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ORIGINAL ARTICLE

International Physical Activity Questionnaire Short Form and accelerometer-assessed physical activity: concurrent validity using six cut-points in HF patients

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Abstract

Aims Physical activity (PA) is an important target for improving clinical outcomes in heart failure (HF) patients. Nonetheless, assessing the daily PA profile in this population is a challenging task, traditionally performed using self-report questionnaires such as the International PA Questionnaire Short Form (IPAQ-SF). This study aimed to evaluate the concurrent validity of the IPAQ-SF and accelerometer-assessed PA using six published cut-points in patients with HF and reduced or mildly reduced ejection fraction.

Methods and results The concordance between the IPAQ-SF and a hip-worn accelerometer regarding daily time spent performing moderate to vigorous PA in bouts of at least 10 min was assessed in 53 participants for seven consecutive days using six different cut-points (Barnett, Dibben, Mark, Sanders, Troiano, and Vaha-Ypya). Spearman's correlation and Bland–Altman plots were used to evaluate concurrent validity between methods. Regressions were used to study the association between patient variables, wear protocol (waking hour or 24 h), and absolute bias. The kappa index was used to evaluate the concordance between IPAQ-SF and accelerometry for classifying patients as active or non-active. All analyses were re-run using non-bouted metrics to investigate the effect of bouted versus non-bouted analysis. The IPAQ-SF and accelerometry showed low to negligible correlation (ρ = 0.12 to 0.37), depending on the cut-point used. The regression analysis showed that the absolute bias was higher in participants following the waking-hour protocol at all cut-points except Dibben's ($P \leq 0.007$). The concordance between the two methods to classify patients as active and non-active was low when using Mark (κ = 0.23) and Barnett (κ = 0.34) cut-points and poor for the remaining cut-points (κ = 0.03 to 0.18). The results of the sensitivity analysis showed negligible to low correlation using non-bouted metrics (ρ = 0.27 to 0.33).

Conclusions Moderate to vigorous PA measures using IPAQ-SF and accelerometers are not equivalent, and we do not encourage researchers to use IPAQ-SF alone when assessing PA in HF patients. Moreover, applying personalized collection and processing criteria is important when assessing PA in HF patients. We recommend following the 24 h protocol and selecting cut-points calibrated in patients with cardiovascular diseases. Finally, it is necessary to develop a new tailored questionnaire that considers walking intensity and is adjusted to the current World Health Organisation recommendations, which use non-bouted metrics.

Keywords Activity monitor; Agreement; Device-based measures; HF; MVPA; Self-reported measures

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Introduction

Physical activity (PA) and exercise-based cardiac rehabilitation are paramount for preventing and managing cardiovascular diseases (CVD) such as heart failure (HF).[1] HF patients with higher levels of moderate to vigorous PA (MVPA) show better quality of life and lower hospitalization and mortality rates.[2] Unsurprisingly, PA is an important target for improving clinical outcomes in HF.[3]

However, assessing the daily PA profile is a challenging task, traditionally performed using self-report questionnaires such as the International PA Questionnaire (IPAQ).[4] The IPAQ Short and Long Form (IPAQ-SF and IPAQ-LF) are instruments designed primarily for population-based surveillance of PA in adults. They have been developed and tested for use in healthy adults aged 15 to 69 years, across different countries and income levels.[5] Even though the IPAQ has not been recommended for research studies that require precise PA quantification to examine changes at the individual level, the questionnaire has been widely used in this context,[6] and both the IPAQ-SF and IPAQ-LF have been applied in populations with clinical conditions such as cancer, fibromyalgia, osteoarthritis, orthopaedic injury, schizophrenia, multiple sclerosis, chronic kidney disease, and HF.[7–15]

Methods for assessing PA have evolved from behavioural observation and self-report using interviews, questionnaires, and diaries to device-based measures using accelerometers, pedometers, armbands, and other instruments that can directly assess one or more dimensions of PA (e.g. frequency, intensity, time, and type) and have the ability to capture a variety of metrics such as number of steps, minutes of activity, intensity of activity, and bouts of activity.[16,17]

