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Original Research

Test-retest reliability, agreement and construct validity of the International Physical Activity Questionnaire short-form (IPAQ-sf) in people with COPD

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ABSTRACT

Introduction: This study assessed the test-retest reliability/agreement and construct validity of the International Physical Activity Questionnaire short-form (IPAQ-sf) in patients with chronic obstructive pulmonary disease (COPD). It also explored differences in its validity according to age, sex and GOLD airflow obstruction levels.

Methods: 62 participants (68 ± 8 years, 53 males, FEV_1 51 ± 23%pred) completed the Portuguese IPAQ-sf, wore an accelerometer for 7 days and completed a second IPAQ-sf. Test-retest reliability/agreement was assessed with Intraclass Correlation Coefficient ($ICC_{2,1}$), 95% Limits of Agreement (LoA), standard error of measurement (SEM) and minimal detectable change (MDC_{95}) for continuous variables, and percentage of agreement (%agreement) for categories ("active"/"inactive"). Validity was assessed with 95% LoA and Spearman's correlations (ρ) between IPAQ-sf 2 (METs-min/week, time in vigorous [VPA], moderate PA [MPA] and walking) and accelerometry (time in MVPA, VPA, MPA and step counts) for continuous variables; %agreement, Cohen's kappa, and sensitivity specificity and±predictive values for categories. Correlations were also performed for age, sex and GOLD airflow obstruction grades.

Results: Reliability was good ($ICC_{2,1} = 0.707$) with wide LoA (-6446—6409 METs-min/week). SEM and MDC_{95} were 1840 and 4971 METs-min/week, respectively. %agreement between the two IPAQ-sf was 84% (kappa = 0.660). Positive, moderate and significant correlations were found between IPAQ-sf and accelerometry ($0.396 \le \rho \le 0.527$, $p < 0.001$), except for VPA ($p > 0.05$). The strongest correlations were found in age (<65 years) and male ($0.466 \le \rho \le 0.653$, $p < 0.05$). %agreement between tools was 65% (kappa = 0.313), with high sensitivity (0.830) but low specificity (0.500).

Conclusions: The IPAQ-sf seems valid to be used in COPD but caution on its widespread use is recommended as its accuracy may be limited.

1. Introduction

People with chronic obstructive pulmonary disease (COPD) are

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markedly inactive in daily life [1] which contributes to a worsening of lung function, health status [2], increased risk of acute exacerbations, hospitalizations and mortality in this population [3]. Physical activity (PA) is a modifiable factor with potential to improve COPD prognosis, therefore the latest Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines [4] have underlined the importance of assessing and promoting regular PA as part of COPD management.

Abbreviations' list

ACSM	American College of Sports Medicine
BMI	Body mass index
CCI	Charlson Comorbidity Index
CI	Confidence Intervals
ciTechCare	Centre for Innovative Care and Health Technology
COPD –	Chronic Obstructive Pulmonary Disease
COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
FEV_1	Forced Expiratory Volume in first second
GOLD	Global Initiative for Chronic Obstructive Lung Disease
ICC	Intraclass Correlation Coefficient
IPAQ-sf	International Physical Activity Questionnaire short-form
LoA	Limits of agreement
MDC_{95}	Minimal detectable change
METs	Metabolic equivalents
mMRC	modified Medical Research Council dyspnoea scale
MPA –	moderate physical activity
MVPA	Moderate and vigorous physical activity
NPV	Negative predictive value
PA –	Physical Activity
PAR	Stanford Seven-Day Physical Activity Recall
PPV –	Positive predictive value
SD	Standard deviation
SEM	Standard error of measurement
SPSS	Statistical Package for the Social Sciences
VPA –	vigorous physical activity
WHO	World Health Organisation

The International Physical Activity Questionnaire short-form (IPAQ-sf) is one of the most widely used self-reported questionnaires to assess PA. Although good measurement properties were reported in the healthy population of the original study [5], measurement properties are population-specific. In fact, a systematic review has shown that studies assessing the validity of this instrument presented conflicting results, suggesting that evidence to support its use as an indicator of PA is weak [6]. Moreover, poor validity results have also been found in populations with chronic conditions, such as in rheumatoid arthritis [7], fibromyalgia [8] or systemic lupus erythematosus [9]. In COPD, the IPAQ-sf has been used in several studies to estimate patients' PA levels [10–12]. This study showed strong, positive and significant correlations between the IPAQ-sf METs-min/week and moderate and vigorous physical activity (MVPA) measured with an accelerometer ($r = 0.729$, $p = 0.017$), but low percentage of agreement (% agreement) in identifying "physically active" and "physically inactive" patients (% agreement = 20%, kappa = −0.538), and poor to moderate test-retest reliability (Intraclass Correlation Coefficient [ICC] = 0.439, 95% Confidence Intervals [95%CI] −0.267 — 0.838). The small sample size of this study hinders the generalisability of the findings. Further research is therefore needed to assess the measurement properties of the IPAQ-sf in COPD. Furthermore, previous studies have shown differences in PA levels among GOLD airflow obstruction levels [13], and an influence of age and sex in patients' PA behaviour [14], hence it may be important to explore the performance of the IPAQ-sf in these specific subgroups.

This study aimed to assess the test-retest reliability/agreement and construct validity of the IPAQ-sf in people with COPD. A secondary aim of this study was to explore potential differences in the validity of the tool among groups of age, sex, and COPD levels of airflow obstruction.

2. Methods

2.1. Study design

This was a cross-sectional study which was part of a larger study (ref. POCI-01-0145-FEDER-028446; PTDC/SAU-SER/28446/2017). Construct validity of the IPAQ-sf was assessed using accelerometer-based data. Test-retest reliability/agreement was calculated using the IPAQ-sf results obtained in two different occasions separated by 7 days, corresponding to the time participants used the accelerometer.

2.2. Ethical considerations

Ethical approval was obtained prior to study commencement from the Health Units participating in this study. Participants received verbal and written information about the study and provided written informed consent before data collection.

2.3. Sample size

Sample size was defined according to the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) guidelines [15,16], which recommend that a minimum of 50 individuals should be recruited to ensure the quality of studies assessing the measurement properties of instruments.

