MISS JOANA CRUZ (Orcid ID : 0000-0002-4911-4469)

MISS ALDA MARQUES (Orcid ID : 0000-0003-4980-6200)

Article type : Original Article

Construct Validity of the Brief Physical Activity Assessment Tool for Clinical Use in COPD

Joana Cruz[1,2,*] PhD, Cristina Jácome[2,3] PhD, Ana Oliveira[2,4,5] PhD, Cátia Paixão[2,6] MSc, Patrícia Rebelo[2,6] MSc, Sofia Flora[7] PT BSc, Filipa Januário[8] MD BSc, Carla Valente[9] MD BSc, Lília Andrade[9] MD BSc, Alda Marques[2,6] PhD

1 Centre for Innovative Care and Health Technology (ciTechCare), School of Health Sciences (ESSLei), Polytechnic of Leiria, Leiria, Portugal

2 Lab 3R – Respiratory Research and Rehabilitation Laboratory, School of Health Sciences, University of Aveiro (ESSUA), Aveiro, Portugal

3 CINTESIS –Center for Health Technology and Services Research, Faculty of Medicine, University of Porto, Porto, Portugal

4 Respiratory Medicine, West Park Healthcare Centre, Toronto, Canada;

5 School of Rehabilitation Sciences, Faculty of Health Sciences, McMaster University, Hamilton, Canada;

6 iBiMED – Institute of Biomedicine, University of Aveiro, Aveiro, Portugal

7 Centre for Innovative Care and Health Technology (ciTechCare), Polytechnic of Leiria, Leiria, Portugal

8 Serviço de Medicina Física e de Reabilitação - Centro Hospitalar de Leiria, Leiria, Portugal

9 Pulmonology Department, Centro Hospitalar do Baixo Vouga, Aveiro, Portugal

***Corresponding author:**

Joana Cruz, joana.cruz@ipleiria.pt
School of Health Sciences, Polytechnic of Leiria (ESSLei)
Campus 2, Morro do Lena – Alto do Vieiro
Apartado 4163 | 2411-901 Leiria – PORTUGAL

Short running title: Construct validity of the BPAAT in COPD

Authorship Statement: JC, CJ, AO and AM were responsible for designing and performing the research study. JC, CP, PR, SF collected the data, with support of FJ, CV and LA. JC analyzed the data and drafted the manuscript. All authors revised critically the manuscript for important intellectual content and approved the final version of the manuscript.

Declarations of interest: none.
Data availability statement: Data available on request from the authors

Construct Validity of the Brief Physical Activity Assessment Tool for Clinical Use in COPD

Abstract

Introduction: Low physical activity (PA) levels are associated with poor health-related outcomes in Chronic Obstructive Pulmonary Disease (COPD). Thus, PA should be routinely assessed in clinical practice.

Objectives: This study assessed the construct validity of the Brief Physical Activity Assessment Tool (BPAAT) for clinical use in COPD, and explored differences in age, sex and COPD grades.

Methods: After linguistic adaptation of the tool to Portuguese, 110 patients (66.4±9.6yrs, 72.7% male, FEV_1=59.3±25.5%predicted) completed the BPAAT and received an accelerometer. The BPAAT includes two questions assessing the weekly frequency and duration of vigorous- and moderate-intensity PA/walking, classifying individuals as insufficiently or sufficiently active. The BPAAT was correlated with accelerometry (moderate PA, MPA=1952-5724 counts-per-min[CPM]); vigorous PA, VPA=5725-∞CPM; moderate-to-vigorous PA, MVPA=1952-∞CPM; daily steps), through: Spearman's correlations (ρ) for continuous data; %agreement, Kappa, sensitivity and specificity, positive and negative predictive values (PPV, NPV) for categorical data.

Results: The BPAAT was weakly to moderately correlated with accelerometry ($0.394 \leq \rho \leq 0.435$, $p<0.05$), except for VPA ($p=0.440$). This was also observed in age (<65/≥65yrs), COPD grades (GOLD 1-2/3-4), and in male patients ($0.363 \leq \rho \leq 0.518$, $p<0.05$ except for VPA). No significant correlations were found in female patients ($p>0.05$). The BPAAT correctly identified 73.6% patients as 'insufficiently active' and 26.4% as 'sufficiently active'. Agreement was fair to moderate ($0.36 \leq$ kappa ≤ 0.43; $73.6\% \leq$ %agreement $\leq 74.5\%$; $0.50 \leq$ sensitivity ≤ 0.52; $0.84 \leq$ specificity ≤ 0.91, $0.55 \leq$ PPV ≤ 0.79, $0.72 \leq$ NPV ≤ 0.82).

Conclusion: The BPAAT may be useful to screen patients' PA, independently of age and COPD grade, and identify male patients who are insufficiently active. Care should be taken when using this tool to assess vigorous PA or female patients.

Keywords: Activity Categories; Chronic Obstructive Pulmonary Disease; Daily Activity; Validation Study.

Introduction

Low levels of physical activity (PA) have been related to poor health outcomes and a higher risk of acute exacerbations, hospitalizations and mortality in patients with chronic obstructive pulmonary disease (COPD)[1]. Since PA is a modifiable factor with potential to improve COPD prognosis, the latest Global Strategy for the Diagnosis Management and Prevention of COPD (GOLD) guidelines have underlined the importance of promoting regular PA in patients at all COPD grades[2].