The literature shows that self-reported measures have important limitations, including recall bias, missingness, and low precision for measuring time in MVPA, while accelerometers cannot capture the context of PA.[16,18–20] Thus, questionnaires and device-based measures should be applied simultaneously, as they capture different aspects of PA and may influence each other. Device-based measures such as accelerometry provide more consistent results for assessing time in MVPA and estimating rates of adherence to PA guidelines. Nevertheless, their precision in estimating PA levels depends on standardized data collection and processing criteria.[21] Regarding data collection, there is no consensus about which wear protocol (i.e. waking hours and 24 h) to use for assessing MVPA in CVD patients.[22] As for processing criteria, the selection of software (e.g. ActiLife and GGIR) and/or acceleration metrics (e.g. counts/min and raw acceleration) to convert raw acceleration data for analyses has a crucial impact on the accelerometer outcomes.[21] Cut-points have been the most widely used method to link accelerometer metrics with PA intensity (i.e. sedentary, light, moderate, and vigorous).[23]

A recently published review[22] assessed the methods used for collecting and processing accelerometer data in HF patients, reporting that Freedson et al.'s[24] cut-points are the most frequently used. Troiano et al.'s[25] cut-points were also used in one study. Both sets of cut-points were calibrated and validated in healthy adults. Two subsequent studies[12,26] that would have met the review's inclusion criteria applied Dibben et al.'s[27] cut-points, which were calibrated and validated in HF patients, and Santos-Lozano et al.'s[28] cut-points, which were calibrated and validated in healthy older adults. Another study in patients with coronary artery disease[29] used Mark et al.'s[30] cut-points, which were calibrated and validated in the same population. Adults with chronic diseases[31] have been assessed using Hildebrand et al.'s[32] cut-points, which were calibrated and validated in health adults; lung cancer patients[33] using Barnett et al.'s[34] cut-points; and those with metabolic syndrome[35] using Sanders et al.'s cut-points.[36] The latter two sets of cut-points were both calibrated and validated in healthy adults.

The IPAQ-SF has been widely used to monitor PA and compare it with accelerometer measurements. Published studies in clinical populations show different levels of concordance, ranging from significant correlation to no correlation at all. These disparities have been observed in both total PA and PA intensity levels.[8,9,11,12,37]

In HF studies, Schmidt et al.[12] challenged the validity of the IPAQ-SF, suggesting that self-reported measures overestimate MVPA in patients with HF with preserved ejection fraction (HFpEF). Additionally, according to accelerometry measures, these patients spent little time in MVPA, which was the only PA pattern positively associated with prognostic indicators.[12] However, the certainty of these results was limited by the study's small sample size (n = 24) and the single cut-point value used.[28] Moreover, there were no previous studies that correlated IPAQ-SF with accelerometer-derived data conducted in patients with HF with mildly reduced (HFmrEF) or reduced ejection fraction (HFrEF).

This study aims to assess the concurrent validity of the IPAQ-SF and accelerometer-assessed PA using six published cut-points in patients with HF (i.e. HFmrEF or HFrEF).

Methods

Participants and design

This study took place at the Dr Balmis General University Hospital (Alicante, Spain). Patients with HFmrEF (left ventricular ejection fraction [LVEF]: 41% to 49%) or HFrEF (LVEF: ≤40%), as confirmed by an attending cardiologist in the HF unit, were consecutively recruited from December 2020 to July 2022. Inclusion criteria were aged 18 years or older, LVEF of less than 50%, and able to walk independently of aids.

Exclusion criteria were incapacity for ambulatory movement and the inability to understand verbal and written Spanish instructions. Eligible patients were invited to participate, and those who provided written informed consent were included.

Procedure

Participants received an accelerometer and instruction sheet on how to wear it for a period of 7 days (see *Appendix S1*). Anthropometric variables (i.e. weight, height, and body mass index) were recorded, as were clinical characteristics (e.g. aetiology and co-morbidities) collected from medical records. LVEF was measured by echocardiography, which was performed by an experienced cardiologist using an ultrasound system. Images were obtained during a breath hold. Cardiac chamber dimensions, volumes, and LV diastolic function were measured following the American Society of Echocardiography guidelines.[38] LV systolic function was evaluated by calculating biplane ejection fraction (Simpson's method). After returning accelerometers (i.e. on the eighth day), the IPAQ-SF and sociodemographic variables were collected through a personal interview. The period assessed using the IPAQ-SF was the same as for the accelerometer record (i.e. the previous 7 days).