2.4. Participants

Patients with COPD were identified by physicians of the Leiria Hospital Centre, Baixo Vouga Hospital Centre, University Hospital Centre North Lisbon and a primary care centre (USF Santiago Marrazes), who ensured the fulfilment of the eligibility criteria. Patients included in the study had to be: 18 years old or more; diagnosed with COPD according to the GOLD criteria [4]; clinically stable in the previous month (i.e., no hospital admissions or acute exacerbations); able to understand Portuguese and to provide informed consent. Exclusion criteria consisted of the presence of severe neurologic (e.g., Parkinson, stroke), musculoskeletal (e.g., severe osteoarthritis) or psychiatric disorders (e.g., schizophrenia), unstable cardiovascular disease, or other health condition/impairment (e.g., severe visual or hearing impairment) that could preclude patients from understanding the study and/or participating in data collection. Data were collected at the Centre for Innovative Care and Health Technology (ciTechCare) of the Polytechnic of Leiria, at the Respiratory Research and Rehabilitation Laboratory – School of Health Sciences, University of Aveiro (Lab3R-ESSUA), or at the health units, depending on patients' and services' availability.

2.5. Data collection

Participants completed a structured questionnaire with sociodemographic (age, sex, education level and work status) and general clinical information such as smoking status (never, current or former smokers), dyspnoea perception (modified Medical Research Council dyspnoea scale [mMRC] [17]) and presence of comorbidities (Charlson Comorbidity Index [CCI] [18]) to characterise the sample. Comorbidities were classified as mild (CCI scores of 1–2), moderate (CCI scores of 3–4) or severe (CCI scores ≥5) [18]. Height and weight were collected to calculate the body mass index (BMI). Lung function was assessed according to standardised guidelines [19] with a portable spirometer (MicroLoop, CareFusion, Kent, UK) to characterise airflow obstruction limitation [4]: GOLD grades 1–4 (considering patients' Forced Expiratory Volume in first second percentage predicted [FEV_1% predicted]: GOLD 1 – $FEV_1 \geq 80\%$; GOLD 2–50 ≤ $FEV_1 \leq 79\%$; GOLD 3–30 ≤ FEV_1 ≤ 49% and GOLD 4 – $FEV_1 <30\%$). All patients were advised to take their usual medication before data collection.

Then, participants completed the IPAQ-sf (IPAQ-sf 1) and received an accelerometer (ActiGraph GT3X+, Pensacola, FL) to use for 7 days [20]. Patients were instructed to wear the accelerometer at the waist, on the dominant side, during waking hours, except for bathing or swimming. A second appointment was scheduled 8 days after the first appointment to retrieve the accelerometers and complete the IPAQ-sf once more (IPAQ-sf 2), for further assessment of test-retest reliability and agreement of the tool.

2.6. Measures

2.6.1. International physical activity questionnaire short-form (IPAQ-sf)

The IPAQ-sf is composed of 7 questions, simple to administer in clinical practice, and provides information on the number of days/week and average time/day spent walking, in moderate- and vigorous-intensity activities and sitting, based on the previous 7 days, to further calculate energy expenditure in metabolic equivalents (METs) [5]. The continuous score of the IPAQ-sf can be calculated as "MET level × minutes of activity per day × days per week" and is expressed in METs-min/week. It can be calculated for walking (3.3 METs), MPA (4 METs) and VPA (8 METs). The categorical score of the IPAQ-sf classifies a patients' PA level as "low", "moderate" or "high" [21]. These classifications can be then translated to "physically active" (corresponding to "moderate" or "high" PA levels) and "physically inactive" (which corresponds to "low" PA level) (Table 1). The Portuguese version of IPAQ-sf was used in this study [5] and it takes about 10 min to complete. The questionnaire is free of charge and can be found in the IPAQ website (https://sites.google.com/site/theipaq/home), along with a detailed scoring information.

2.6.2. Accelerometry

Accelerometry was used as a criterion measure to validate the IPAQ-sf, similarly to other validation studies [9,22–24]. In this study, the triaxial accelerometer ActiGraph GT3X+ was used, which has been validated in the COPD population [20,25]. The device collects and stores PA data which can be downloaded and converted into time-stamped PA counts and step counts using specific software (ActiLife 6, version 6.13.3, Pensacola, FL). A valid day was defined as a minimum of 8 h of wearing time [26]. Patients who had less than 5 days of valid data from the 7-day wear interval were excluded, since 4 days are the minimum number of days needed for an accurate assessment of patients' PA using accelerometers [26], and at least 5 days are required to assess whether patients are physically active or not (considering the moderate-intensity PA – Table 1) [27]. Accelerometer-based data were then downloaded and analysed using the algorithms of Freedson (1998) [28] with 60-s epoch, incorporated in the Actilife software: daily time (in min) spent in light-intensity PA (100–1951 counts-per-minute [CPM]), MPA (1952–5724 CPM), VPA (≥5725 CPM), and a combination of both (MVPA) [28]. Data were retrieved in min/week to facilitate the comparison with the results from IPAQ-sf. The number of steps per day and per week was also collected. Participants were classified as "physically active" or "physically inactive" using two approaches, an intensity-based approach and a step-based approach, according to the American College of Sports Medicine (ACSM) guidelines [27] and World Health Organisation (WHO) [29] (Table 1).

Table 1
Categories of "physically active" and "physically inactive" obtained with the IPAQ-sf and accelerometer-based data.

Category	Physically active	Physically inactive
IPAQ-sf	Correspond to "high" and "moderate" scores of the IPAQ-sf: **"High PA level"** a) vigorous-intensity PA on ≥ 3 days achieving ≥1500 MET-min/week OR b) 7 days of any combination of walking, moderate- or vigorous-intensity PA achieving ≥3000 MET-min/week **"Moderate PA level"** a) ≥ 3 days of vigorous-intensity PA of ≥20 min/day OR b) ≥ 5 days of moderate-intensity PA and/or walking of ≥30 min/day OR c) ≥ 5 days of any combination of walking, moderate- or vigorous-intensity PA achieving ≥600 MET-min/week	Correspond to "low" score of the IPAQ-sf: **"Low PA level"** a) No PA is reported OR b) Some PA is reported but not enough to meet categories "high" or "moderate"
Accelerometer (intensity-based approach) [27]	a) ≥ 20 min/day of vigorous-intensity PA on ≥ 3 days, to reach a total of at least 75 min/week OR b) ≥ 30 min/day of moderate-intensity PA on ≥ 5 days, to reach a total of at least 150 min/week OR c) a combination of both	a) No PA is reported OR b) Some PA is reported but not enough to meet the guidelines
Accelerometer (step-based approach) [27]	a) ≥ 7000 steps/day	a) Not achieving the minimum of 7000 steps/day

Legend: IPAQ-sf, International Physical Activity Questionnaire - short form; METs, metabolic equivalent; PA, physical activity.