Healthcare professionals play a central role in encouraging patients to be physically active[3]. Therefore, identifying patients who are insufficiently active is fundamental[4]. A recent study found that routine assessment of PA in clinical care could identify patients with COPD at high risk of mortality after hospitalization[5], thus reinforcing the importance of assessing patients' PA levels. There are numerous tools available to assess daily PA in the clinical context, either objective or subjective[6]. Objective tools, such as activity monitors (e.g., accelerometers), capture the movement as it occurs and provide information on the amount and/or intensity of daily PA. These tools have shown good construct validity against indirect calorimetry in patients with COPD[7]. However, they are too expensive to be used in resource-constrained settings[6]. Pedometers are less costly options and they have been used to assess PA in COPD[8], although they may under/overestimate PA in slow walking populations[9,10] including COPD[8], and are unable to capture the frequency, duration and intensity of PA[11]. Therefore, subjective tools such as questionnaires seem to be a more feasible approach to quickly screen patients' PA in clinical practice.

There are several PA assessment questionnaires already tested in people with COPD, but only the Stanford 7-day Physical Activity Recall (PAR) questionnaire showed significant correlations with objectively-measured PA ($0.46 \leq r \leq 0.83$)[12]. Moreover, most of these questionnaires are time consuming to complete and calculate the scores, and some of them are not able to identify 'insufficiently active' patients which makes it difficult for clinicians to provide adequate advice. Recently, hybrid tools combining self-reported and activity monitor data were developed to capture patients' experience of PA (Daily and Clinical visit PROactive physical activity in COPD tools)[13]. These tools are valid, reliable and innovative as they provide a comprehensive assessment of the amount of and difficulties with PA in the COPD population; however, they still rely on activity monitors, which may hinder their widespread use in clinical practice. Therefore, easy-to-

use PA screening tools that can be implemented as part of regular health appointments to quickly identify (in)active patients are needed.

The Brief Physical Activity Assessment Tool (BPAAT) was originally developed to enable healthcare professionals to identify inactive patients in primary care[14]. It is a simple and quick (<5min) questionnaire which allows the classification of individuals as sufficiently/insufficiently active[14]. The BPAAT classification categories showed good construct validity ($0.40 \leq Kappa \leq 0.64$[14-16]; sensitivity=0.75 95%CI: 0.70–0.79, specificity=0.74 95%CI: 0.71–0.77[16]) in patients with various health conditions, when compared to accelerometry and to other PA questionnaires. Thus, this may be a valuable tool to screen PA levels in clinical practice. However, its validity in patients with COPD is still unknown.

This study assessed the construct validity of the Portuguese version of the BPAAT[14] for clinical use in COPD, by comparing it to objectively-measured PA (accelerometry). A secondary aim was to explore potential differences in the validity of the tool among age, sex and COPD grades, as previous studies have shown a gradual reduction in PA levels across GOLD grades[17,18], and an influence of age and sex in patients' PA behavior[19].

Materials and Methods

Study Design

This is a secondary analysis of the baseline data of participants with COPD from 3 research projects on COPD management (SFRH/BD/81328/2011, NCT02122614**;** SAICT-POL/23926/2016; NCT03799666)[20,21] and PA promotion in COPD (POCI-01-0145-FEDER-028446) conducted between 2013 and 2019. Ethical approval was obtained from the institutions collaborating in the projects.

Construct (convergent) validity was assessed by comparing the results from the BPAAT and accelerometry, according to the taxonomy of the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN) guidelines[22]. Construct validity was assessed in the whole sample and in subgroups (age, sex and COPD grades). Criterion validity was not possible to assess as there is still no gold standard for the assessment of daily PA[11,23].

Participants

Patients with COPD were recruited from five primary care centers and two hospitals in the center region of Portugal. Physicians (general practitioners or pulmonologists, depending on the place of

recruitment) of the institutions identified potential participants and ensured the fulfilment of the eligibility criteria. Patients were included if they were: 18 years old or older, diagnosed with COPD according to the GOLD criteria[2], clinically stable in the last month (i.e., no hospital admissions or exacerbations), able to read and understand the Portuguese language.

Exclusion criteria consisted of the presence of severe neurologic (e.g., stroke, Parkinson), musculoskeletal (e.g., severe osteoarthritis) or psychiatric (e.g., schizophrenia) disorders, unstable cardiovascular disease, or severe visual impairment that could preclude patients from understanding the study and/or participating in data collection.

Patients who agreed to participate were contacted by researchers to schedule an appointment to provide more information about the study and collect data. Written informed consent was obtained before data collection.

Procedures

Participants completed a questionnaire with sociodemographic (age, sex), anthropometric (weight and height to compute body mass index [BMI]) and clinical (dyspnea during activities with the modified British Medical Research Council (mMRC) questionnaire[24]) information. Lung function was assessed with a portable spirometer (MicroLab 3500, CareFusion, Kent) according to the European Respiratory Society guidelines[25], to further categorize patients by COPD grade based on the GOLD criteria (GOLD 1-4)[2]. Participants were then asked to complete the Portuguese version of the BPAAT[14] and received a triaxial accelerometer (Actigraph GT3X+, Pensacola, FL, USA). A second appointment was scheduled one week later to collect the accelerometer data.

Measures

Brief Physical Activity Assessment Tool (BPAAT)

The BPAAT is a PA assessment tool composed of two questions, one regarding the frequency and duration of vigorous-intensity PA and the other regarding moderate-intensity PA and walking performed in an individual's usual week[14]. Each question is rated in a 1-4 scale. Total score varies from 0 to 8 and it allows further classification of the individual as 'insufficiently active' (score 0–3) or 'sufficiently active' (score≥4) (Table 1)[14].