International Physical Activity Questionnaire - Short Form

The Spanish translation of the IPAQ-SF (*Appendix S2*) was used to assess self-reported PA. The IPAQ-SF evaluates the number of days and time spent performing MVPA, walking, and sitting in bouts of at least 10 min over the previous 7 days. The summary score is expressed in PA metabolic equivalent of task (MET)-min per day or week.

Calculation of moderate to vigorous physical activity time in metabolic equivalent of task-minutes

In this study, MET-min were estimated for each participant and classified according to the cumulative weekly MET-min following the IPAQ-SF analysis instructions[4] for both IPAQ-SF and accelerometry data. Specifically, IPAQ-SF weekly MET-min were calculated by adding MET-min of moderate PA (4.0 MET-min/min), vigorous PA (8.0 MET-min/min), and walking (3.3 MET-min/min).[4] Total weekly MET-min from accelerometers were calculated by adding the MET-min of moderate PA (4.0 MET-min/min), and vigorous PA (8.0 MET-min/min). The cumulative weekly MET-min were then used to classify participants into three categories[4]:

- low PA (individuals who did not meet criteria for moderate or high categories);
- moderate PA (≥3 days of vigorous-intensity activity of at least 20 min per day; ≥5 days of moderate-intensity activity and/or walking of at least 30 min per day; or 3–5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum total PA of at least 600 MET-min/week);
- high PA (vigorous activity on at least 3 days with a minimum total PA of at least 1500 MET-min/week or 7 days of any combination of walking and moderate or vigorous activities with a minimum total PA of 3000 MET-min/week).

Additionally, patients were classified as either active or non-active based on their adherence to World Health Organization (WHO) PA recommendations,[39] for both MVPA (≥150 or <150 MVPA-min/week) and/or vigorous PA (≥75 or <75 min/week).

Accelerometers and processing data

Device-based measures of PA were assessed for 7 days using an accelerometer (wGT3X-BT, ActiGraph, Pensacola, FL, USA) worn on the right hip, using waking-hour or 24 h wear protocol.[22] Accelerometer data were processed and analysed either with ActiLife software (for count-based cut-points) or the GGIR package in R (for raw acceleration-based cut-points). Processing details can be found in the supporting information (ActiLife: *Appendix S3*; GGIR: RStudio script, *Appendix S4*). Six different cut-points, validated in patients with CVD,[27,30] older adults,[34,36] and adults,[25,40] were applied to calculate time spent in MVPA (*Appendices S5* and *S6*), which was then translated to MET-min.[4] Steps/min outcomes from accelerometers were treated[41,42] to assess walking cadence and intensity in bouts of at least 10 min (*Appendix S7*).

Wear time validation was performed in line with previous studies,[22,43] including at least three weekdays and one weekend day of 10 h/day or more of monitoring for the waking-hour protocol and at least 16 h/day of monitoring for the 24 h protocol. Non-wear time in ActiLife was identified as at least 90 consecutive minutes of zero activity counts, with allowance for 2 min of activity counts between 0 and 100.[44] Non-wear time in GGIR was estimated based on the standard deviation and the value range of the raw data from each accelerometer axis. Classification was done per 15-min block and based on the characteristics of the 60-min window, centred at these 15 min. A block was classified as non-wear time if the standard deviation of the 60-min window was <13 milligravities (mg, 1 mg = 0.00981 $m \cdot s^{-2}$) and the value range of the 60-min window was <50 mg, for at least two out of the three accelerometer axes.[45] Bouted and non-bouted minutes of MVPA were calculated. An MVPA bout was defined as ≥10 consecutive min above the MVPA cutoff, with the allowance of 2 min below the cutoff.[46] Bouted minutes

of MVPA were determined as mean daily minutes in MVPA bouts. Non-bouted MVPA was determined as the daily average of the total MVPA minutes.

