A. Ruiz-Casado, L. B.Alejo, A. Santos-Lozano, A. Soria, M. J. Ortega, I. Pagola, C. Fiuza-Luces, I. Palomo, N. Garatachea, H. Cebolla, A. Lucia

www.thieme.com

Validity of the Physical Activity Questionnaires IPAQSF and GPAQ for Cancer Survivors: Insights from a Spanish Cohort

DOI 10.1055/s-0042-103967
Int J Sports Med

Publishing House and Copyright:
© 2015 by
Georg Thieme Verlag KG
Rüdigerstraße 14
70469 Stuttgart
ISSN 0172-4622

Thieme

Validity of the Physical Activity Questionnaires IPAQ-SF and GPAQ for Cancer Survivors: Insights from a Spanish Cohort

Authors A. Ruiz-Casado[1], L. B.Alejo[2], A. Santos-Lozano[3], A. Soria[4], M. J. Ortega[4], I. Pagola[2], C. Fiuza-Luces[6], I. Palomo[4], N. Garatachea[7], H. Cebolla[8], A. Lucia[2]

Affiliations Affiliation addresses are listed at the end of the article

Key words
- tumor
- self-reported physical activity
- physical inactivity
- accelerometer

Abstract

Regular physical activity (PA) decreases mortality risk in survivors of breast and colorectal cancer. Such impacts of exercise have prompted initiatives designed both to promote and adequately monitor PA in cancer survivors. This study examines the validity of 2 widely used self-report methods for PA determination, the International Physical Activity Questionnaire short version (IPAQ-SF) and Global Physical Activity Questionnaire (GPAQ). Both instruments were compared with the triaxial accelerometry (Actigraph) method as an objective reference standard. Study participants were 204 cancer survivors (both sexes, aged 18–79 years). Compared with accelerometry, both questionnaires significantly overestimated PA levels (across all intensities) and underestimated physical inactivity levels. No differences were detected between the 2 questionnaires except for a shorter inactivity time estimated by GPAQ ($p=0.001$). The Bland and Altman method confirmed that both questionnaires overestimated all PA levels. Receiver operating characteristic (ROC) analysis classified IPAQ and GPAQ as fair and poor predictors, respectively, of the proportions of survivors fulfilling international PA recommendations ($\geq 150\,\text{min}\cdot\text{week}^{-1}$ of moderate-vigorous PA). IPAQ-SF showed a higher sensitivity but lower specificity than GPAQ. Our data do not support the use of IPAQ-SF or GPAQ to determine PA or inactivity levels in cancer survivors.

Introduction

The possible link between levels of physical activity (PA) and cancer is receiving increasing attention. So far, research has shown a rising incidence of both cancer and physical inactivity, and the latter has been held accountable for 10+% of the disease burden of breast and colon cancer, both of which are highly prevalent in the developed world [27]. It has been estimated that ~1/3 of adults worldwide engage in $<150\,\text{min}\cdot\text{week}^{-1}$ of moderate-intensity PA such as brisk walking [17]. Higher levels of regular PA have been associated with: (i) a lower cancer risk in the general population [1, 3, 4, 6, 13, 32, 48, 55, 56] and (ii) a lower mortality risk among cancer survivors, particularly of breast and colorectal cancer [8, 20, 46]. Further, there are also data to support an overall dose-dependent benefit of PA, at least for the risk of breast cancer [26, 30, 31, 55].

Thus, besides a need for effective PA assessment in cancer-related epidemiological research, adequate tools for this purpose would be useful to monitor cancer survivors or populations at cancer risk [29, 44]. In effect, PA can be objectively quantified through accelerometry [10] whereby minute-by-minute recordings of PA can be made. Notably, accelerometers were used to show that PA levels were low, i.e., well below minimum recommendations of $150\,\text{min}\cdot\text{week}^{-1}$, in US [35, 36, 50] or Canadian and Australian cohorts of cancer survivors [34]. At least 3–5 days of accelerometer monitoring is required to reliably estimate habitual PA [49] and it is generally accepted that the device should be worn for a minimum of 10 h per day [39]. To simplify data collection, the more conventionally used method of obtaining self-reported PA data through questionnaires may be used. This method is also inexpensive and generally well-accepted by participants, although the validity of obtained data is more questionable [41]. Of several questionnaires developed for PA assessment [51], 2 have been widely used: the International Physical Activity (IPAQ) and Global Physical Activity (IPAQ) questionnaires. The IPAQ was originally developed as an instrument for cross-national records of PA [9]. Today, a simpler, short form (IPAQ-SF) and a

accepted after revision
February 15, 2016

Bibliography
DOI http://dx.doi.org/10.1055/s-0042-103967
Published online: 2016
Int J Sports Med

ISSN 0172-4622

Correspondence
Dr. Ana Ruiz-Casado
Department of Oncology
Hospital Universitario Puerta de Hierro
28222 Majadahonda
Spain
Tel.: +00/341/9171 48
Fax: +00/34911/966 71
arcasado@salud.madrid.org

long form (IPAQ-LF) exist, both of which involve 7-day recall of PA. The short version is recommended for national monitoring [9]. Other than a recent study reporting that IPAQ-LF overestimated PA levels in women with breast cancer [21], no study has assessed the validity of IPAQ in cancer survivors. The other questionnaire, GPAQ, was developed by the World Health Organization for PA surveillance across countries and no validation data are available for cancer survivors.

The present study was designed to determine the validity of IPAQ-SF and GPAQ in a Spanish population of cancer survivors using accelerometry as the reference standard.

Methods

This cross-sectional study examined a cohort of cancer survivors undergoing follow-up at a large hospital in Madrid (Hospital Universitario de Fuenlabrada, Madrid, Spain). Accelerometry PA data for this cohort have been recently reported by our group [42]. The study protocol met the ethical standards of the journal [18] and adhered to the tenets of the Declaration of Helsinki and the statements in Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [52,53]. The study received Institutional Review Board (Hospital Universitario de Fuenlabrada) approval. Written informed consent was obtained from all participants.