Since the questionnaire was not available in Portuguese, a linguistic adaptation was first conducted using the forward- and back-translation method[26]. Two independent researchers translated the original questionnaire (available in English[14]) into Portuguese. They were native Portuguese

speakers with proficiency in English and experience in PA assessment and COPD management. After translation, the researchers compared the two versions of the questionnaire and reached a consensus. The back-translation to the original language was conducted by a native English speaker with high proficiency in Portuguese, who was blinded to the original questionnaire. The back-translated and the original versions were then compared by four bilingual researchers to reach a final version (supplementary material). A pilot test with 5 patients was conducted to check for clarity of the instructions and response items of the questionnaire.

Accelerometry

The Actigraph GT3X+ triaxial accelerometer (Pensacola, FL, USA) was chosen as it is validated in COPD[7]. After initialization, the device collects and stores PA data which can be further downloaded and converted into time-stamped PA counts and step counts using specific software (Actilife, Pensacola, FL, USA).

Participants wore the accelerometer at the waist on an elastic belt over the right hip, during waking hours (except when bathing or swimming). They were instructed to use the accelerometers for at least 4 consecutive days during their usual activities and asked to report if any activity different from their routine was performed during that period. Participants were included if they had ≥4 days with ≥8h of wearing time/day in the accelerometer[27], as defined in the main projects from where this study was derived[20,21]. An average of the daily time spent in moderate-intensity PA (1952-5724 counts-per-minute[CPM]), vigorous-intensity PA (5725-∞CPM), and a combination of moderate-to-vigorous intensity PA (MVPA, 1952-∞CPM) was calculated using the algorithms incorporated in the software[28]. These algorithms are commonly used in COPD[29]. The average number of steps per day was also collected. Patients were classified according to the ACSM guidelines[30] as 'insufficiently active' or 'sufficiently active' using two approaches: intensity-based and step-based (Table 1).

(table 1)

Statistical analysis

Descriptive statistics were used to characterize the sample and describe the PA results obtained from the two PA assessment methods.

Construct validity of the BPAAT was assessed against accelerometry using both continuous values and activity categories as described in Table 1. Spearman's rank correlation coefficient (ρ) was used to assess correlations between the BPAAT scores and accelerometry variables (i.e., time spent in moderate PA, vigorous PA and MVPA per day; daily steps), since data were not normally distributed. Correlations were performed considering the total sample and its stratification by age (<65/≥65 years), sex and COPD grade (GOLD 1-2/3-4). The strength of correlations was interpreted as follows: 0-0.09 negligible correlation; 0.1-0.39 weak correlation; 0.4-0.69 moderate correlation; 0.7-0.89 strong correlation; 0.9-1 very strong correlation[31]. Correlations of ≥0.40 were expected between measures, as this is the smallest value considered adequate according to previous systematic reviews on measurement properties of PA questionnaires for adults[11,32]. Independent t-tests or Mann-Whitney U tests (for normally and non-normally distributed data, respectively) were conducted to assess differences in accelerometry data between sufficiently/insufficiently active groups, as defined by the BPAAT cut-off scores[14].

The ability of the BPAAT to correctly identify insufficiently/sufficiently active patients was assessed by comparing the activity categories obtained from the two PA assessment methods (Table 1), specifically:

(1) percentage of agreement (%agreement), defined as the total number of participants assigned to the same category by both measures, divided by the total number of participants:

% agreement=100*('insufficiently active' agreement+'sufficiently active' agreement)/n total

(2) Cohen's Kappa. The following cut-off values were considered[33]: slight (≤0.20), fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.81–1.00). The 95% confidence intervals (95%CI) were also calculated:

95%CI=Kappa±1.96SE where SE is the standard error of Kappa[34]

(3) Sensitivity and specificity[35]. Sensitivity was used to describe the proportion of sufficiently active patients (using accelerometry categories as the reference) who were correctly classified by the BPAAT, and specificity was used to describe the proportion of insufficiently active patients who were correctly classified by the BPAAT. The 95%CI were calculated using the formula[34]:

$p \pm 1.96\sqrt{(p[1-p]/n \text{ total})}$, where 'p' is the relevant proportion (i.e., sensitivity or specificity)

(4) Positive and negative predictive values (PPV and NPV, respectively) and its 95% CI.[34]. The PPV refers to the proportion of participants with a BPAAT score ≥4 who were sufficiently active

(using the accelerometry categories as the reference) and the NPV provides information on the proportion of participants with a BPAAT score 0-3 who were insufficiently active.

Data were analyzed using SPSS v25 (IBM, Armonk, USA). Significance was set at $p<0.05$.

Results

Participants

One hundred and twenty-five (n=125) patients with COPD participated. From these, 15 patients did not have at least 4 valid days and, therefore, were excluded from the analyzes. The final sample consisted of 110 patients. Participants had a mean age of 66.4±9.6 years, were mostly male (n=80; 72.7%), with a mean forced expiratory volume in one second (FEV_1) of 59.3±25.5% predicted, and were on average overweight (BMI 27.0±4.7kg/m^2) (Table 2 and Table S1).

(table 2)

Comparison of the BPAAT and accelerometry

The mean BPAAT total score was 1.6±2. Fifty-four (49.1%) patients scored the lowest possible score and 2 (1.8%) achieved the highest possible score. The BPAAT score was weakly to moderately correlated with all accelerometer-based PA variables ($0.394\leq\rho\leq0.435$, $p<0.05$), except vigorous-intensity PA ($\rho=0.074$, $p=0.440$) (Table 3 and Figure S1).