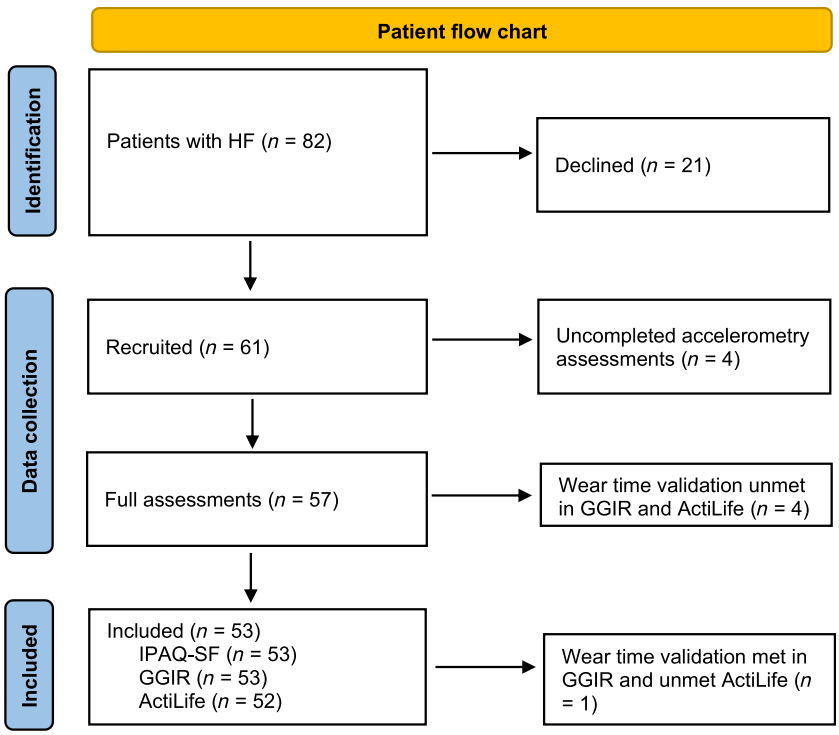
Data analysis

Patients' characteristics were reported as means (standard deviation) for continuous variables and as absolute and relative frequency for categorical variables. The Shapiro–Wilk test and box plots were used to test the normality of the distribution. Non-parametrically distributed values were expressed as medians (interquartile range). Percentiles were calculated as the weighted mean. The Spearman correlation coefficient was used to study the correlation between IPAQ-SF and accelerometry-derived MET-min based on the selected cut-points. The magnitude of correlations was described as follows: 0.00 to 0.30, negligible; 0.31 to 0.50, low; 0.51 to 0.70, moderate; 0.71 to 0.90, high; and 0.91 to 1.00, very high. The absolute bias for each cut-point was calculated as the difference between IPAQ-SF and accelerometry-derived MET-min. Bland–Altman plots were used to study the agreement between IPAQ-SF and accelerometry-derived MET-min. Maximally acceptable limits of agreement were not defined a priori. Simple linear regressions were used to study the association that absolute bias showed with wear protocol (24 h protocol vs. waking-hour protocol) and patient characteristics [i.e. age, weight, height, body mass index, LVEF, categorical LVEF (HFmrEF vs. HFrEF), sex (males vs. females), aetiology (ischaemic vs. non-ischaemic), diabetes (i.e. yes vs. no), dyslipidaemia (i.e. yes vs. no), hypertension (i.e. yes vs. no)]. Regression coefficients represent the increase in absolute bias when the independent variable increases one unit. Subsequently, multiple linear regression analyses were performed for the variables that reached statistical significance in the previous simple linear regressions. On the other hand, the Kappa index was used to evaluate concordance between IPAQ-SF and accelerometry in classifying patients as active or non-active. Concordance was judged as follows: 0.00 to 0.20, poor; 0.21 to 0.40, low; 0.41 to 0.60, moderate; 0.61 to 0.80, good; and 0.81 to 1.00, excellent.[47] Statistical significance was set at $P \leq 0.050$. As a form of sensitivity analysis, all analyses were re-run using non-bouted MET-min (*Appendix S8*). STATA software (version 16.0; Stata Corp LLC, College Station, TX, USA) was used to carry out statistical analyses.

Results

Figure 1 shows the patient flow chart. Of the 82 patients with HF who were initially invited to participate, 61 were finally

Figure 1 Patient flow chart.



recruited, and 4 were excluded because completed assessments (i.e. IPAQ-SF and accelerometry) were not provided. Therefore, 57 patients completed the assessment, and 53 met accelerometry inclusion criteria.