As detailed elsewhere [42], cancer survivors (n = 204) were recruited from the hospital's Oncology Department between May 2011 and June 2012 if they met the following criteria: aged 18–79 years; able to walk independently and understand requirements for valid accelerometry; time after cancer diagnosis ≥ 1 year; time after last anti-cancer treatment (chemotherapy, radiotherapy or surgery) ≥ 3 months; no evidence of tumor recurrence or metastasis.

All accelerometry data (see below) were analyzed by the same experienced observer (C.F.-L.). To check the reliability of these measurements, data from 18 randomly selected participants (9/group) were analyzed by an external observer who was blinded to the results obtained (N.G.). A third researcher with expertise in accelerometry recordings compared the results obtained by the 2 independent observers (A.S.-L.). All subjects wore a triaxial Actigraph GT3X monitor device (Actigraph, Pensacola, FL, USA) for a minimum of 5 (and a maximum of 10) consecutive days. The validity of this device to quantify free-living PA, at least within frequencies (~2–4 Hz) common to most types of daily activities, has been previously shown by our group [45]. In each participant, monitoring was continued for a minimum of 5 days including 2 weekend days, and a minimum of 10 h of complete accelerometry data were recorded per day. For participants providing more than 5 consecutive days of recordings, only the data for the last 5 days including 2 weekend days were used [42]. The predefined epoch and sample rate were 15 s and 30 Hz, respectively. Data were analyzed using ActiLife5 LITE software (Actigraph, Pensacola, FL, USA). Outcome variables were expressed as average intensity (counts $\cdot$ min^{-1}) and counts were transformed into time (average min $\cdot$ day^{-1} and total min $\cdot$ week^{-1}) engaged in either physical inactivity or light, moderate and vigorous PA using the following cut-offs [14]: inactivity < 100 counts $\cdot$ min^{-1}; light PA = 100–1 951 counts $\cdot$ min^{-1}; moderate PA = 1 952–5 724 counts $\cdot$ min^{-1} [corresponding to 3–5.9 metabolic equivalents (METs), where 1 MET is equivalent to an oxygen consumption of 3.5 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}]; and vigorous PA ≥ 5 725 counts $\cdot$ min^{-1} (≥ 6 METs). For any PA to be considered 'moderate PA', 10 consecutive minutes of observation had to exceed the moderate intensity cut-off, with allowance for a maximum of 2 observations falling below the cut-off during that period (8 out of 10 min had to be above the cut-off).

All participants completed the Spanish versions of IPAQ-SF [38] and GPAQ upon return of the accelerometers (within the same day and with no predetermined or randomized order for the 2 questionnaires) [2].

Data analysis

Outliers in questionnaire and accelerometry data, i.e., data outside the inter-quartile range, were removed by constructing box and whisker plots. Since PA data did not follow a normal distribution, we used the Wilcoxon signed-rank to compare the differences between questionnaire and accelerometry data. Agreement between the 2 questionnaires (IPAQ-SF and GPAQ) vs. accelerometry was assessed with the Bland-Altman technique [5]. Association between the difference and magnitude of measurements (i.e., heteroscedasticity) was examined by regression analysis, entering the difference between the 2 methods (IPAQ-SF or GPAQ vs. accelerometry) as the dependent variable and the averaged value between them as the independent variable [45].

The χ^2 test was used to evaluate the difference between: i) the percentage of subjects who fulfilled minimum PA recommendations according to IPAQ-SF, GPAQ and accelerometry data and ii) the sensitivity and specificity of the IPAQ-SF and GPAQ. Finally, receiver operating characteristic (ROC) curves were constructed to determine the areas under the curve (AUC) and 95 % confidence intervals, specificity and sensitivity. According to AUCs, the 3 methods were classified as excellent (≥ 0.90), good (0.80 to 0.89), fair (0.70 to 0.79) or poor (< 0.70) predictors of the fulfillment of minimum PA recommendations. All statistical tests were performed using PASW software (v. 22.0 for MAC, Chicago).

Results

Table 1 shows the main clinical characteristics of study cohort. Patients did not have any evidence of cancer and all had completed the treatment. Almost half (46 %) of the total sample had breast cancer and 26 % had colorectal cancer. Outliers were identified from IPAQ-SF, GPAQ and accelerometer data, resulting in 11 values from 204 (**Fig. 1**). Finally, complete accelerometer data were available for 177 cancer survivors whereas complete IPAQ-SF and GPAQ data were available for 183 participants.

Levels of PA obtained through IPAQ-SF, GPAQ and accelerometry and χ^2 test for adherence to minimum PA recommendations are provided in **Table 2**. Compared with the accelerometry data, both questionnaires significantly overestimated PA levels across all intensities and underestimated inactivity levels ($p < 0.01$). No differences were detected between the 2 questionnaires except for a shorter inactivity time estimated by GPAQ ($p = 0.010$). The aforementioned results did not change essentially when analyzing both sexes separately or the most frequent type of cancer in the present cohort (breast cancer) vs. the other type of tumors) (**Supplementary File 1**).

The Bland and Altman procedure (**Table 3** and **Supplementary File 2**) confirmed that both questionnaires overestimated all intensities of PA. According to the heteroscedasticity data, the

Table 1 Main descriptive and clinical data of the study cohort (initial n = 204).