Considering the activity categories, the BPAAT classified 81 (73.6%) patients as 'insufficiently active' and 29 (26.4%) as 'sufficiently active'. Duration of PA at different intensities and number of steps/day obtained via accelerometry were significantly different between these groups ($p<0.05$), except for vigorous-intensity PA ($p=0.298$) (Table 3).

(table 3)

Table 4 presents the comparison of the activity categories obtained from the two PA assessment methods. Since none of the participants reached ≥20 min/day of vigorous-intensity PA in ≥3 days[30] in the accelerometry data (Table 1), the criterion for being 'sufficiently active' was based on MVPA duration (≥30 min/day of MVPA). Considering the intensity-based approach (accelerometer-MVPA) as the reference, the BPAAT correctly identified 58 (52.7%) 'insufficiently active' and 23 (20.9%) 'sufficiently active' patients. When accelerometer-steps/day

approach was used, 66 (60%) 'insufficiently active' and 13 (11.8%) 'sufficiently active' patients were correctly identified by the BPAAT (Table 4).

Agreement between the BPAAT and accelerometry to identify sufficiently/insufficiently active patients was fair to moderate considering the intensity-based approach (Kappa=0.43 95%CI: 0.26–0.60, %agreement=73.6%), and slight to moderate using the step-based approach (Kappa=0.36 95%CI: 0.17–0.55, %agreement=74.5%) (Table 4). When MVPA (intensity-based approach) was used as the reference, the sensitivity of the BPAAT was 0.50 (95%CI 0.41–0.59) and specificity was 0.91 (95%CI 0.85–0.96). Using the step-based approach, sensitivity was 0.52 (95%CI 0.42–0.61) and specificity was 0.84 (95%CI 0.77–0.91) (Table 4). PPV and NPV were 0.79 (95%CI 0.72–0.87) and 0.72 (95%CI 0.63–0.80), respectively, when considering MVPA, and 0.55 (95%CI 0.46–0.65) and 0.82 (95%CI 0.74–0.89) when using the steps/day approach.

(table 4)

Comparison of the BPAAT and Accelerometry by Age, Sex and COPD Grades

The BPAAT score was moderately correlated with accelerometer-based PA variables independently of the age group (<65 year group: $0.414 \leq \rho \leq 0.449$; ≥65 year group: $0.440 \leq \rho \leq 0.475$; $p<0.05$), except for vigorous PA ($p>0.05$) (Table 5). A similar result was obtained in male patients ($0.437 \leq \rho \leq 0.470$, $p<0.05$ for all variables with also no correlation in vigorous PA, $\rho=0.135$, $p=0.231$). In female patients, negligible to weak correlations between the BPAAT score and accelerometry were found ($-0.003 \leq \rho \leq 0.339$, $p>0.05$) (Table 5).

When stratifying by COPD grades, the BPAAT score was weakly to moderately correlated with all accelerometer-based PA variables (GOLD 1-2: $0.363 \leq \rho \leq 0.386$; GOLD 3-4: $0.445 \leq \rho \leq 0.518$, $p<0.05$), except vigorous PA ($p>0.05$) (Table 5).

(table 5)

Discussion

This study assessed the validity of the BPAAT for clinical use in COPD. Findings suggest that this tool has acceptable validity and may be able to identify insufficiently active patients. These results were also observed in different age groups and COPD grades, and male patients, but not in female patients or when considering vigorous-intensity PA only.

The BPAAT score was significantly correlated with all accelerometer-based PA variables, except with vigorous-intensity PA. These results were expected, as few individuals with COPD engage in vigorous PA and its duration is usually limited[36]. These findings suggest that the first question of the BPAAT may not be adjusted to all patients with COPD, as it is specifically directed to vigorous-intensity PA ("*How many times a week, do you usually do 20 minutes of vigorous physical activity that makes you sweat or puff and pant? (for example, jogging, heavy lifting, digging, aerobics, or fast bicycling)?*"). It is also possible that the accelerometer used in the present study was not sensitive enough to assess vigorous activities. A previous study aimed to determine inter-instrument reliability of the ActiGraph GT3X+ under free-living conditions showed that, when moderate and vigorous PA were assessed individually, results were poorer than when their combination (i.e., MVPA) was considered[37]. However, the algorithms used to define PA intensity in that study[37] were different from the ones used in the present study, therefore, it is not possible to draw firm conclusions.

Correlations between the BPAAT score and accelerometer-based MVPA and steps/day achieved the recommended value of ≥ 0.40[11,32]. In a previous study[16] conducted in Spain with patients with various health conditions, including COPD, correlations between the BPAAT scores from each question and accelerometry variables were lower than those of the present study ($r=0.215$ for moderate PA and $r=0.282$ for vigorous PA). However, patients with moderate or severe COPD were excluded and results were not stratified by health condition, which hinders comparisons between studies. Another study assessing the validity of four PA questionnaires in COPD found weak correlations between the questionnaires and time spent in MVPA obtained through accelerometry ($0.01 \leq r \leq 0.19$) except for the Stanford 7-day PAR questionnaire ($r=0.54$ $p<0.001$)[12]. Correlations obtained in the present study were slightly lower than those of the Stanford 7-day PAR questionnaire[12]. This is an interviewer-administered questionnaire with 7 questions related to leisure and occupational PA in the previous 7 days which provides a self-estimated number of hours dedicated to activities requiring at least moderate effort[38]. In COPD, this tool was found to be useful for stratifying patients according to activity levels (sensitivity and specificity of 0.79 and 0.80, respectively, area under the curve 0.83)[12]. However, it takes approximately 15 min to complete[12] which may be too long for routine use in time-constrained clinical settings. The BPAAT may be a more feasible option. Sensitivity of the BPAAT ranged from 0.50 to 0.52 and specificity from 0.84 to 0.91, suggesting that this tool may be useful to identify insufficiently active patients (specificity) but its ability to identify sufficiently active patients is limited

(sensitivity). Being such a concise measure, it was not expected to perform better than more comprehensive PA measures, such as the PAR. Even so, the PPV of the BPAAT was above 0.70 which means that more than 70% of participants who were identified as 'sufficiently active' by the BPAAT were actually sufficiently active (using accelerometry as the reference). Similar results were found for NPV in 'insufficiently active' individuals, except when using the step-based approach. This finding may have to do with the different prevalence[34] of 'sufficiently active' patients observed in the two accelerometry approaches (intensity-based approach, prevalence=41.8%; step-based approach, prevalence=28.2%).