Table 1 shows participants' characteristics. Walking was the only form of PA for 90% of the participants.

Table 2 presents the correlations between IPAQ-SF and accelerometry-derived MET-min. The IPAQ-SF showed low correlation with Dibben et al.'s[26] and Barnett et al.'s[34] cut-points (ρ = 0.35 to 0.37), and negligible correlation with Troiano et al.'s,[25] Mark et al.'s,[30] Sanders et al.'s,[36] and Vaha-Ypya et al.'s[40] cut-points (ρ = 0.12 to 0.23).

Table 3 presents the median IPAQ-SF score and accelerometry-derived MET-min and the absolute bias between the two measures (IPAQ-SF vs accelerometry). The median absolute bias ranged from 691 to 1386 MET-min.

Bland–Altman plots for IPAQ and accelerometry-derived MET-min based on the selected cut-points are shown in *Figure 2*.

Simple regression analyses showed statistically significant differences ($P \leq 0.050$) only according to the protocol used, with each cut-point except for Dibben et al.[27] Therefore, multiple linear regression analyses were not conducted. Regression analyses including the one variable that reached statistical significance (i.e. protocol) are shown in *Table 4*. Absolute bias was higher in participants following the waking-hour protocol ($P \leq 0.007$). The remaining analyses can be found in *Table S4* (*Appendix S8*).

The concordance between the two methods to classify patients as active and non-active following WHO PA recommendations[39] is presented in *Table 5*. Low concordance was found when Mark et al.'s[30] (κ = 0.23) and Barnett et al.'s[34] (κ = 0.34) cut-points were used, while poor concordance was found for the remaining cut-points (κ = 0.03 to 0.18).

The results of the sensitivity analysis using non-bouted MET-min are presented in the supplementary material (*Appendix S8*, *Tables S4* to *S7*). The IPAQ showed low correlation with accelerometry-derived MET-min when using Dibben et al.'s,[27] Mark et al.'s,[30] Barnett et al.'s,[34] Vaha-Ypya et al.'s[40] cut-points (*Table S5*). Compared with the primary analysis, negative median absolute bias was found when Dibben et al.'s[27] and Mark et al.'s[30] cut-points were used (*Table S6*). Bland–Altman plots are shown in *Figure S1*. The results of the regression analyses were comparable with those of the primary analyses (*Table S7*). Concerning participants' classification following WHO PA recommendations, poor concordance was found, regardless of the cut-points used.

When assessing descriptive weekly time in MVPA using both methods (see *Appendix S6*, *Table S2*), participants reported a median of 0 min in IPAQ-SF excluding walking and 440 min including walking. In contrast, with accelerometry, we obtained a median range of 11 to 239 min. As for weekly walking time (see *Appendix S7*, *Table S3*), the results showed that participants reported a median of 420 min walking in

Table 1 Participant characteristics (n = 53)

Variable	Frequency
Age, years	63.6 (9.9) [40–82]
Weight, kg	81.4 (19.3) [51.5–161.6]
Height, cm	168.0 (9.6) [149–183]
BMI, kg/m^2	28.7 (5.3) [18.7–50.4]
LVEF, %	34.7 (7.8) [15–49]
LVEF	
Mildly reduced	17 (32.1)
Reduced	36 (67.9)
Sex	
Male	38 (71.7)
Female	15 (28.3)
NYHA functional class	
I	34 (64.1)
II	18 (34.0)
III	1 (1.9)
Smoking	
Current	17 (32.1)
Never smoker	20 (37.7)
Ex-smoker	16 (30.2)
Aetiology	
Ischaemic	23 (43.4)
Non-ischaemic	30 (56.6)
Co-morbidities	
Type 2 diabetes	18 (34.0)
Dyslipidaemia	32 (60.4)
Hypertension	24 (45.3)
Protocol	
24 h	28 (52.8)
Waking-hour	25 (47.2)
IPAQ-SF score	
Low	13 (24.5)
Moderate	27 (51.0)
High	13 (24.5)
IPAQ-SF weekly MVPA time (without walking)	
Zero	47 (88.7)
Nonzero	6 (11.3)