Gender	
Men (%)	36%
Women (%)	64%
Age (mean ± D)	54 ± 11 yr
BMI (mean ± SD)	27.9 ± 4.9 kg/m^2
Overweight (% with BMI > 25 kg/m^2)	40%
Obese (% with BMI > 30 kg/m^2)	33%
Smokers	
Yes (%)	22%
No (%)	80%
Remember having received PA recommendation by any health practitioner?	
Yes (%)	48%
No (%)	52%
Exercise recommendation registered in medical records	
Yes	15%
No (%)	85%
Type of cancer	
Breast	46%
Colon	17%
Rectal	9%
Testicular/germinal	5%
Ovarian	4%
Lung	4%
Head and neck	3%
Uterine cervix	2%
Bladder	2%
Stomach	2%
Other (sarcoma, uterus, pancreas, renal, nasopharynx, thymus – each < 2%)	6%
Survival time (median ± SD)	4 ± 4 yr
Time since end-treatment (median ± SD)	3 ± 4 yr
Type of treatment	
Surgery	97%
Chemotherapy	81%
Radiotherapy	54%

BMI, body mass index; PA, physical activity

difference and the average total time estimated by GPAQ/IPAQ-SF vs. accelerometry in all PA intensities were only significantly correlated for vigorous PA (▶ **Table 3**). Moreover, significant positive association was detected between both questionnaires in all PA intensities as well as inactivity (▶ **Table 3**, right column, i.e., all *p*-values for Pearson correlation coefficients < 0.001). Our ROC analysis served to identify IPAQ-SF and GPAQ as fair and poor predictors, respectively, of the proportion of patients meeting minimum PA recommendations (▶ **Table 4**). IPAQ-SF showed a higher sensitivity (true positive rate) but lower specificity (true negative rate) than GPAQ.

Discussion

This study is the first to compare the performance of 2 widely used PA questionnaires (IPAQ-SF and GPAQ) using accelerometer data as reference to determine PA and inactivity levels in cancer survivors. General agreement between self-reported and accelerometer-measured PA levels was poor and correlation coefficients were lower than recommended [51]. Hence, according to our data, these questionnaires cannot be considered the best option to assess PA or inactivity levels in this subject population, as they tend to overestimate PA levels while underestimating inactivity time. A systematic review concluded that IPAQ-SF overestimated PA as measured by objective criterion by an average of 84% [28]. Greatest differences between self-reported and accelerometry data were produced for vigorous PA and inactivity levels. Thus, these questionnaires are not even useful to identify individuals who do not meet minimum PA recommendations. Given the recently reported benefits of PA against cancer risk or mortality [44] and provocative data indicating a relationship between PA and lower cancer mortality [24, 25, 33], our findings have implications for the adequate quantification of PA in cancer survivors.

Subjective methods (questionnaires) of PA determination have been used in the most influential studies leading to international recommendations, and these methods are considered useful for large-scale screening as they are inexpensive and easy to administer. However, questionnaires often seem to overestimate (or even underestimate) PA levels [43]. Self-reported PA data are susceptible to error due to misreporting because of a tendency to reflect social desirability or due to cognitive limitations related to recall or comprehension. In effect, self-reporting of PA can be particularly difficult in the elderly. Individuals also tend to overreport PA and underestimate sedentary pursuits such as watching television [23]. Sims et al. noted that people who had been specifically encouraged to exercise reported a greater volume of PA compared with PA levels inferred from heart rate data [47]. In a recent report, the authors argued that the use of questionnaires to estimate PA and inactivity levels could result in failure to detect real relationships with metabolic and vascular disease risk factors or underestimation of the strength of those relationships [8].

IPAQ was developed to evaluate an individual's level of PA in terms of getting around, leisure time activities and household tasks. The questionnaire targets the age range 15–65 and until further development and testing is undertaken, its use in older or younger persons is not recommended. IPAQ-SF was designed for surveillance studies in which time is limited and consists of 8 items to estimate time spent conducting moderate to vigorous PA and inactivity (time spent sitting). This short form assesses 4 PA intensity levels: 1) vigorous PA such as aerobics, 2) moderate-intensity PA such as leisure-cycling, 3) walking and 4) sitting. The first comprehensive validation of IPAQ-SF was conducted across 12 countries, and correlations with data obtained using the uniaxial CSA model 7164 accelerometer were reported [9]. Spain was not included among these countries. However, the wide range of Spearman correlations reported raises concerns about the validity of the questionnaire for use across populations. Indeed, the single study using the expensive doubly labeled water technique revealed marked underestimation of questionnaire-derived energy expenditure at higher PA levels [37]. In a systematic review of 23 validation studies of the IPAQ-SF it was also observed that in most studies, this questionnaire only shows discrete correlation with objective measures of PA such as accelerometers [28]. Effectively, although some authors indicate a few exceptions (with vigorous PA and walking providing some acceptable correlations), none of the IPAQ-SF studies reviewed reached the minimal acceptable correlation standard of 0.5 recommended for objective measures. These authors make a call for additional well-designed studies. A recent meta-analysis showed overall convergent validity of IPAQ within each PA category; using a short form to estimate the amount of PA as a form of continuous measures was found acceptable if the primary interest of the study is not domain-specific measures [22].