2.7. Data analysis

Descriptive statistics were used to characterise the sample regarding age, sex, FEV_1% predicted, BMI, education level, work status, smoking status, GOLD airflow obstruction limitation (1–4), dyspnoea (mMRC), comorbidities (CCI) and PA results (IPAQ-sf and accelerometer-based data).

2.7.1. Reliability and agreement

Test-retest reliability of the IPAQ-sf was assessed using: 1) continuous values of IPAQ-sf 1 and IPAQ-sf 2 (METs-min/week); and 2) categories of IPAQ-sf 1 and 2 (i.e., "low PA", "moderate PA" and "high PA"; and "physically active" vs. "physically inactive"). According to the guidelines [16,30,31], the following analyses were conducted:

1) For continuous variables:
   a. Reliability was assessed using $ICC_{2,1}$ and its 95% CI [32]. An ICC of at least 0.70 was considered as a minimum standard for good reliability [33].
   b. Agreement was calculated using the standard error of measurement (SEM $= \frac{SD_{differences}}{\sqrt{2}}$), minimal detectable change at the 95%

confidence level (MDC_{95} = SEM × $\sqrt{2}$ × 1.96), and the Bland and Altman 95% limits of agreement (LoA) [34].

2) For categorical variables:
   a. Percentage of agreement was defined as the total number of participants assigned to the same category (either "physically active" or "physically inactive") by both measures, divided by the total number of participants.
   b. Cohen's weighted kappa coefficient and its 95% CI were used for ordinal variables ("low PA", "moderate PA" and "high PA") and Cohen's kappa for nominal variables ("physically inactive" and "physically active"). Results were interpreted as follows [35]: 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). An acceptable value of kappa was considered as ≥ 0.70 [33].

2.7.2. Construct validity

The IPAQ-sf 2 and accelerometer-based data were used to assess the construct validity of the PA assessment tool, since they referred to the same period. Criterion validity was not possible to assess as there is still no gold standard for the assessment of daily PA [16,36].

The variables used from IPAQ-sf were the following (all in min/week): METs-min/week, time spent in VPA (i.e., product of IPAQ-sf questions 1 and 2), time spent in MPA (i.e., product of IPAQ-sf questions 3 and 4) and in time spent in walking (i.e., product of IPAQ-sf questions 5 and 6). From accelerometry, the following variables were used: time spent in VPA, MPA and MVPA (combination between VPA and MPA) (in min/week), and step counts per week. The question regarding the time spent sitting (Q7) is not included as part of the continuous score and was not addressed in the present study. Normality of data distribution was assessed using the Kolmogorov-Smirnov test for each variable. The following analyses were conducted, according to the guidelines [30]:

1) For continuous variables:
   a. Spearman's rank-order correlations (ρ) or Pearson's correlation coefficient (r) (according to the [non-]normality of data distribution) were used in the total sample and in the following subgroups: 1) age (<65 and ≥65 years old); 2) sex (male and female); and 3) GOLD airflow obstruction levels (GOLD 1, 2, 3 and 4). Construct validity is often considered good if correlations are positive, significant and ≥0.50 [33]. Strength of the correlations were based on criteria from Evans [37]: very weak (0.00–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79) and very strong (0.80–1.0).
   b. Bland and Altman's 95% LoA were used to compare the two measurement methods on variables that have used same units: weekly time spent on vigorous activity (VPA), moderate activity (MPA) and walking.
2) For categorical variables:
   a. The ability of the IPAQ-sf for classifying "physically active" and "physically inactive" patients was evaluated against the accelerometer-based data, using the cut-off points previously described (Table 1). Percentage of agreement and Cohen's kappa coefficient were used.
   b. Sensitivity (i.e., those who were correctly classified as "physically active" by the IPAQ-sf using the accelerometer-based data) and specificity (i.e., those who were correctly classified as "physically inactive" by the IPAQ-sf using the same criteria) were also calculated, including the 95% CI. The 95% CI were calculated for sensitivity and specificity using the following formula = $p \pm 1.96\sqrt{\frac{p(1-p)}{n}}$, where "p" is the relevant proportion (i.e., sensitivity or specificity) and "n" is the total sample [32].
   c. Positive and negative predictive values (PPV and NPV, respectively) were calculated and refer to the proportion of "physically active" (PPV) and "physically inactive" (NPV) participants classified by the IPAQ-sf who were "truly physically active" and "truly physically inactive", respectively, having the accelerometer as the reference standard.

All data were analysed using SPSS version 24 (IBM Corp., Armonk, USA) and GraphPad Prism Version 8.0.1. (263). Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participants

A total of 103 patients with COPD were identified. From these, 18 refused to participate, 2 withdrew from participating and 1 died. Additionally, 2 reported having had an exacerbation in the previous days and 7 were not available to participate at the moment of data collection. When considering the IPAQ scoring guidelines [38] eleven participants were excluded from the analysis due to: presenting a very high score, i.e., >16 h at walking, moderate and vigorous PA (n = 3); being significative outliers, i.e., ≥16 h of different intensities PA (n = 3) and missing data (n = 5; 2 in the IPAQ-sf and 3 in accelerometry). The final sample was composed of 62 participants.

Participants had a mean (± standard deviation) age of 68 ± 8 years old and 53 (86%) participants were male. They were slightly overweight (BMI = 27 ± 5 kg/m^2) and presented a FEV_1 of 51 ± 23% predicted. Their detailed sociodemographic and clinical characteristics are presented in Table 2. Most participants were in GOLD 2 (n = 25, 40%) and GOLD 3 (n = 20, 32%) of airflow obstruction. All participants reported comorbidities, the most common being arterial hypertension (n = 26, 43%), dyslipidemia (n = 18, 30%) and mental health problems, such as anxiety and depression (n = 23, 43%).

Table 2
Participants' sociodemographic and clinical characteristics (n = 62).