Values are reported as mean (standard deviation) [range] or frequency (percentage).
BMI, body mass index; IPAQ-SF, International Physical Activity Questionnaire - Short Form; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

Table 2 Spearman correlation analyses between International PA Questionnaire Short Form and accelerometry-derived MET-min, by cut-point

	Mark et al.[30a]	Barnett et al.[34a]	Troiano et al.[25a]	Dibben et al.[27]	Sanders et al.[36]	Vaha-Ypya et al.[40]
Spearman's rho (95% CI)	0.22 (−0.05; 0.47)	0.35 (0.08; 0.56)	0.12 (−0.16; 0.38)	0.37 (0.11; 0.58)	0.20 (−0.08; 0.44)	0.23 (−0.04; 0.47)

CI, confidence interval; Spearman's rho, Spearman correlation coefficient.
[a]One patient did not meet Active Life wear time validation criteria (n = 52).

Table 3 Total weekly MET-min, by cut-point, and absolute bias

	IPAQ	Mark et al.[30a]	Barnett et al.[34a]	Troiano, Berrigan et al.[25a]	Dibben et al.[27]	Sanders et al.[36]	Vaha-Ypya et al.[40]
Total weekly MET-min	1466 (693, 2892)	372 (85, 870)	442 (158, 1021)	44 (0, 386)	944 (156, 1873)	166 (0, 560)	329 (0, 884)
Absolute bias (MET-min)		1199 (279, 2357)	1197 (158, 2077)	1386 (462, 2713)	691 (−357, 1678)	1386 (414, 2354)	1288 (301, 2135)

Absolute bias was calculated as the difference between IPAQ-SF and accelerometry-derived MET-min. Values are reported as median (interquartile range).
IPAQ, International Physical Activity Questionnaire.
[a]One patient did not meet Active Life wear time validation criteria ($n = 52$).

Figure 2 Bland–Altman plot for IPAQ and cut-points used.

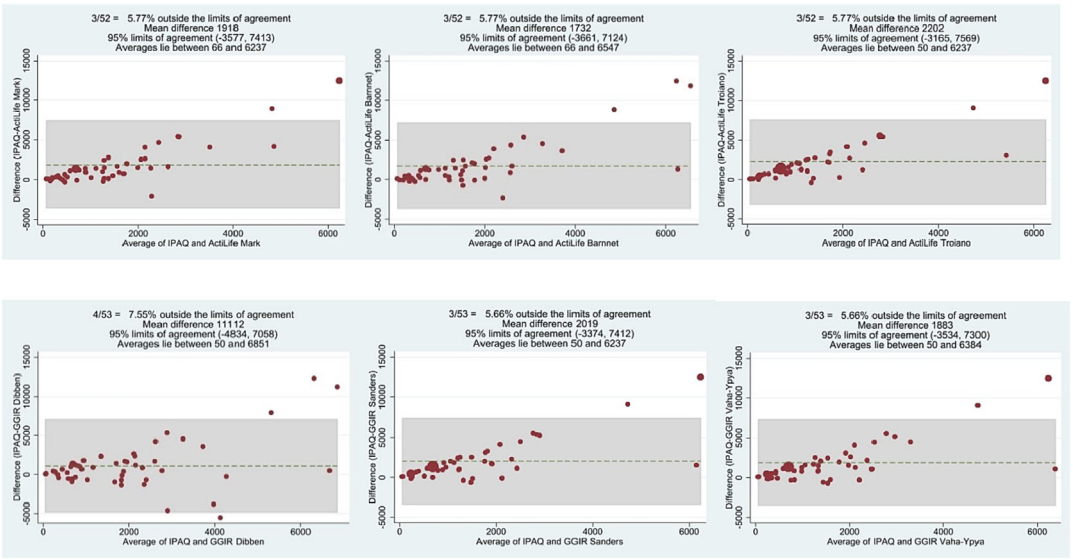


Table 4 Significant results in the regression analysis, showing association between absolute bias and the protocol used (24 h vs. waking-hours)

Cut-points	Variable	*B*	(95% CI)	*P*
Mark et al.[30a]	Protocol	2496	(1081; 3910)	0.001*
Barnett et al.[34a]	Protocol	2184	(760; 3607)	0.003*
Troiano et al.[25a]	Protocol	2176	(760; 3592)	0.003*
Sanders et al.[36]	Protocol	2027	(602; 3453)	0.006*
Vaha-Ypya et al.[40]	Protocol	2021	(588; 3454)	0.007*

The waking-hour protocol was coded with the highest value (i.e.1).
B, regression coefficient; CI, confidence interval.
[a]One patient did not meet Active Life wear time validation criteria ($n = 52$).
*$P \leq 0.050$.