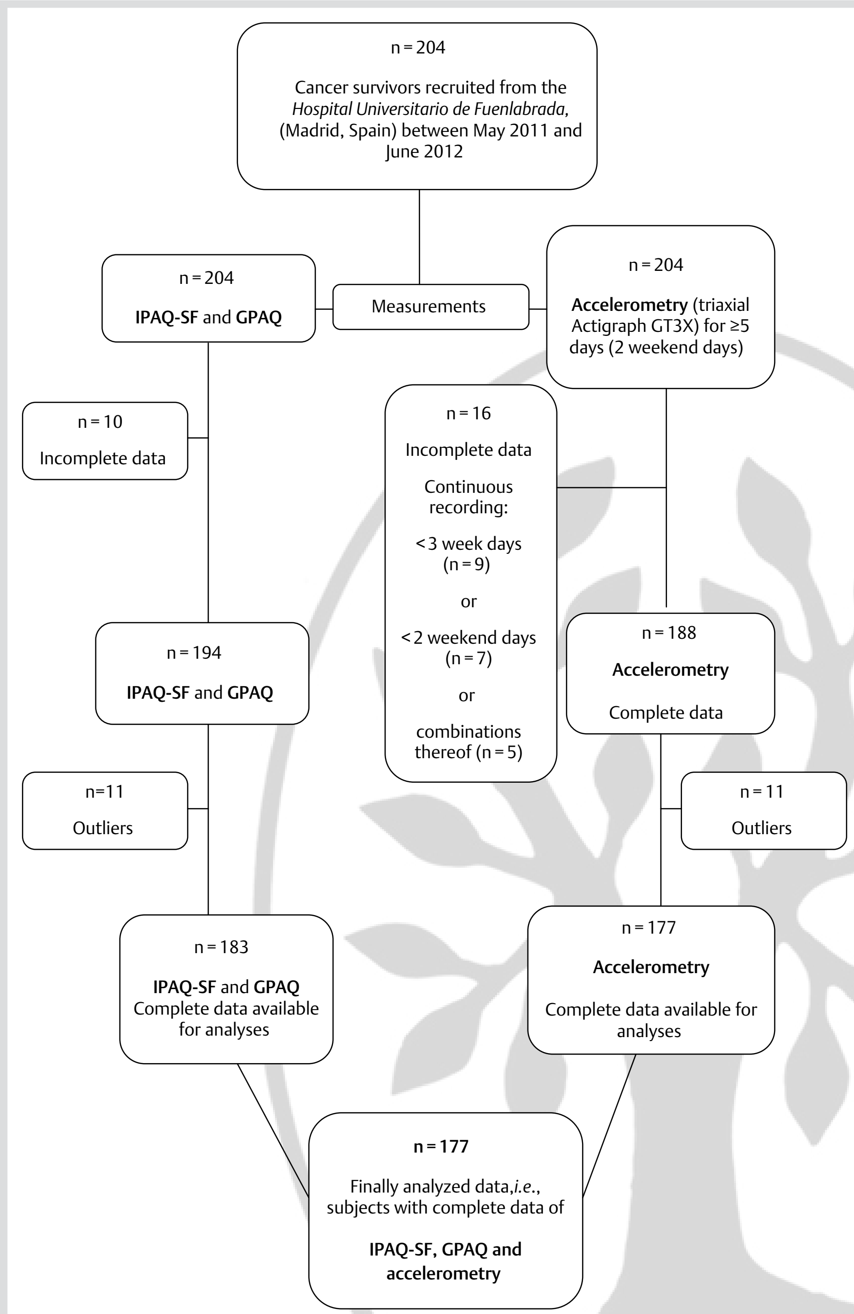


Fig. 1 Flow diagram of participants and measurements.

Table 2 Physical activity and inactivity levels determined using the 3 assessment methods.

	Accelerometry	IPAQ-SF	GPAQ	*p*-value accelerometry vs. IPAQ-SF	*p*-value accelerometry vs. GPAQ	*p*-value IPAQ-SF vs. GPAQ
Vigorous PA (min·week^{-1})	6 ± 17	37 ± 114	17 ± 47	**0.002**	**0.007**	0.182
Moderate PA (min·week^{-1})	360 ± 196	650 ± 586	606 ± 637	**<0.001**	**<0.001**	0.127
Inactivity (min·week^{-1})	3 583 ± 1 065	1 793 ± 914	1 635 ± 947	**<0.001**	**<0.001**	**0.010**
Adherence to minimum PA recommendations (%)	91 %	87 %	81 %	0.490	0.060	0.330

Data are from cancer survivors with complete data of the 3 methods (n = 177) and expressed as mean ± SD. GPAQ, global physical activity questionnaire; IPAQ-SF, international physical activity questionnaire short form; PA, physical activity. Note: Minimum recommendations are ≥150 min·week^{-1} of MVPA. Significant *p*-values are in bold

Our findings are consistent with reports indicating the IPAQ-SF questionnaire's over-reporting of total PA. Johnson-Kozlow et al. compared IPAQ-LF with 7-Day Physical Activity Recall (PAR) in women diagnosed with breast cancer [21]. Besides poor validity correlation (0.33), IPAQ-LF overestimated total PA by 247 % and showed poor sensitivity (71 %) and specificity (59 %) for predicting adherence to minimum PA recommendations. After its translation and adaptation for use in Latin American subjects [38, 40], IPAQ-SF has also shown poor validity for assessing moderate to vigorous PA [40].

Table 3 Bland and Altman analysis (Bias, SD, 95 % LOA) and heteroscedasticity analysis (Pearson's R, 95 % CI and *p*-value) of physical activity and inactivity data.

	Accelerometry vs. IPAQ-SF	Accelerometry vs. GPAQ	IPAQ-SF vs. GPAQ
Vigorous PA (min·week^{-1})			
Bias	27	7	12
SD	111	34	81
95 % LOA	−190, 245	−60, 75	−147, 170
Pearson's R	0.98	0.73	0.40
95 % CI	(0.97, 0.99)	(0.65, 0.79)	(0.27, 0.52)
p-value	**<0.001**	**<0.001**	**<0.001**
Moderate PA (min·week^{-1})			
Bias	279	242	43
SD	574	588	647
95 % LOA	−845, 1 403	−911,6, 1 395	−1 312, 1 225
Pearson's R	−0.04	−0.03	0.25
95 % CI	(−0.19, 0.11)	(−0.18, 0.12)	(0.11, 0.38)
p-value	0.62	0.68	**<0.001**
Inactivity (min·week^{-1})			
Bias	−1 824	1 988	169
SD	1 308	1 231	864
95 % LOA	−4 367, 739	−4 400, 425	−1 863, 1 525
Pearson's R	0.07	0.17	0.67
95 %CI	(−0.08, 0.22)	(0.02, 0.31)	(0.58, 0.74)
p-value	0.36	**0.02**	**<0.001**

95 % CI, 95 % confidence interval; 95 % LOA, 95 % limit of agreement; GPAQ, global physical activity questionnaire: IPAQ-SF, international physical activity questionnaire short form; PA, physical activity. Significant *p*-values are in bold

Table 4 Receiver operating characteristic (ROC) data for the capacity of IPAQ-SF and GPAQ to predict the fulfillment of minimum physical activity recommendations (≥150 min·week^{-1} of moderate-vigorous physical activity).