Participants' characteristics (n = 62)	
Age (years), mean (SD)	68 (8)
Sex (male), n (%)	53 (86%)
FEV_1% predicted, mean (SD)	51 (23)
BMI (kg/m^2), mean (SD)	27 (5)
Education Level, n (%)	
No qualifications	2 (3%)
1st cycle (years 1–4)	26 (42%)
2nd cycle (years 5–6)	7 (11%)
3rd cycle (years 7–9)	7 (11%)
High school (years 10–12)	14 (23%)
University	6 (10%)
Work status, n (%)	
Retired	50 (82%)
Full/part-time employment	5 (8%)
Unemployed (health-related reason)	5 (8%)
Smoking status, n (%)[1]	
Never	8 (14%)
Current smokers	11 (19%)
Former smokers	39 (68%)
GOLD airflow obstruction levels, n (%)	
GOLD 1	5 (8%)
GOLD 2	25 (40%)
GOLD 3	20 (32%)
GOLD 4	12 (19%)
mMRC, median [Q1; Q3]	2 [1; 2]
CCI, n (%)	
Mild	8 (13%)
Moderate	43 (71%)
Severe	10 (16%)

Legend: BMI, body mass index; CCI, Charlson comorbidity index; FEV_1, forced expiratory volume in first second; FVC, forced vital capacity; mMRC, Modified Medical Research Council; SD, standard deviation. Q, quartile. [1]Missing cases: 4.

3.2. Physical activity levels

Physical activity data are presented in Table 3. None of the variables from the IPAQ-sf or the accelerometer followed a normal distribution, hence data are presented as median (quartile [Q]1; Q3). More than 50% of the sample did not meet the international PA recommendations (median of MPA = 85 min/week), which is lower than the 150 min/week recommended [27]. From 62 participants, 56 used the accelerometer for 7 days (4 used for 6 days and 2 used for 5 days).

3.3. Test-retest reliability and agreement of IPAQ-sf

3.3.1. IPAQ-sf continuous scores

Test-retest reliability and agreement of the IPAQ-sf were first analysed using the continuous scores from IPAQ-sf 1 and 2 (in METs-min/week). The ICC was 0.707 (95% CI 0.515–0.823), and the values of the SEM and MDC_{95} were 1840 METs-min/week and 4971 METs-min/week, respectively.

Fig. 1 presents a Bland and Altman plot with the 95% LoA between the IPAQ-sf 1 and 2 (METS-min/week). A bias (i.e., mean differences between IPAQ-sf 1 and 2) of −18.6 METs-min/week (standard deviation of bias = 3279 METs-min/week) was observed, with wide 95% LoA ranging from −6446 to 6409 METs-min/week, and no evidence of consistent bias was found.

3.3.2. IPAQ-sf categories

The percentage of agreement among IPAQ-sf categories (“low PA”, “moderate PA” and “high PA”) obtained from IPAQ-sf 1 and 2 was 66% and the weighted Cohen’s kappa was 0.496 (95% CI 0.329–0.663), as shown in appendix A. When considering the categories “physically inactive” (i.e., low PA) and “physically active” (i.e., moderate to high PA), the agreement was 84% and the Cohen’s kappa was 0.660 (95% CI 0.493–0.827), as shown in Table 4.

3.4. Validity of the IPAQ-sf

3.4.1. IPAQ-sf and accelerometry - continuous variables

Correlations between measurement methods were positive, moderate and significant in all PA variables ($0.396 \leq \rho \leq 0.527$, $p < 0.001$), except for VPA ($\rho = 0.006$ $p > 0.05$) (appendix B). Overall, the IPAQ-sf overestimated the weekly time spent in activity (mean differences between methods [95% LoA] for VPA = 45 min/week [135–224], MPA = 18 min/week [−480 – 515] and Walking = 35 min/week, [−491 – 561] and this was more evident the longer the patients report being active, particularly in VPA (Figures 2, 3 and 4).

Table 3
Data from the IPAQ-sf, IPAQ-sf 2 (retest) and accelerometer-based data (n = 62).

IPAQ-sf 1 (min/week)	
Total energy expenditure (METs-min/week)	1193 [220; 2996]
Time in moderate PA	60 [0; 285]
Time in vigorous PA	0 [0; 0]
Time in walking	130 [0; 300]
IPAQ-sf 2, median (min/week)	
Total energy expenditure (METs-min/week)	1550 [309; 3254]
Time in moderate PA	73 [0; 304]
Time in vigorous PA	0 [0; 180]
Time in walking	140 [28; 360]
Accelerometry (min/week)	
Time in moderate PA	85 [46; 248]
Time in vigorous PA	1 [1; 2]
Total time in MVPA	87 [47; 248]
Steps (per day)	3504 [2313; 5766]

Legend: IPAQ-sf, International Physical Activity Questionnaire-short form; METs, metabolic equivalent; Min, minutes; MVPA, moderate and vigorous physical activity; PA, physical activity; SD, standard deviation. The results are presented in median (the percentile 25 [Q1]; percentile 75 [Q3]).

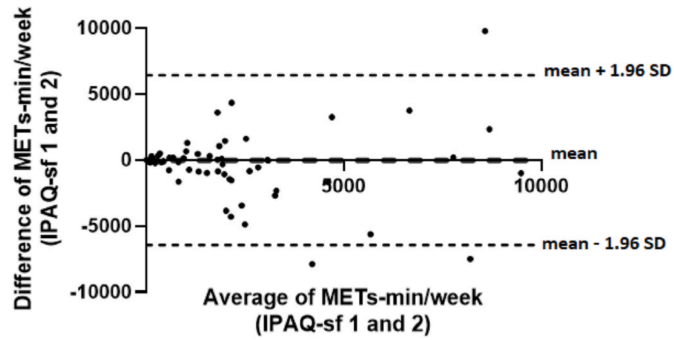

Fig. 1. Bland and Altman plots between IPAQ-sf 1 e 2 (total METs-min/week) in patients with chronic obstructive pulmonary disease (n = 62).

Table 4
Percentage of agreement and weighted Cohen’s kappa among IPAQ-sf categories (“physically inactive” and “physically active”) (n = 62).

		IPAQ-sf 2		% Agreement	Kappa (95% CI)
		Physically Inactive	Physically Active		
IPAQ-sf 1	Physically Inactive	19	6	84%	0.660 (0.493–0.827)
	Physically Active	4	33		

Legend: CI, confidence intervals; IPAQ-sf, International Physical Activity Questionnaire-short form.

