focus on maximising endurance capacity of the patients.

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