	AUC	Sensitivity *	Specificity * *
IPAQ-SF	0.716 (95 %CI: 0.546, –0.886)	89 %	46 %
GPAQ	0.640 (95 %CI: 0.468, 0.812)	82 %	54 %

AUC, area under the curve; CI, confidence interval; GPAQ, global physical activity questionnaire; IPAQ-SF, international physical activity questionnaire short form
* *p*-value for IPAQ-SF vs. GPAQ = 0.228; * * *p*-value for IPAQ-SF vs. GPAQ = 0.322

The validity of GPAQ determined here with respect to the reference accelerometry method was similar to that observed for IPAQ-SF, and this instrument also returned a poor negative predictive value [11]. In the present clinical setting, these 2 widely used questionnaires failed to identify people who were physically inactive. We would particularly need to identify these persons to target them for interventions promoting PA. Recent epidemiologic studies have reported on the health hazards of sedentary behavior especially sitting time. This behavior is perhaps one of the most difficult domains to assess through questionnaires as demonstrated by poor correlations with objectively measured sedentary time according to Helmerhorst [19] and confirmed by our data. A Norwegian study also detected large variations between self-reported (IPAQ-SF) and accelerometer-measured PA and sedentary time [12]. The higher volume of self-reported vs. accelerometer-measured vigorous-intensity PA detected here is consistent with the findings of others [12, 15, 41]. Thus, differences between the 2 types of data were enhanced for the higher activity levels, which is also in agreement with the results of other validation studies using different IPAQ versions [15, 16, 54].

The major strength of our study is that it is the largest to compare self-reported and accelerometry PA data in individuals with a history of cancer and the first to compare IPAQ-SF and GPAQ against accelerometer data in this type of population. Its main limitation is the small geographical area examined, reducing its external validity. A further limitation is that reliability was not assessed and that the order of questionnaire administration was not randomized. Accelerometry also has some inherent limitations including its inability to accurately assess the intensity of specific exercise modalities such as weight-lifting, cycling and swimming. The choice of somewhat arbitrary cut-offs to classify intensities could be viewed as another limitation of this method.

In conclusion, our data do not support the use of IPAQ-SF or GPAQ to determine PA or inactivity levels in cancer survivors. We propose the use of more objective methods to cover the need to accurately quantify PA levels and promote PA both in cancer survivors or other target populations and for research purposes.

Acknowledgements

This study was funded by a grant from "Fondos para las estrategias 2010 del Ministerio de Sanidad y Política Social" approved at the Consejo Interterritorial del Sistema Nacional de Salud (Spain) as support for the program Management Strategies in Cancer.

Research by A. Lucia is supported by Fondo de Investigaciones Sanitarias (FIS, grant#PI12/00914) and Fondos Feder

Conflict of interest: The authors have no conflict of Authors to declare.

Affiliations
[1] Department of Medical Oncology, Hospital Universitario Puerta de Hierro, Majadahonda, Spain
[2] Universidad Europea. Instituto de Investigación i + 12, Madrid, Spain Ciencias del Deporte, European University of Madrid, Madrid, Spain
[3] Department of Health Sciences, European University Miguel de Cervantes, Valladolid, Spain
[4] Department of Oncology, Hospital Universitario de Fuenlabrada, Madrid, Spain
[5] Sports, European University of Madrid, Madrid, Spain
[6] Instituto de Investigación i +12, Madrid, Spain Biomedicine, Universidad Europea de Madrid, Madrid, Spain

[7] Physiotherapy and Nursing, University of Zaragoza, Huesca, Spain, Huesca, Spain
[8] Department of Social Stratification, Universidad Nacional Educación a Distancia, Madrid, Spain