Agreement between the activity categories obtained from the BPAAT and accelerometry (MVPA) was fair to moderate. In the original BPAAT study, the agreement between the BPAAT and accelerometry using the same activity categories was slightly lower than in the present study (Kappa=0.40, 95%CI 0.12–0.69, %agreement=71%)[14]. The Spanish version of the tool also showed moderate agreement, although the BPAAT categories were compared to those of the Stanford 7-day PAR questionnaire (Kappa=0.45, 95%CI 0.41–0.51)[16] or the International Physical Activity Questionnaire ($0.58 \leq Kappa \leq 0.64$)[15], instead of comparing them with accelerometry.

The BPAAT was significantly correlated to accelerometer-based MVPA and steps/day in all subgroups analyzes ($0.369 \leq \rho \leq 0.518$, $p<0.001$) except for the female subgroup ($-0.003 \leq \rho \leq 0.339$, $p>0.05$). These results were not found in a previous validation study considering age and sex[16]. The sample of female patients was small (n=30) which may have partially contributed to the present results. A systematic review comparing objective versus self-report PA measures in adults found that women tended to self-report higher levels of PA[39], which may also have occurred in the present sample. Future studies with a larger sample should be conducted to confirm the findings.

Taken together, these findings suggest that the BPAAT may be of added value to quickly screen patients' PA in routine appointments, although further research is still needed before it can be used with confidence in clinical practice.

Strengths and limitations

This study has strengths and limitations that should be acknowledged. One of the strengths concerns the use of accelerometry. Accelerometry was chosen to assess the validity of the BPAAT, since comparisons with direct observation or doubly labelled water are not feasible in real-life situations and large samples. Another strength is the fact that both intensity-based and step-based approaches were used to discriminate sufficiently/insufficiently patients. Previous

validation studies have only accounted for PA intensity[14,16]; however, since daily steps are often used to provide PA recommendations[40] (also in COPD[20,41]), and one of the BPAAT questions includes walking, it was important to explore if this PA assessment tool could also relate to the number of steps/day. In this study, correlations between the BPAAT score and steps/day were similar to the correlations with MVPA (i.e., ρ=0.435 for daily steps and ρ=0.405 for MVPA). It is tempting to speculate that steps were performed in at least moderate intensity (which corresponds to approximately ≥100 steps/min[42,43]); however, step cadence was not assessed in this study.

One of the limitations of the present study concerns the accelerometer wearing time. Other validation studies have considered valid days those with ≥10h[16] or ≥22.5h[12] of accelerometer data. Since this was a secondary study, it was not possible to define *a priori* the number of hours/day and days patients had to use the accelerometer to be included. Nevertheless, research has shown that 3-5 days are required to reliably estimate habitual PA using accelerometry[44]. In COPD, a previous study showed that 2 days may be sufficient[45]. Another limitation was the period of data collection. Patients completed the BPAAT and used the accelerometer in the following week, which might not have represented their usual week. Still, patients were instructed to maintain their daily routine when using the accelerometer and they were asked to report if some activity was different from their usual weeks. The accelerometer does not allow the assessment of water-based activities (e.g., swimming) which may limit its ability to monitor all daily activities in some patients.

Patients were recruited mainly from primary care centers, and most participants were male and had moderate to severe COPD (GOLD 2-3, 69%), which may limit the external validity of the findings. Future studies should have a more balanced sample and include other clinical measures, such as the GOLD ABCD classification and measures of functional status (e.g., distance walked in the 6-min walk test), as they may be related to patients' PA levels[46,47].

This study showed that 49.1% of patients scored the lowest possible score, suggesting that the BPAAT has floor effects. Further research should be conducted to assess the validity of the BPAAT in other countries and patient populations, as this measure is easy and quick to apply.

Acknowledgments: The authors would like to thank Professor Timothy Oswald (Department of Languages and Cultures, University of Aveiro, Aveiro, Portugal) for collaborating in the back-translation of the tool. This work is a secondary study of three projects funded by Fundo Europeu de Desenvolvimento Regional (FEDER) - Comissão Diretiva do Programa Operacional Regional

do Centro and by Fundação para a Ciência e Tecnologia - FCT (SAICT-POL/23926/2016), and partially funded by Programa Operacional Competitividade e Internacionalização (COMPETE), through COMPETE 2020 (POCI-01-0145-FEDER-016701 and POCI-01-0145-FEDER-028446) and FCT (SFRH/BD/81328/2011; UIDB/04501/2020, UIDB/05704/2020 e UIDP/05704/2020). The funding sources had no role in study design, data collection/analysis/interpretation, writing or decision to submit the manuscript for publication.