3.4.2. Subgroup analyses

Significant, positive and moderate correlations were found between the IPAQ-sf and accelerometry in patients independently of the age group and in male patients (except for VPA in both groups, $p > 0.05$). The highest values were obtained in patients with <65 years ($0.467 \leq \rho \leq 0.651$, $p < 0.05$) and in male patients ($0.466 \leq \rho \leq 0.653$, $p < 0.001$). Correlations were negative and non-significant for female patients ($-0.594 \leq \rho \leq -0.159$, $p > 0.05$). In GOLD grades, significant correlations were only found for: IPAQ-sf total score and total duration in MVPA (accelerometry) (GOLD 2 and 4), time in MPA (GOLD 2), time in walking and in MPA (GOLD 4), and time in walking and steps per week (GOLD 1 and 4) ($p < 0.05$). All correlations can be found in appendix C.

3.4.3. IPAQ-sf and accelerometry - categorical variables

The agreement between instruments to identify “physically active” or “physically inactive” participants was 65% and Cohen’s kappa was 0.313 (95% CI 0.146–0.480) (Table 5). The sensitivity and specificity of IPAQ-sf 2 were 0.830 (95% CI 0.739–0.921) and 0.500 (95% CI 0.380–0.621), respectively. PPV and NPV were 0.564 (95% CI 0.503–0.625) and 0.783 (95% CI 0.731–0.833), respectively (Table 5).

4. Discussion

The present study suggests that the IPAQ-sf is valid to be used in patients with COPD and has good test-retest reliability but with wide limits of agreement which may limit the accuracy of this instrument. When stratifying patients by age, sex and GOLD airflow obstruction levels, the highest correlations were found in patients with <65 years and in male patients.

These findings show that the IPAQ-sf may not be a reliable measure, nevertheless, patients may have also increased awareness of their PA levels by wearing the accelerometer [39,40]. Similar results have been reported in other studies assessing the test-retest reliability of IPAQ-sf in several populations [5,41,42]. Results from the present study were, in general, more positive than the results from a previous exploratory study conducted in COPD [41], which revealed a lower ICC in test-retest

Table 5
Comparison of the activity categories ("physically active" and "physically inactive") obtained from the IPAQ-sf 2 and accelerometer-based data (n = 62).

		Accelerometer		% agreement	Kappa (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
		Physically Inactive	Physically Active						
IPAQ-sf 2	Physically Inactive	18	5	65%	0.313 (0.146–0.480)	0.830 (0.739–0.921)	0.500 (0.380–0.621)	0.564 (0.503–0.625)	0.783 (0.731–0.833)
	Physically Active	17	22						

Legend: CI, confidence intervals; IPAQ-sf, International Physical Activity Questionnaire-short form; NPV, Negative predictive value; PPV, Positive predictive value.

reliability (ICC = 0.439, 95% CI -0.267—0.838) and even wider limits of agreement (−10361—4548 METs-min/week).

This study showed that, when considering the test-retest agreement using the LoA, the standard deviation of the bias of the IPAQ-sf (3279 MET-min/week) was higher than the IPAQ-sf cut-off scores for categorising individuals as "physically active" (i.e., at least 600 MET-min/week) [21]. A similar finding was observed in the MDC_{95} (4971 METs-min/week). When analysing the IPAQ-sf categories "physically active" and "physically inactive", the percentage of agreement was higher than when the categories "high PA level", "moderate PA level" and "low PA level" were considered (84% vs. 66%, respectively), and above the recommended standard for reliability coefficients [16]. This can be justified by the fact that the category "physically active" includes both "high PA level" and "moderate PA level". LoA (or the MDC95) can be considered "true" changes after an intervention [16], and the LoA were wide (i.e., higher than the IPAQ-sf cut-off scores for categorising individuals as "physically active" - at least 600 MET-min/week), the IPAQ-sf may not be appropriate to assess patients' PA levels throughout time. This was somewhat expected since the IPAQ-sf questionnaire was originally designed for PA surveillance studies [5] and not for assessing PA changes or the impact of interventions on individuals' PA levels. Thus, caution is needed when using the IPAQ-sf to register patients' PA evolution/progression in PA levels in clinical practice to avoid imprecise assessment which may interfere with the tailored intervention.

The Stanford Seven-Day Physical Activity Recall (PAR), which was previously tested for construct validity in patients with COPD using accelerometry, showed similar results to the ones provided in the present study ($r = 0.54$, $p < 0.001$) [43]. When comparing the IPAQ-sf to the Clinical Visit PROactive tool [44], this instrument presented slightly higher correlations with related constructs ($r > 0.6$) and higher test-retest reliability (ICC≥0.9). However, the PROactive tool is a hybrid tool (i.e., combines a short patient-reported outcome questionnaire and an activity monitor), which makes it less feasible to be used in clinical settings with low resources. Therefore IPAQ-sf seems to be an applicable questionnaire to assess PA in patients with COPD since the correlations were higher than the threshold recommended [33] in most variables and presented similar results compared to more complex instruments [45, 46]. Nevertheless, no significant correlations were found in VPA measured with the two instruments. This is somewhat expected as few patients engage in vigorous-intensity PA and its duration is normally limited [47]; and IPAQ-sf may overestimate time spent in VPA in this population. The exploratory study carried out in patients with COPD [41] revealed a higher correlation between IPAQ-sf and accelerometry than in the present study ($r = 0.729$, $p = 0.017$). The bigger sample size of the present study may justify the differences found between studies and suggests that larger studies should be carried out in this population to ensure more robust results.

In clinical practice, an accurate tool for assessing PA levels and identifying physically inactive patients is crucial to enable healthcare professionals to provide adequate advice. The IPAQ-sf may be useful for this purpose in COPD but caution is required, since it has high sensitivity but a low specificity (0.830 and 0.500, respectively), which means that the IPAQ-sf may wrongly classify individuals as "active" when they are actually "truly inactive" (low specificity, i.e., a high number of false positives having the accelerometer as the reference standard). These results are in line with a previous study [48], which has adapted and validated the IPAQ-sf to the elderly population (IPAQ-E). The authors found sensitivity results similar to the present study (81%) but higher specificity (85%), since it was an adapted version of IPAQ-sf. Future research should explore whether the IPAQ-E is more suitable for the COPD population, as most patients are older [49]. To the best of the authors' knowledge, previous studies on measurement properties of instruments for PA assessment in patients with COPD have not provided information of sensitivity and specificity. To overcome the uncertainty of classifying a "truly inactive patient" as "physically active" with the IPAQ-sf in clinical practice, the authors suggest healthcare professionals to confirm this categorisation through other methods, such as asking patients about PA routines or, if possible, perform an objective assessment using PA monitors.