References

1 *Abioye AI, Odesanya MO, Abioye AI, Ibrahim NA.* Physical activity and risk of gastric cancer: a meta-analysis of observational studies. Br J Sports Med 2015; 49: 224–229
2 *Armstrong T, Bull F.* Development of the World Health Organisation Global Physical Activity Questionnaire (GPAQ). J Public Health 2006; 14: 66–70
3 *Behrens G, Jochem C, Keimling M, Ricci C, Schmid D, Leitzmann MF.* The association between physical activity and gastroesophageal cancer: systematic review and meta-analysis. Eur J Epidemiol 2014; 29: 151–170
4 *Behrens G, Leitzmann MF.* The association between physical activity and renal cancer: systematic review and meta-analysis. Br J Cancer 2013; 108: 798–811
5 *Bland JM, Altman DG.* Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1: 307–310
6 *Boyle T, Keegel T, Bull F, Heyworth J, Fritschi L.* Physical activity and risks of proximal and distal colon cancers: a systematic review and meta-analysis. J Natl Cancer Inst 2012; 104: 1548–1561
7 *Campbell PT, Patel AV, Newton CC, Jacobs EJ, Gapstur SM.* Associations of recreational physical activity and leisure time spent sitting with colorectal cancer survival. J Clin Oncol 2013; 31: 876–885
8 *Celis-Morales CA, Perez-Bravo F, Ibanez L, Salas C, Bailey ME, Gill JM.* Objective vs. self-reported physical activity and sedentary time: effects of measurement method on relationships with risk biomarkers. PLoS One 2012; 7: e36345
9 *Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P.* International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003; 35: 1381–1395
10 *Chen KY, Bassett DR Jr.* The technology of accelerometry-based activity monitors: current and future. Med Sci Sports Exerc 2005; 37: S490–S500
11 *Chu AH, Ng SH, Koh D, Muller-Riemenschneider F.* Reliability and validity of the self- and interviewer-administered versions of the global physical activity questionnaire (GPAQ). PLoS One 2015; 10: e0136944
12 *Dyrstad SM, Hansen BH, Holme IM, Anderssen SA.* Comparison of self-reported versus accelerometer-measured physical activity. Med Sci Sports Exerc 2014; 46: 99–106
13 *Farris MS, Mosli MH, McFadden AA, Friedenreich CM, Brenner DR.* The association between leisure time physical activity and pancreatic cancer risk in adults: a systematic review and meta-analysis. Cancer Epidemiol Biomarkers Prev 2015; 24: 1462–1473
14 *Freedson PS, Melanson E, Sirard J.* Calibration of the computer science and applications, inc. accelerometer. Med Sci Sports Exerc 1998; 30: 777–781
15 *Hagstromer M, Ainsworth BE, Oja P, Sjostrom M.* Comparison of a subjective and an objective measure of physical activity in a population sample. J Phys Act Health 2010; 7: 541–550
16 *Hagstromer M, Oja P, Sjostrom M.* The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr 2006; 9: 755–762
17 *Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, Lancet Physical Activity Series Working G.* Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet 2012; 380: 247–257
18 *Harriss DJ, Atkinson G.* Ethical standards in sport and exercise science research: 2016 update. Int J Sports Med 2016; 36: 1121–1124
19 *Helmerhorst HJ, Brage S, Warren J, Besson H, Ekelund U.* A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. Int J Behav Nutr Phys Act 2012; 9: 103
20 *Holmes MD, Chen WY, Feskanich D, Kroenke CH, Colditz GA.* Physical activity and survival after breast cancer diagnosis. JAMA 2005; 293: 2479–2486
21 *Johnson-Kozlow M, Sallis JF, Gilpin EA, Rock CL, Pierce JP.* Comparative validation of the IPAQ and the 7-Day PAR among women diagnosed with breast cancer. Int J Behav Nutr Phys Act 2006; 3: 7
22 *Kim Y, Park I, Kang M.* Convergent validity of the international physical activity questionnaire (IPAQ): meta-analysis. Public Health Nutr 2013; 16: 440–452
23 *Klesges RC, Eck LH, Mellon MW, Fulliton W, Somes GW, Hanson CL.* The accuracy of self-reports of physical activity. Med Sci Sports Exerc 1990; 22: 690–697
24 *Kuiper JG, Phipps AI, Neuhouser ML, Chlebowski RT, Thomson CA, Irwin ML, Lane DS, Wactawski-Wende J, Hou L, Jackson RD, Kampman E, Newcomb PA.* Recreational physical activity, body mass index, and survival in women with colorectal cancer. Cancer Causes Control 2012; 23: 1939–1948
25 *Lahart IM, Metsios GS, Nevill AM, Carmichael AR.* Physical activity, risk of death and recurrence in breast cancer survivors: A systematic review and meta-analysis of epidemiological studies. Acta Oncol 2015; 54: 635–654
26 *Laukkanen JA, Rauramaa R, Makikallio TH, Toriola AT, Kurl S.* Intensity of leisure-time physical activity and cancer mortality in men. Br J Sports Med 2011; 45: 125–129
27 *Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, Lancet Physical Activity Series Working G.* Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012; 380: 219–229
28 *Lee PH, Macfarlane DJ, Lam TH, Stewart SM.* Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): a systematic review. Int J Behav Nutr Phys Act 2011; 8: 115
29 *Leitzmann M, Powers H, Anderson AS, Scoccianti C, Berrino F, Boutron-Ruault MC, Cecchini M, Espina C, Key TJ, Norat T, Wiseman M, Romieu I.* European Code against Cancer 4th Edition: Physical activity and cancer. Cancer Epidemiol 2015, doi:10.1016/j.canep.2015.03.009
30 *Li T, Wei S, Shi Y, Pang S, Qin Q, Yin J, Deng Y, Chen Q, Wei S, Nie S, Liu L.* The dose-response effect of physical activity on cancer mortality: findings from 71 prospective cohort studies. Br J Sports Med 2015, doi:10.1136/bjsports-2015-094927
31 *Li Y, Gu M, Jing F, Cai S, Bao C, Wang J, Jin M, Chen K.* Association between physical activity and all cancer mortality: Dose-response meta-analysis of cohort studies. Int J Cancer 2015, doi:10.1002/ijc.29828
32 *Liu L, Shi Y, Li T, Qin Q, Yin J, Pang S, Nie S, Wei S.* Leisure time physical activity and cancer risk: evaluation of the WHO's recommendation based on 126 high-quality epidemiological studies. Br J Sports Med 2015, doi:10.1136/bjsports-2015-094728
33 *Lu Y, John EM, Sullivan-Halley J, Vigen C, Gomez SL, Kwan ML, Caan BJ, Lee VS, Roh JM, Shariff-Marco S, Keegan TH, Kurian AW, Monroe KR, Cheng I, Sposto R, Wu AH, Bernstein L.* History of recreational physical activity and survival after breast cancer: The california breast cancer survivorship consortium. Am J Epidemiol 2015; 181: 944–955
34 *Lynch BM, Boyle T, Winkler E, Occleston J, Courneya KS, Vallance JK.* Patterns and correlates of accelerometer-assessed physical activity and sedentary time among colon cancer survivors. Cancer Causes Control 2015, doi:10.1007/s10552-015-0683-4
35 *Lynch BM, Dunstan DW, Healy GN, Winkler E, Eakin E, Owen N.* Objectively measured physical activity and sedentary time of breast cancer survivors, and associations with adiposity: findings from NHANES (2003–2006). Cancer Causes Control 2010; 21: 283–288
36 *Lynch BM, Dunstan DW, Winkler E, Healy GN, Eakin E, Owen N.* Objectively assessed physical activity, sedentary time and waist circumference among prostate cancer survivors: findings from the National Health and Nutrition Examination Survey (2003–2006). Eur J Cancer Care (Engl) 2011; 20: 514–519
37 *Maddison R, Ni Mhurchu C, Jiang Y, Vander Hoorn S, Rodgers A, Lawes CM, Rush E.* International Physical Activity Questionnaire (IPAQ) and New Zealand Physical Activity Questionnaire (NZPAQ): a doubly labelled water validation. Int J Behav Nutr Phys Act 2007; 4: 62
38 *Martinez SM, Ainsworth BE, Elder JP.* A review of physical activity measures used among US Latinos: guidelines for developing culturally appropriate measures. Ann Behav Med 2008; 36: 195–207
39 *Matthews CE, Hagstromer M, Pober DM, Bowles HR.* Best practices for using physical activity monitors in population-based research. Med Sci Sports Exerc 2012; 44: S68–S76
40 *Medina C, Barquera S, Janssen I.* Validity and reliability of the International Physical Activity Questionnaire among adults in Mexico. Rev Panam Salud Publica 2013; 34: 21–28
41 *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
42 *Ruiz-Casado A, Verdugo AS, Solano MJ, Aldazabal IP, Fiuza-Luces C, Alejo LB, del Hierro JR, Palomo I, Aguado-Arroyo O, Garatachea N, Cebolla H, Lucia A.* Objectively assessed physical activity levels in Spanish cancer survivors. Oncol Nurs Forum 2014; 41: E12–E20
43 *Sallis JF, Saelens BE.* Assessment of physical activity by self-report: status, limitations, and future directions. Res Q Exerc Sport 2000; 71: S1–S14