References

1. Watz H, Pitta F, Rochester CL, et al. An official European Respiratory Society statement on physical activity in COPD. *Eur. Respir. J.* 2014;44(6):1521-1537.
2. Global Strategy for the Diagnosis Management and Prevention of COPD. *Global Initiative for Chronic Obstructive Lung Disease (GOLD). Available from: http://www.goldcopd.org/.* 2020.
3. Lewthwaite H, Effing TW, Olds T, Williams MT. Physical activity, sedentary behaviour and sleep in COPD guidelines: A systematic review. *Chron. Respir. Dis.* 2017;14(3):231-244.
4. Sallis R. Developing healthcare systems to support exercise: exercise as the fifth vital sign. *Br. J. Sports Med.* 2011;45(6):473-474.
5. Moy ML, Gould MK, Liu I-LA, Lee JS, Nguyen HQ. Physical activity assessed in routine care predicts mortality after a COPD hospitalisation. *ERJ Open Research.* 2016;2(1):00062-02015.
6. Strath SJ, Kaminsky LA, Ainsworth BE, et al. Guide to the Assessment of Physical Activity: Clinical and Research Applications: A Scientific Statement From the American Heart Association. *Circulation.* 2013;128:2259-2279.
7. Rabinovich RA, Louvaris Z, Raste Y, et al. Validity of physical activity monitors during daily life in patients with COPD. *Eur. Respir. J.* 2013;42(5):1205-1215.
8. Armstrong M, Winnard A, Chynkiamis N, Boyle S, Burtin C, Vogiatzis I. Use of pedometers as a tool to promote daily physical activity levels in patients with COPD: a systematic review and meta-analysis. *European Respiratory Review.* 2019;28(154):190039.
9. Martin JB, Krč KM, Mitchell EA, Eng JJ, Noble JW. Pedometer accuracy in slow walking older adults. *International journal of therapy and rehabilitation.* 2012;19(7):387-393.

10. Bassett DR, Jr., Toth LP, LaMunion SR, Crouter SE. Step Counting: A Review of Measurement Considerations and Health-Related Applications. *Sports medicine (Auckland, N.Z.)*. 2017;47(7):1303-1315.
11. Sattler MC, Jaunig J, Tösch C, et al. Current Evidence of Measurement Properties of Physical Activity Questionnaires for Older Adults: An Updated Systematic Review. *Sports Med.* 2020;50(7):1271-1315.
12. Garfield BE, Canavan JL, Smith CJ, et al. Stanford Seven-Day Physical Activity Recall questionnaire in COPD. *Eur. Respir. J.* 2012;40(2):356-362.
13. Gimeno-Santos E, Raste Y, Demeyer H, et al. The PROactive instruments to measure physical activity in patients with chronic obstructive pulmonary disease. *Eur. Respir. J.* 2015;46(4):988-1000.
14. Marshall AL, Smith BJ, Bauman AE, Kaur S. Reliability and validity of a brief physical activity assessment for use by family doctors. *Br. J. Sports Med.* 2005;39(5):294-297; discussion 294-297.
15. Puig Ribera A, Peña Chimenis Ò, Romaguera Bosch M, et al. Cómo identificar la inactividad física en atención primaria: validación de las versiones catalana y española de 2 cuestionarios breves. *Aten. Primaria.* 2012;44(8):485-493.
16. Puig-Ribera A, Martín-Cantera C, Puigdomenech E, et al. Screening Physical Activity in Family Practice: Validity of the Spanish Version of a Brief Physical Activity Questionnaire. *PLoS One.* 2015;10(9):e0136870.
17. Shrikrishna D, Patel M, Tanner RJ, et al. Quadriceps wasting and physical inactivity in patients with COPD. *Eur. Respir. J.* 2012;40(5):1115-1122.
18. Troosters T, Sciurba F, Battaglia S, et al. Physical inactivity in patients with COPD, a controlled multi-center pilot-study. *Respir. Med.* 2010;104(7):1005-1011.
19. Gimeno-Santos E, Frei A, Steurer-Stey C, et al. Determinants and outcomes of physical activity in patients with COPD: a systematic review. *Thorax.* 2014;69:731–739.
20. Cruz J, Brooks D, Marques A. Walk2Bactive: A randomised controlled trial of a physical activity-focused behavioural intervention beyond pulmonary rehabilitation in chronic obstructive pulmonary disease. *Chron. Respir. Dis.* 2016;13(1):57-66.
21. Marques A, Jácome C, Rebelo P, et al. Improving access to community-based pulmonary rehabilitation: 3R protocol for real-world settings with cost-benefit analysis. *BMC Public Health.* 2019;19(1):676.

22. Mokkink LB, Prinsen CA, Patrick DL, et al. *COSMIN Study Design checklist for Patient-reported outcome measurement instruments.* 2019.
23. Terwee CB, Mokkink LB, van Poppel MN, Chinapaw MJ, van Mechelen W, de Vet HC. Qualitative attributes and measurement properties of physical activity questionnaires: a checklist. *Sports Med.* 2010;40(7):525-537.
24. Hajiro T, Nishimura K, Tsukino M, Ikeda A, Koyama H, Izumi T. Analysis of clinical methods used to evaluate dyspnea in patients with chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 1998;158(4):1185-1189.
25. Miller MR, Hankinson J, Brusasco V, et al. Standardisation of spirometry. *Eur. Respir. J.* 2005;26(2):319-338.
26. Sousa VD, Rojjanasrirat W. Translation, adaptation and validation of instruments or scales for use in cross-cultural health care research: a clear and user-friendly guideline. *J. Eval. Clin. Pract.* 2011;17(2):268-274.
27. Demeyer H, Burtin C, Van Remoortel H, et al. Standardizing the analysis of physical activity in patients with copd following a pulmonary rehabilitation program. *Chest.* 2014;146(2):318-327.
28. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. *Med. Sci. Sports Exerc.* 1998;30(5):777-781.
29. Byrom B, Rowe DA. Measuring free-living physical activity in COPD patients: Deriving methodology standards for clinical trials through a review of research studies. *Contemp. Clin. Trials.* 2016;47:172-184.
30. Garber CE, Blissmer B, Deschenes MR, et al. 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.* 2011;43(7):1334-1359.
31. Schober P, Boer C, Schwarte LA. Correlation Coefficients: Appropriate Use and Interpretation. *Anesth. Analg.* 2018;126(5):1763-1768.
32. van Poppel MN, Chinapaw MJ, Mokkink LB, van Mechelen W, Terwee CB. Physical activity questionnaires for adults: a systematic review of measurement properties. *Sports Med.* 2010;40(7):565-600.
33. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977;33(1):159-174.