When stratifying patients by subgroups, correlations in the subgroup of ≥65 years were below the recommended threshold ($\rho > 0.50$), although significant; additionally, the strongest correlations were found in total METs-min/week in males ($\rho = 0.653$, $p < 0.001$) and <65 years ($\rho = 0.651$, $p < 0.001$), which is in line with the fact that IPAQ-sf was initially developed to people with <65 years [5] and, thus, it may not be adjusted to older people. The study of Hurting-Wennlöf's et al. [48] presented a positive correlation between self-reported activity domains with the objectively assessed PA by an accelerometer ($\rho = 0.277$–0.471), but with a systematic error observed.

Although the IPAQ-sf is widely used in several populations [6–9], this study highlights that caution should be taken when using it as an isolated indicator of PA in COPD [6].

4.1. Limitations and future work

This study has some limitations that need to be acknowledged. The IPAQ-sf was designed to be used by adults aged 18–65 years [5] and, in this study, participants had a mean (±SD) age higher than that range (68 ± 8 years) which may have had influenced the results. Additionally, the original authors of the IPAQ-sf [5] recommended the "last 7 days recall" version of IPAQ-sf for studies assessing PA. However, the last 7 days may not represent the usual pattern of patients' weekly PA, which is dependent of several factors, such as weather conditions [50]. Further studies should explore the "usual week" IPAQ-sf to understand if the correlations remain consistent. Nevertheless, there was only a small percentage (10%) of patients who had less than 7 valid days of PA monitoring. Another limitation concerns to the use of accelerometers as the comparator (*gold standard*). Although they are valid to assess PA of patients with COPD [20,25], some activities such as water-based activities and movement of the upper limbs cannot be assessed [51]. This study was conducted with stable patients with COPD hence, generalisability of results to other states of COPD and/or to other diseases is not possible. In addition, most participants in this sample were male. In female patients, no significant correlations were found between the IPAQ-sf 2 and any of the PA variables obtained through accelerometry. This could be justified by the lower sample size in the female subgroup (n = 9). In addition, there was some variability in the correlation results in the different GOLD grades. This finding may be partially explained by the unbalanced sample sizes in the groups, but it may also indicate that the IPAQ-sf is not an adequate tool for assessing PA levels in different airflow obstruction levels of the disease. Further research with a larger, more balanced sample of female patients and patients in the different GOLD groups and different countries, as well as longitudinal studies, are needed to reenforce these findings and to ensure external validity of findings.

5. Conclusions

Findings from this study showed that the IPAQ-sf presents positive and significant correlations with accelerometry, as well as high test-retest reliability but with large 95% limits of agreement, suggesting that the IPAQ-sf may not be appropriate to assess patients' PA levels throughout time. This was somehow expected since the IPAQ-sf questionnaire was originally designed for PA surveillance studies and not for assessing PA changes or the impact of interventions on individuals' PA levels.

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CRediT authorship contribution statement

Sofia Flora: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **Alda Marques:** Conceptualization, Writing – review & editing, Supervision. **Nádia Hipólito:** Investigation, Writing – review & editing. **Nuno Morais:** Validation, Formal analysis, Resources, Writing – review & editing, Supervision. **Cândida G. Silva:** Validation, Formal analysis, Resources, Writing – review & editing, Supervision. **Filipa Januário:** Writing – review & editing, Supervision. **Fátima Rodrigues:** Writing – review & editing, Supervision. **Bruno P. Carreira:** Writing – review & editing, Supervision. **J. Cruz:** Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing – review & editing, Visualization, Supervision, Project administration.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmed.2022.107087.

Appendix A. Percentage of agreement and weighted Cohen's kappa among IPAQ-sf categories ("low PA", "moderate PA" and "high PA") (n = 62)

		IPAQ-sf 2			% agreement	Kappa (95% CI)
		Low PA	Moderate PA	High PA		
IPAQ-sf 1	Low PA	19	2	4	66%	0.496 (0.329–0.663)
	Moderate PA	4	13	9		
	High PA	0	2	9		

Legend: CI, confidence intervals; IPAQ-sf, International Physical Activity Questionnaire-short form; PA, physical activity.

Appendix B. Correlations (ρ) between IPAQ-sf 2 and accelerometry (n = 62)

Source	Correlations (min/week)	ρ
IPAQ-sf Accelerometry	Total METs-min/week Time in MVPA	0.527**
IPAQ-sf Accelerometry	Time in VPA Time in VPA	0.006
IPAQ-sf Accelerometry	Time in MPA Time in MPA	0.444**
IPAQ-sf Accelerometry	Time in Walking Time in MPA	0.396**
IPAQ-sf Accelerometry	Time in walking Number of steps/week	0.434**

Legend: IPAQ-sf, International Physical Activity Questionnaire-short form; MPA, moderate physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; VPA, vigorous physical activity. *$p < 0.05$ **$p < 0.001$.

Appendix C. Correlations (ρ) between IPAQ-sf 2 and accelerometer-based data stratified by age, sex and GOLD grades

Source	(min/week)	Age		Sex		GOLD airflow obstruction levels			
		< 65 years (n = 20)	≥ 65 years (n = 42)	Male (n = 53)	Female (n = 9)	GOLD 1 (n = 5)	GOLD 2 (n = 25)	GOLD 3 (n = 20)	GOLD 4 (n = 12)
IPAQ-sf 2	Total METs-min	0.651**	0.443**	0.653**	−0.450	0.300	0.491**	0.437	0.635*
AC	Total MVPA								
IPAQ-sf 2	Time in VPA	0.240	−0.152	0.092	−0.359	0.057	0.242	−0.317	0.305
AC	Time in VPA								
IPAQ-sf 2	Time in MPA	0.517*	0.393*	0.524**	−0.294	0.051	0.431*	0.352	0.541
AC	Time in MPA								
IPAQ-sf 2	Time in Walking	0.467*	0.395**	0.466**	−0.159	0.564	0.159	0.312	0.640*
AC	Time in MPA								
IPAQ-sf 2	Time in MPA and walking	0.377	0.444**	0.507**	−0.594	0.975**	0.232	0.282	0.707*
AC	Number of steps/ week								

Legend: AC, accelerometry; COPD, Chronic Obstructive Pulmonary Disease; IPAQ-sf, International Physical Activity Questionnaire-short form; MPA, moderate physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; VPA, vigorous physical activity. *$p < 0.05$ **$p < 0.001$.