44 *Sanchis-Gomar F*, *Lucia A*, *Yvert T*, *Ruiz-Casado A*, *Pareja-Galeano H*, *Santos-Lozano A*, *Fiuza-Luces C*, *Garatachea N*, *Lippi G*, *Bouchard C*, *Berger NA*. Physical inactivity and low fitness deserve more attention to alter cancer risk and prognosis. Cancer Prev Res (Phila) 2015; 8: 105–110

45 *Santos-Lozano A*, *Marin PJ*, *Torres-Luque G*, *Ruiz JR*, *Lucia A*, *Garatachea N*. Technical variability of the GT3X accelerometer. Med Eng Phys 2012; 34: 787–790

46 *Schmid D*, *Leitzmann MF*. Association between physical activity and mortality among breast cancer and colorectal cancer survivors: a systematic review and meta-analysis. Ann Oncol 2014; 25: 1293–1311

47 *Sims J*, *Smith F*, *Duffy A*, *Hilton S*. The vagaries of self-reports of physical activity: a problem revisited and addressed in a study of exercise promotion in the over 65 s in general practice. Fam Pract 1999; 16: 152–157

48 *Thune I*, *Furberg AS*. Physical activity and cancer risk: dose-response and cancer, all sites and site-specific. Med Sci Sports Exerc 2001; 33: S530–S550 discussion S609–S510

49 *Trost SG*, *McIver KL*, *Pate RR*. Conducting accelerometer-based activity assessments in field-based research. Med Sci Sports Exerc 2005; 37: S531–S543

50 *Tucker JM*, *Welk GJ*, *Beyler NK*. Physical activity in U.S.: adults compliance with the Physical Activity Guidelines for Americans. Am J Prev Med 2011; 40: 454–461

51 *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: 565–600

52 *Vandenbroucke JP*, *von Elm E*, *Altman DG*, *Gotzsche PC*, *Mulrow CD*, *Pocock SJ*, *Poole C*, *Schlesselman JJ*, *Egger M*, *Initiative S*. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. PLoS Med 2007; 4: e297

53 *von Elm E*, *Altman DG*, *Egger M*, *Pocock SJ*, *Gotzsche PC*, *Vandenbroucke JP.Initiative S*. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Ann Intern Med 2007; 147: 573–577

54 *Wolin KY*, *Heil DP*, *Askew S*, *Matthews CE*, *Bennett GG*. Validation of the International Physical Activity Questionnaire – Short among Blacks. J Phys Act Health 2008; 5: 746–760

55 *Wu Y*, *Zhang D*, *Kang S*. Physical activity and risk of breast cancer: a meta-analysis of prospective studies. Breast Cancer Res Treat 2013; 137: 869–882

56 *Zhong S*, *Ma T*, *Chen L*, *Chen W*, *Lv M*, *Zhang X*, *Zhao J*. Physical activity and risk of lung cancer: A meta-analysis. Clin J Sport Med 2015, doi:10.1097/JSM.0000000000000219

Supplementary Material

Supplementary File 1 Physical activity and inactivity levels using the three methods according to sex and type of tumor (breast vs other than breast).

Physical inactivity and activity levels determined using the 3 assessment methods in women only with complete data of the 3 methods (n = 118).

	Accelerometry	IPAQ-SF	GPAQ	*p*-value accelerometry vs. IPAQ-SF	*p*-value accelerometry vs. GPAQ	*p*-value IPAQ-SF vs. GPAQ
Vigorous PA (min · week^{-1})	3 ± 10	34 ± 108	13 ± 30	**0.001**	**0.012**	0.520
Moderate PA (min · week^{-1})	364 ± 181	636 ± 610	610 ± 591	**< 0.001**	**< 0.001**	0.875
Inactivity (min · week^{-1})	3 653 ± 979	1 644 ± 830	1 582 ± 836	**< 0.001**	**< 0.001**	0.172
Adherence to minimum PA recommendations (%)	89 %	85 %	83 %	0.335	0.189	0.723

Physical inactivity and activity levels determined using the 3 assessment methods in men only with complete data of the 3 methods (n = 59).