34. Watson PF, Petrie A. Method agreement analysis: a review of correct methodology. *Theriogenology.* 2010;73(9):1167-1179.
35. Mokkink LB, Terwee CB, Patrick DL, et al. *COSMIN checklist manual.* COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN);2012.
36. Geidl W, Carl J, Cassar S, et al. Physical Activity and Sedentary Behaviour Patterns in 326 Persons with COPD before Starting a Pulmonary Rehabilitation: A Cluster Analysis. *J Clin Med.* 2019;8(9).
37. Jarrett H, Fitzgerald L, Routen AC. Interinstrument Reliability of the ActiGraph GT3X+ Ambulatory Activity Monitor During Free-Living Conditions in Adults. *Journal of Physical Activity and Health.* 2015;12(3):382-387.
38. Sallis JF, Haskell WL, Wood PD, et al. Physical activity assessment methodology in the Five-City Project. *Am. J. Epidemiol.* 1985;121(1):91-106.
39. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int. J. Behav. Nutr. Phys. Act.* 2008;5:56.
40. Marshall SJ, Levy SS, Tudor-Locke CE, et al. Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes. *Am. J. Prev. Med.* 2009;36(5):410-415.
41. Demeyer H, Louvaris Z, Frei A, et al. Physical activity is increased by a 12-week semiautomated telecoaching programme in patients with COPD: a multicentre randomised controlled trial. *Thorax.* 2017;72(5):415-423.
42. Tudor-Locke C, Craig CL, Thyfault JP, Spence JC. A step-defined sedentary lifestyle index: <5000 steps/day. *Appl. Physiol. Nutr. Metab.* 2013;38(2):100-114.
43. O'Brien MW, Kivell MJ, Wojcik WR, D'Entremont G, Kimmerly DS, Fowles JR. Step Rate Thresholds Associated with Moderate and Vigorous Physical Activity in Adults. *Int. J. Environ. Res. Public Health.* 2018;15(11):2454.
44. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. *Med. Sci. Sports Exerc.* 2005;37(11 Suppl):S531-543.
45. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. *Am. J. Respir. Crit. Care Med.* 2005;171(9):972-977.

46. Koolen EH, van Hees HW, van Lummel RC, et al. "Can do" versus "do do": A Novel Concept to Better Understand Physical Functioning in Patients with Chronic Obstructive Pulmonary Disease. *J Clin Med.* 2019;8(3):340.
47. Mihaltan F, Adir Y, Antczak A, et al. Importance of the relationship between symptoms and self-reported physical activity level in stable COPD based on the results from the SPACE study. *Respir. Res.* 2019;20(1):89.

Table 1. Activity categories according to the cut-off values of the Brief Physical Activity Assessment Tool (BPAAT) and accelerometry.

Activity category	**BPAAT**[14]	**Accelerometry (intensity-based approach)**[30]	**Accelerometry (step-based approach)** [30]
Sufficiently active	Total score ≥ 4	a) ≥ 20 min/day of vigorous-intensity PA on ≥3 days OR b) ≥ 30 min/day of moderate-intensity PA on ≥5 days OR c) a combination of both	≥7000 steps/day
Insufficiently active	Total score 0–3	a) Not achieving the minimum recommendations of moderate-to-vigorous PA according to the guidelines	Not achieving the minimum of 7000 steps/day

Abbreviations: BPAAT, Brief Physical Activity Assessment Tool; PA, physical activity.

Notes: The intensity of physical activity assessed by accelerometry was calculated using the algorithms from Freedson et al.[28], based on the number of counts-per-minute (CPM): moderate-intensity PA (1952-5724 CPM); vigorous-intensity PA (5725-∞CPM); moderate-to-vigorous intensity PA (MVPA, 1952-∞CPM).

Table 2. Participants' characteristics (n=110).

	Participants (n=110)
Age, years	66.4±9.6
Sex (male), n(%)	80 (72.7)
BMI, Kg/m^2	27.0±4.7
mMRC, M [Q1-Q3]	2 [1 – 2]
FEV_1, L	1.5±0.7
FEV_1 % predicted	59.3±25.5
FVC, L	7.2±36.0
FVC % predicted	78.6±20.0
FEV_1/FVC ratio	56.0±13.7
GOLD grade, n(%)	
Mild (GOLD 1)	21 (19.1)
Moderate (GOLD 2)	43 (39.1)
Severe (GOLD 3)	33 (30.0)
Very severe (GOLD 4)	13 (11.8)

Data are presented as mean±standard deviation, unless otherwise indicated. Abbreviations: BMI, body mass index; FEV_1, forced expiratory volume in one second; FVC, Forced Vital Capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; mMRC, modified British Medical Research Council questionnaire; M, median; Q, quartile.