Appendix D. Bland and Altman plots (n = 62)

Figures 2, 3 and 4 present a Bland and Altman plot with the 95% LoA between the IPAQ-sf 2 and accelerometery regarding VPA (mean differences (bias) = 45 min/week, SD of bias = 91 min/week, 95% LoA = −135 – 224 min/week), MPA (bias = 18 min/week, SD of bias = 254 min/week, 95% LoA = −480 – 515 min/week) and Walking (bias = 35 min/week, SD of bias = 268 min/week, 95% LoA = −491 – 561 min/week), respectively.

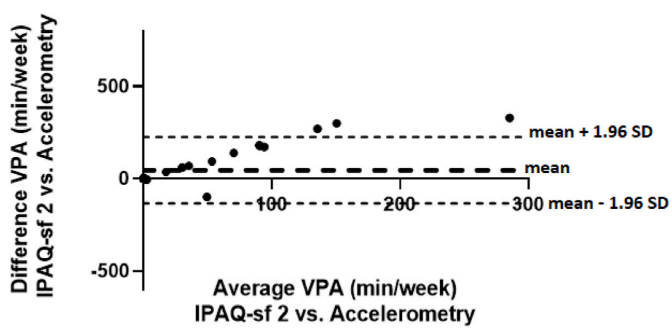

Fig. 2. Bland and Altman plots for vigorous physical activity (VPA) in patients with chronic obstructive pulmonary disease (n = 62). Comparison between IPAQ-sf 2 and accelerometry measurements (min/week).

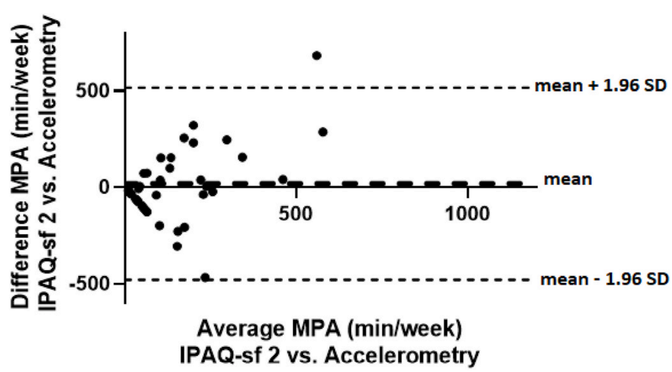

Fig. 3. Bland and Altman plots for moderate physical activity (MPA) in patients with chronic obstructive pulmonary disease (n = 62). Comparison between IPAQ-sf 2 and accelerometry measurements (min/week).

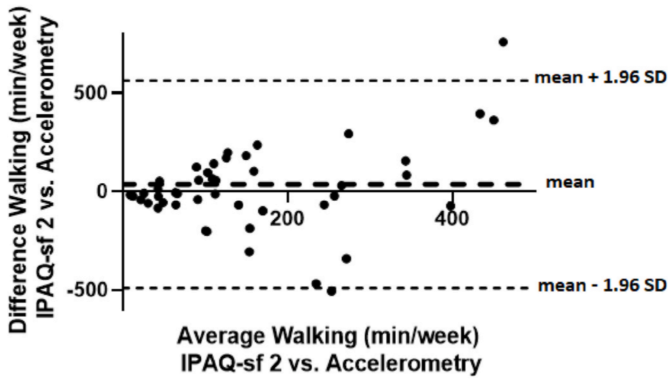

Fig. 4. Bland and Altman plots for walking in patients with chronic obstructive pulmonary disease (n = 62). Comparison between IPAQ-sf 2 and accelerometry measurements (min/week).