	Accelerometry	IPAQ-SF	GPAQ	*p*-value accelerometry vs. IPAQ-SF	*p*-value accelerometry vs. GPAQ	*p*-value IPAQ-SF vs. GPAQ
Vigorous PA (min · week^{-1})	10 ± 26	43 ± 123	26 ± 69	0.353	0.215	0.227
Moderate PA (min · week^{-1})	375 ± 246	686 ± 536	609 ± 718	**0.001**	0.221	**0.008**
Inactivity (min · week^{-1})	3 500 ± 1 140	2 077 ± 1 004	1 739 ± 1 132	**< 0.001**	**< 0.001**	**0.018**
Adherence to minimum PA recommendations (%)	92 %	90 %	80 %	0.752	0.066	0.124

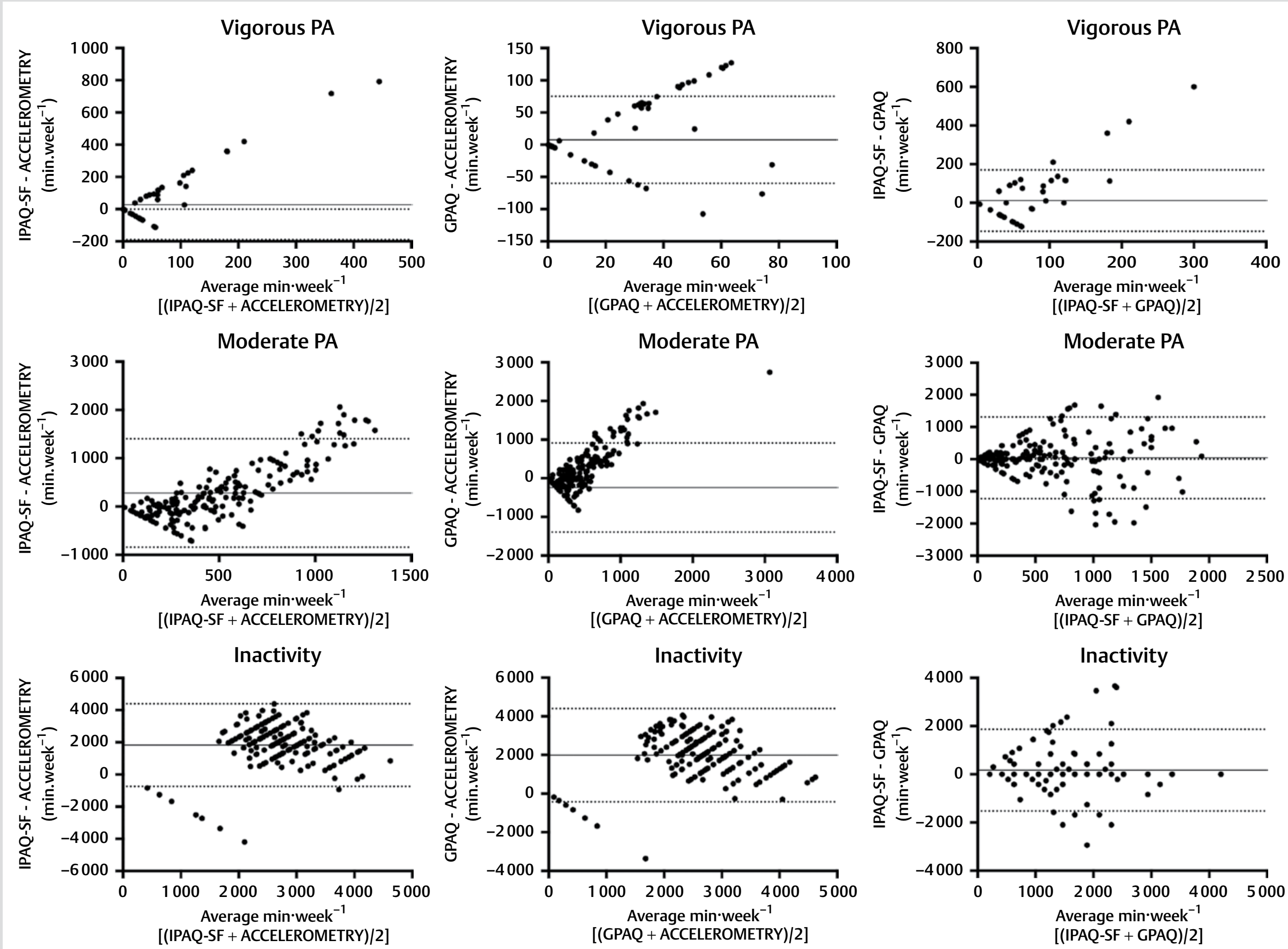
Physical inactivity and activity levels determined using the 3 assessment methods in subjects with breast cancer only with complete data of the 3 methods (n = 85 (99 % women)).

	Accelerometry	IPAQ-SF	GPAQ	*p*-value accelerometry vs. IPAQ-SF	*p*-value accelerometry vs. GPAQ	*p*-value IPAQ-SF vs. GPAQ
Vigorous PA (min · week^{-1})	3 ± 10	33 ± 101	11 ± 28	**0.020**	**0.022**	0.426
Moderate PA (min · week^{-1})	342 ± 163	627 ± 611	577 ± 598	**0.001**	**0.003**	0.636
Inactivity (min · week^{-1})	3 686 ± 969	1 635 ± 850	1 651 ± 800	**< 0.001**	**< 0.001**	0.642
Adherence to minimum PA recommendations (%)	87 %	84 %	82 %	0.516	0.394	0.838

Physical inactivity and activity levels determined using the 3 assessment methods in subjects with tumors other than breast cancer with complete data of the 3 methods (n = 92).

	Accelerometry	IPAQ-SF	GPAQ	*p*-value accelerometry vs. IPAQ-SF	*p*-value accelerometry vs. GPAQ	*p*-value IPAQ-SF vs. GPAQ
Vigorous PA (min · week^{-1})	8 ± 22	40 ± 123	23 ± 58	**0.040**	0.101	0.292
Moderate PA (min · week^{-1})	376 ± 221	669 ± 566	631 ± 670	**< 0.001**	**0.004**	0.072
Inactivity (min · week^{-1})	3 496 ± 1 135	1 925 ± 949	1 622 ± 1 059	**< 0.001**	**< 0.001**	**0.003**
Adherence to minimum PA recommendations (%)	92 %	88 %	82 %	0.321	**0.029**	0.218

Data are mean ± SD. GPAQ, global physical activity questionnaire; IPAQ-SF, international physical activity questionnaire short form; PA, physical activity. Note: Minimum recommendations are ≥ 150 min · week^{-1} of MVPA. Significant *p*-values are in bold



Supplementary File 2 Bland and Altman analyses.