IPAQ-SF, while participants spent 147 min at a cadence of over 60 steps/min (considered continuous walking or running) according to accelerometry. Of these 147 min, 98 min (67%) were performed at slow to medium walking cadence.

Discussion

The main findings of this study are as follows. (i) Correlations between IPAQ-SF and accelerometer measurements are poor (i.e. negligible or low) for all six cut-points used in this study. (ii) The device wear protocol may affect the absolute bias in most cut-points for accelerometry-based measures. (iii) There is no concordance between IPAQ-SF and accelerometers when classifying participants as active or non-active following WHO PA recommendations. (iv) The disparity between self-report and accelerometry-based measure of MVPA cannot be attributed to the IPAQ-SF data collection criteria (bouts of at least 10 min duration).

While the correlations between the IPAQ-SF and accelerometry were low, the highest correlation came about when applying cut-points calibrated to patients with the same traits (i.e. HF).[27] In line with previous comparisons between IPAQ-SF and accelerometry conducted in HFpEF patients[12] and other clinical populations,[8,9,14,15] our data show lower

Table 5 Patient WHO PA classification, kappa index, and concordance between the accelerometry cut-points and IPAQ-SF

		IPAQ			
Cut-points		Non-active	Active	κ	Concordance
Mark et al.[30a]	Non-active	9 (18%)	21 (40%)	0.23	Low
	Active	1 (2%)	21 (40%)		
Barnett et al.[34a]	Non-active	10 (19%)	18 (35%)	0.34	Low
	Active	0 (0%)	24 (46%)		
Troiano et al.[25a]	Non-active	9 (18%)	35 (67%)	0.03	Poor
	Active	1 (2%)	7 (13%)		
Dibben et al.[27]	Non-active	6 (11%)	15 (28%)	0.18	Poor
	Active	4 (8%)	28 (53%)		
Sanders et al.[36]	Non-active	10 (19%)	30 (56%)	0.14	Poor
	Active	0 (0%)	13 (25%)		
Vaha-Ypya et al.[40]	Non-active	10 (19%)	27 (51%)	0.18	Poor
	Active	0 (0%)	16 (30%)		

IPAQ, International Physical Activity Questionnaire.
[a]One patient did not meet Active Life wear time validation criteria ($n = 52$).

PA by accelerometry compared with self-report, a disparity in PA measurements, and a lack of agreement between methods in patients with HFmrEF or HFrEF. Additionally, the Bland–Altman magnitude of the difference between the two methods was higher in more active patients. The lack of correlation and agreement between methods may be related to the different constructs measured by the two instruments. While accelerometry measures motion through acceleration of body mass above a defined threshold, the IPAQ-SF measures the time or perceived time spent performing specific behaviours.[48] Therefore, the use of device-based measures of PA could contribute to avoiding bias in populations with limited physical function and limited knowledge and past experience of regular PA.[49] Thus, in agreement with previous studies, our results support the use of accelerometry for measuring absolute intensity of PA in order to assess adherence to PA guidelines. Having said that, and despite the low correlation found, we encourage researchers to choose cut-points calibrated to the population studied.[16,22] For acceleration metrics based on activity counts, Mark et al.'s[30] cut-points seem to be the most appropriate, even though Freedson et al.'s[24] are the most frequently used in studies with CVD and patients with HF.[16,22] Similarly, for metrics based on mean amplitude deviation (MAD) and sum of vector magnitudes (SVM), we recommend Dibben et al.'s[27] cut-points. Recently, researchers have published open-source alternatives like the GGIR package for processing raw accelerations to obtain different types of acceleration metrics (e.g. Euclidean norm minus one, MAD, and SVM). These tools facilitate the processing and extraction of data collected with several accelerometers, providing valuable insights on PA patterns.[50] This alternative transfers the choice of signal processor from the manufacturer of the accelerometer to PA researchers.[45]

As for the influence of the patient's profile, our data suggest that the device wear protocol may affect the results when using most of the cut-points.[27,30,34,36,40] This finding is attributable to a higher margin of error with the waking-hour versus 24 h protocol. Regarding the wear protocol, as most researchers agree,[22] the 24 h protocol seems more appropriate even if only to monitor MVPA. Nonetheless, future studies are needed to analyse the influence of the 24 h versus waking-hour protocol.