References

[1] S.N.W. Vorrink, et al., Level of daily physical activity in individuals with COPD compared with healthy controls, Respir. Res. 12 (2011) 1–8.
[2] B. Waschki, et al., Disease progression and changes in physical activity in patients with chronic obstructive pulmonary disease, Am. J. Respir. Crit. Care Med. 192 (3) (2015) 295–306.
[3] H. Watz, et al., An official European Respiratory Society statement on physical activity in COPD, Eur. Respir. J. 44 (6) (2014) 1521–1537.
[4] Global strategy for the diagnosis management and prevention of COPD, Global Initiative for Chronic Obstructive Lung Disease (GOLD), Available from: https://goldcopd.org/gold-reports/.2022.
[5] C.L. Craig, et al., International physical activity questionnaire: 12-country reliability and validity, Med. Sci. Sports Exerc. 35 (8) (2003) 1381–1395.
[6] P.H. Lee, et al., Validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review, Int. J. Behav. Nutr. Phys. Activ. 8 (2011) 115, 115.
[7] M. Tierney, A. Fraser, N. Kennedy, Criterion validity of the international physical activity questionnaire short form (IPAQ-SF) for use in patients with rheumatoid arthritis: comparison with the SenseWear armband, Physiotherapy 101 (2) (2015) 193–197.
[8] A.S. Kaleth, et al., Validity and reliability of community health activities model program for seniors and short-form international physical activity questionnaire as physical activity assessment tools in patients with fibromyalgia, Disabil. Rehabil. 32 (5) (2010) 353–359.
[9] G.E. Ahn, et al., Self-reported and objectively measured physical activity in adults with systemic lupus erythematosus, Arthritis Care Res. 67 (5) (2015) 701–707.
[10] S.M. Nyssen, et al., Levels of physical activity and predictors of mortality in COPD, J. Bras. Pneumol. 39 (2013) 659–666.
[11] M. Saglam, et al., Functional capacity, physical activity, and quality of life in hypoxemic patients with chronic obstructive pulmonary disease, Int. J. Chronic Obstr. Pulm. Dis. 10 (2015) 423–428.
[12] V. Voncken-Brewster, et al., A randomized controlled trial evaluating the effectiveness of a web-based, computer-tailored self-management intervention for people with or at risk for COPD, Int. J. Chronic Obstr. Pulm. Dis. 10 (2015) 1061–1073.
[13] S. Zogg, et al., Differences in classification of COPD patients into risk groups A-D: a cross-sectional study, BMC Res. Notes 7 (1) (2014) 562.
[14] E. Gimeno-Santos, et al., Determinants and outcomes of physical activity in patients with COPD: a systematic review, Thorax 69 (8) (2014) 731–739.
[15] Lidwine B. Mokkink, et al., COSMIN Methodology for Systematic Reviews of Patient-Reported Outcome Measures, PROMs), 2018.
[16] C.B. Terwee, et al., Qualitative attributes and measurement properties of physical activity questionnaires: a checklist, Sports Med. 40 (7) (2010) 525–537.
[17] D.E. Doherty, et al., Chronic obstructive pulmonary disease: consensus recommendations for early diagnosis and treatment, J. Fam. Pract. Supplement (2006) S1–S8.
[18] M.E. Charlson, et al., A new method of classifying prognostic comorbidity in longitudinal studies: development and validation, J. Chron. Dis. 40 (5) (1987) 373–383.
[19] M.R. Miller, et al., Standardisation of spirometry, Eur. Respir. J. 26 (2) (2005) 319–338.
[20] R.A. Rabinovich, et al., Validity of physical activity monitors during daily life in patients with COPD, Eur. Respir. J. 42 (5) (2013) 1205–1215.
[21] IPAQ, Guidelines for the Data Processing and Analysis of the International Physical Activity Questionnaire, 2005.
[22] A.L. Marshall, et al., Reliability and validity of a brief physical activity assessment for use by family doctors, Br. J. Sports Med. 39 (5) (2005) 294–297. ; discussion 294-7.
[23] A. Puig-Ribera, et al., Screening physical activity in family practice: validity of the Spanish version of a brief physical activity questionnaire, PLoS One 10 (9) (2015), e0136870.
[24] M. Wanner, et al., Validation of the long international physical activity questionnaire: influence of age and language region, Preventive Medicine Reports 3 (2016) 250–256.
[25] H. Van Remoortel, et al., Validity of activity monitors in health and chronic disease: a systematic review, Int. J. Behav. Nutr. Phys. Activ. 9 (1) (2012) 84.
[26] H. Demeyer, et al., Standardizing the analysis of physical activity in patients with copd following a pulmonary rehabilitation program, Chest 146 (2) (2014) 318–327.
[27] C.E. Garber, 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. 43 (7) (2011) 1334–1359.
[28] P.S. Freedson, E. Melanson, J. Sirard, Calibration of the computer science and applications, inc. accelerometer, Med. Sci. Sports Exerc. 30 (5) (1998) 777–781.
[29] WHO, WHO guidelines on physical activity and sedentary behaviour, Available from: https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi, 2020.
[30] J. Kottner, et al., Guidelines for reporting reliability and agreement studies (GRRAS) were proposed, Int. J. Nurs. Stud. 48 (6) (2011) 661–671.
[31] C.A.C. Prinsen, et al., COSMIN guideline for systematic reviews of patient-reported outcome measures, Qual. Life Res. : an international journal of quality of life aspects of treatment, care and rehabilitation 27 (5) (2018) 1147–1157.
[32] P.F. Watson, A. Petrie, Method agreement analysis: a review of correct methodology, Theriogenology 73 (9) (2010) 1167–1179.
[33] C.B. Terwee, Qualitative attributes and measurement properties of physical activity questionnaires, Sports Med. 40 (7) (2010) 525–537.
[34] M.J. Bland, D.G. Altman, Statistical methods for assessing agreement between two methods of clinical measurement, Lancet 327 (8476) (1986) 307–310.
[35] G.K.J. Landis, The measurement of observer agreement for categorical data, Biometrics 33 (1) (1977) 159–174.
[36] M.C. Sattler, et al., Current evidence of measurement properties of physical activity questionnaires for older adults: an updated systematic review, Sports Med. 50 (7) (2020) 1271–1315.
[37] J.D. Evans, Straightforward Statistics for the Behavioral Sciences, Brooks/Cole Publishing, Pacific Groove, 1996.
[38] IPAQ Research Committee, Guidelines for data processing and analysis of the international physical activity questionnaire (IPAQ) – short and long form. https://sites.google.com/site/theipaq/scoring-protocol, 2005.
[39] T. Blikman, et al., Reliability and validity of the Dutch version of the International Physical Activity Questionnaire in patients after total hip arthroplasty or total knee arthroplasty, J. Orthop. Sports Phys. Ther. 43 (9) (2013) 650–659.
[40] G.C. Wendel-Vos, et al., Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity, J. Clin. Epidemiol. 56 (12) (2003) 1163–1169.
[41] J. Cruz, C. Jácome, A. Marques, Is the international physical activity questionnaire (IPAQ-sf) valid to assess physical activity in patients with COPD? Comparison with accelerometer data, BMC Health Serv. Res. 18 (2) (2018) 684.
[42] G. Faulkner, T. Cohn, G. Remington, Validation of a physical activity assessment tool for individuals with schizophrenia, Schizophr. Res. 82 (2–3) (2006) 225–231.
[43] B.E. Garfield, et al., Stanford seven-day physical activity recall questionnaire in COPD, Eur. Respir. J. 40 (2) (2012) 356.
[44] E. Gimeno-Santos, et al., The PROactive instruments to measure physical activity in patients with chronic obstructive pulmonary disease, Eur. Respir. J. 46 (4) (2015) 988–1000.
[45] J.L. Copeland, D.W. Esliger, Accelerometer assessment of physical activity in active, healthy older adults, J. Aging Phys. Activ 17 (1) (2009) 17–30.
[46] A.M. Swartz, et al., Estimation of energy expenditure using CSA accelerometers at hip and wrist sites, Med. Sci. Sports Exerc. 32 (9 Suppl) (2000) S450–S456.

[47] J.E. Hartman, et al., Physical Activity Recommendations in Patients with Chronic Obstructive Pulmonary Disease, Respiration Physiology, 2014.
[48] A. Hurtig-Wennlöf, M. Hagströmer, L.A. Olsson, The International Physical Activity Questionnaire modified for the elderly: aspects of validity and feasibility, Publ. Health Nutr. 13 (11) (2010) 1847–1854.
[49] C. Raherison, P.O. Girodet, Epidemiology of COPD, Eur. Respir. Rev. 18 (114) (2009) 213.
[50] C.B. Chan, D.A. Ryan, Assessing the effects of weather conditions on physical activity participation using objective measures, Int. J. Environ. Res. Publ. Health 6 (10) (2009) 2639–2654.
[51] I.M. Lee, E.J. Shiroma, Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges, Br. J. Sports Med. 48 (3) (2014) 197–201.