Table 3. Physical activity (PA) assessed through the Brief Physical Activity Assessment Tool (BPAAT) and the accelerometer, correlations between PA assessment methods, and comparison of PA duration at different intensities and steps per day between 'insufficiently active' (BPAAT score 0-3) and 'sufficiently active' (BPAAT score ≥4) patients (n=110).

	mean ± SD	**Correlations (ρ)**	**BPAAT Ins. active [b] (n=81)**	**Suf. active [b] (n=29)**	**p-value**
BPAAT total score	1.6±2.0	----	0.5±0.9	4.5±1.2	<0.001
Accelerometer					
Moderate-intensity PA (min/day)[a]	28.8±22.4	0.394**	22.9±17.9	45.5±25.3	<0.001
Vigorous-intensity PA (min/day) [a]	1.3±2.2	0.074	1.1±1.5	1.8±3.3	0.298
MVPA (min/day) [a]	30.1±23.2	0.405**	23.9±18.7	47.3±26.0	<0.001
Daily steps (number)	5490.1±3069.8	0.435**	4714.7±2743.2	7655.8±2930.4	<0.001

* p<0.05 ** p<0.01. Abbreviations: BPAAT, Brief Physical Activity Assessment tool; Ins. active, Insufficiently active; MVPA, moderate to vigorous physical activity; PA, physical activity; SD, standard deviation; Suf. active, sufficiently active.

Notes:

[a]Duration of physical activity at different intensities is presented in minutes per day. The intensity was calculated using the algorithms from Freedson et al.[28], based on the number of counts-per-minute (CPM): moderate-intensity PA (1952-5724 CPM); vigorous-intensity PA (5725-∞CPM); moderate-to-vigorous intensity PA (MVPA, 1952-∞CPM).

[b]Activity categories are based on the cut-off values of the Brief Physical Activity Assessment tool (BPAAT): 'insufficiently active', BPAAT score 0-3; 'sufficiently active', BPAAT score ≥4.

Table 4. Comparison of the activity categories ('insufficiently active' and 'sufficiently active') obtained from the Brief Physical Activity Assessment Tool (BPAAT) and accelerometer data (intensity-based and step-based approaches).

		BPAAT[a] n (%) Ins. active	BPAAT[a] n (%) Suf. active	% Agreement	Kappa (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
MVPA[b]	**Ins. active**	58 (52.7)	6 (5.5)	73.6%	0.43 (0.26–0.60)	0.50 (0.41–0.59)	0.91 (0.85–0.96)	0.79 (0.72–0.87)	0.72 (0.63–0.80)
	Suf. active	23 (20.9)	23 (20.9)						
Steps[c]	**Ins. active**	66 (60.0)	16 (14.5)	74.5%	0.36 (0.17–0.55)	0.52 (0.42–0.61)	0.84 (0.77–0.91)	0.55 (0.46–0.65)	0.82 (0.74–0.89)
	Suf. active	15 (13.6)	13 (11.8)						

Abbreviations: BPAAT, Brief Physical Activity Assessment Tool; Ins. active, insufficiently active; MVPA, moderate to vigorous physical activity; NPV, Negative predictive value; PPV, Positive predictive value; Suf. active, sufficiently active; 95% CI, 95% confidence intervals.

Notes:

[a]Activity categories are based on the cut-off values of the Brief Physical Activity Assessment tool (BPAAT): 'insufficiently active', BPAAT score 0-3; 'sufficiently active', BPAAT score ≥4.

[b]Activity categories are based on cut-off values of the time spent in moderate-to-vigorous physical activity (MVPA) using accelerometry: 'insufficiently active', MVPA <30 minutes per day; 'sufficiently active', MVPA ≥30 minutes per day. MVPA intensity was calculated using the algorithms from Freedson et al.[28], based on the number of counts-per-minute (MVPA, 1952-∞CPM).

[c]Activity categories are based on cut-off values considering the number of daily steps (using accelerometry): 'insufficiently active', <7000 steps/day 'sufficiently active', ≥7000 steps/day.

Table 5. Correlations between BPAAT total score and accelerometry, stratified by age, sex and COPD grades (n=110).

	Correlations with the BPAAT total score (ρ)					
	Age		**Sex**		**COPD grades**	
	<65 years (n=41)	**≥65 years (n=69)**	**Male (n=80)**	**Female (n=30)**	**GOLD 1-2 (n=64)**	**GOLD 3-4 (n=46)**
Accelerometer						
Moderate-intensity PA (min/day)[a]	0.416**	0.440**	0.437**	0.253	0.363**	0.445**
Vigorous-intensity PA (min/day) [a]	-0.050	0.153	0.135	-0.003	0.026	0.134
MVPA (min/day) [a]	0.414**	0.451**	0.455**	0.271	0.369**	0.460**
Daily steps (number)	0.449**	0.475**	0.470**	0.339	0.386**	0.518**

* p<0.05 ** p<0.01. Abbreviations: BPAAT, Brief Physical Activity Assessment Tool; COPD, Chronic obstructive pulmonary disease; MVPA, moderate to vigorous physical activity; PA, physical activity.

[a]Duration of physical activity at different intensities is presented in minutes per day. The intensity was calculated using the algorithms from Freedson et al.[28], based on the number of counts-per-minute (CPM): moderate-intensity PA (1952-5724 CPM); vigorous-intensity PA (5725-∞CPM); moderate-to-vigorous intensity PA (MVPA, 1952-∞CPM).