When classifying participants as active or non-active following the latest WHO PA recommendations,[39] regardless of the statistical correlation between the IPAQ-SF and different cut-points, an average of 46% of participants who were classified as non-active using accelerometry were considered active according to the IPAQ-SF, which confirms that the concordance between tools is suboptimal. Our results are more compelling but in line with a previous study in another clinical population,[9] whose authors warned that using self-reported IPAQ-SF may misclassify patients with optimal PA, leading to sub-optimal disease management. Nonetheless, IPAQ-SF may still be useful for identifying how active patients are relative to other patients.[8]

Additionally, 90% of the participants reported that walking was their only form of PA. This outcome could partially explain the disparity of the results between methods. When assessing walking or running cadence in accelerometry, our results show that participants had a slow to medium walking cadence 67% of the time. Thus, caution is warranted when interpreting the walking as assessed by the IPAQ-SF in patients with HFmrEF or HFrEF. As walking and cycling pace were removed from both IPAQ-SF and IPAQ-LF,[4] we could not assess this outcome in our study, but walking pace should be addressed in future studies that aim to investigate self-reported PA surveillance in patients with HF.

Lastly, investigating the effect of bouted versus non-bouted PA data, and contrary to the results of Schmidt et al.[12] in patients with HFpEF, we observed a worse correlation when processing and analysing accelerometry data as non-bouted. This result contradicts the hypothesis that the poor correlation and non-equivalence between IPAQ and accelerometry data are attributable to patients' failure to consider 10-min bouts when self-reporting with the IPAQ-SF.

The main strength of our study is its novel approach; to our knowledge, there are no other studies comparing IPAQ-SF against different cut-points and accelerometer data processing approaches in a clinical population. Furthermore, as far as we know, there are no previous studies assessing correlation and agreement between IPAQ-SF versus accelerometry in patients with HFmrEF or HFrEF.

This study also has some limitations. Firstly, using two different protocols (i.e. 24 h vs waking-hour protocols) without randomized allocation limits intergroup comparability, and this may affect outcomes. Nonetheless, the two protocols were used, and the influence of the protocol on the difference between self-reported and device-based measurements was investigated. Secondly, due to sample size, adjustment for multiple testing has not been performed, and significant results have to be interpreted as exploratory due to a higher chance of false positive results. Thirdly, the IPAQ-SF does not distinguish between different intensities of walking (i.e. brisk walking = 4 MET); this bias was a limitation when transforming self-reported PA measurements from min to MET-min. Lastly, even though WHO PA guidelines are no longer presented in bouts, the IPAQ-SF still collects data in 10-min bouts.

In conclusion, given that high levels of PA in patients with HF have positive effects on HF prognostic indicators,[19] accurate measurements are paramount for optimal clinical management. Although the IPAQ-SF has been commonly applied to monitor PA within clinical populations, MVPA measures using the IPAQ-SF and accelerometers are not equivalent, and we advise researchers against using the IPAQ-SF alone when assessing PA in patients with HFmrEF or HFrEF. Additionally, we cautiously support following the 24 h protocol and selecting cut-points calibrated to the CVD population.[27,30] Finally, a new tailored questionnaire must be developed to consider walking intensity, in line with current WHO recommendations for PA, that is, collecting data on PA of any duration, without a minimum threshold.

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Conflict of interest

None declared.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Accelerometer instructions for both 24 h and waking-hours wear protocols.
Appendix S2. IPAQ-SF Spanish version.
Appendix S3. ActiLife processing details.
Appendix S4. GGIR RStudio script.
Appendix S5. Cut-point thresholds.
Appendix S6. Cut-point outputs.
Appendix S7. Walking time outputs.
Appendix S8. Sensitivity analyses (non-bouted).
Data S1. Supporting Iinformation.

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