ORIGINAL ARTICLE

COMPARISON OF ACCELEROMETER-BASED MEASUREMENT WITH THE INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (LONG FORM) IN THE ASSESSMENT OF PHYSICAL ACTIVITY LEVEL

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ABSTRACT

Accurate measurement of physical activity depends on the validity and reliability of measurement instruments. The objective of the present study was to compare the assessed moderate-to-vigorous intensity component of physical activity as measured by an accelerometer and by the International Physical Activity Questionnaire. From the target population of Malaysian government employees, 225 participants (mean age= 34.84±8.41 years; 71.1% women) wore an accelerometer on two consecutive weekdays and one weekend day and completed the International Physical Activity Questionnaire (IPAQ). Three assessments were conducted at four- and six-month intervals to compare total time spent in moderate-to-vigorous intensity physical activity (MVPA) as measured by accelerometer and by the IPAQ. The criterion validity of the IPAQ was evaluated by Bland-Altman analysis and Pearson's correlation coefficients, and specificity and sensitivity were calculated. Higher MVPA times were reported on the IPAQ (p<0.001) as compared to the accelerometer, while strong to very strong correlations (ranging from -0.784 to -0.981) were observed between the two instruments. The IPAQ showed good specificity incorrectly classifying adequately active individuals, but its sensitivity to identifying inadequately active people was low. The IPAQ overestimated MVPA among Malaysian government employees and demonstrated modest evidence of criterion validity. Further evaluation of self-report physical activity instruments such as the IPAQ in other Malaysian populations could help to ensure more accurate assessment of physical activity data in the country.

***Key Words**: accelerometer, IPAQ, physical activity*

INTRODUCTION

Levels of physical activity are frequently scrutinized as a means of assessing health behaviours and their relationship with health status and population morbidity and mortality rates.[1-3] Accurate evaluation of physical activity is vital,[4]and this is reliant on the accuracy of the instruments used for measurement.[5-6] Both objective and subjective/self-report instruments are available for evaluating physical activity, and earlier studies have detected some discrepancies in the respective estimates obtained from the two types of measurement.[5, 7-10]

Because the use of accelerometers for large-scale studies may be hindered by restricted expertise and financial resources, subjective self-report measures of physical activity are often more practical for such studies by virtue of their ease of use and low cost. However, such instruments must be valid if they are to provide meaningful and comparable data. As an objective and valid measure of physical activity,[11] the Kenz Lifecorder e-Step accelerometer provides a good reference method for evaluating the validity of physical activity questionnaires.

The International Physical Activity Questionnaire (IPAQ) was developed as a self-report measure by the working group of the World Health Organization and the United States Centers for Disease Control and Prevention to harmonise the assessment of physical activity levels, and to evaluate and compare population physical activity levels in different countries and cultures.[12] The IPAQ has been used worldwide for physical activity research,[4, 12-16]but most validation studies (comparing its outcomes with accelerometer data) were carried out in developed, Western countries. For instance, a study by Craig et al.[12] involved a total of 14 centres in 12 countries: Australia (Perth), Brazil (Sao Paolo), Canada (Ottawa), Finland (Tampere), Guatemala (Guatemala city and rural sample), Italy (older adults sample), Japan (Tokyo), Portugal (Porto), South Africa (Cape Town), Sweden (Karolinska Institute), United Kingdom (Bristol), United Kingdom (Cambridge), United States (San Diego) and United States (South Carolina).

To date, assessment of the validity of IPAQ as part of the questionnaire's initial development process has not been conducted in Malaysia;[12] a recent cultural adaptation study of the long-form IPAQ compared it only with a physical activity log.[17] The objective of the present study was to compare IPAQ and accelerometer estimates of the moderate-to-vigorous intensity component of physical activity in Malaysian government employees.

METHODOLOGY

A total of 225 employees, aged 18 to 59 years, from five government agencies in Putrajaya, Malaysia participated in the present study. Three assessments were conducted, at four- and six-month intervals.

The present study complied with the principles of the Helsinki Declaration, and was approved by the Ethics Committee, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia [Reference No. UPM/FPSK/100-9/2-MJKEtikaPen (JPD_Jan (12) 04)].

To begin, participants' weight was measured to the nearest 0.1 kg, in light clothing and without shoes, using the Tanita Segmental Body Composition Analyser model 418 (Tanita Co., Tokyo, Japan). A rod (Seca, Hamburg, Germany) was used to measure their height to the nearest 0.1 cm. Their body mass index (BMI) was computed as weight in kilograms divided by the squared height in metres.

Physical activity assessment (objective instrument)

The Lifecorder e-Step accelerometer (Suzuken Company Limited, Nagoya, Japan), was used to objectively quantify physical activity. Participants were asked to fasten the accelerometer to the waistband of belt, skirt or trousers on the right side, centred over the foot. The accelerometer was to be worn from the time they woke up in the morning till they went to bed at night, excluding any bathing time and water-based activities.[19]

Previous research has shown that consistent monitoring of physical activity with an accelerometer requires between three and five days of assessment.[20] Because participants' physical activity levels varied noticeably between weekdays and weekend days,[21] they were asked to wear the accelerometer for two consecutive weekdays and one weekend day. Information was sought about duration of wearing the accelerometer in a day; a valid day was defined as at least 10 hours of wear. The mean number of steps per day was then calculated as average steps per day for those three days.

Mean steps per day were categorised according to the classification used by Tudor-Locke et al.[22] Less than 2,500 steps per day was categorized as basal activity; 2,500 to 4,999 steps per day as limited activity; 5,000 to 7,499 steps per day as low active; 7,500 to 9,999 steps per day as somewhat active; 10,000 to 12,499 steps per day as active; and 12,500 or more steps per day as highly active.

Physical activity assessment (subjective instrument)

Developed in Geneva in 1998, the IPAQ comprises four questionnaires, with long (five activity domains) and short (four generic items) versions used specifically for self-administration or telephone interview, respectively. Using various survey lengths and formats, pilot testing was conducted across 14 centres in 12 countries to assess the validity and reliability of the instrument. In general, the IPAQ produced repeatable data (Spearman's correlation coefficient clustered around 0.8, based on test-retest repeatability within the same week), with comparable data from long-form and short-form versions. Evaluated against the CSA accelerometer, criterion validity showed a median correlation coefficient of 0.3. The short-form IPAQ is recommended for national monitoring while the long-form version is preferred for research requiring more detailed assessment.[12] In the present study, participants were asked to complete the long-form IPAQ.

Data analysis

Descriptive data were presented as mean ± standard deviation (SD). Inter-class correlation (Pearson's correlation coefficient, r) was conducted to quantify the linear relationship between outputs from the Kenz Lifecorder e-Step accelerometer and the IPAQ—specifically, the time spent on moderate-to-vigorous intensity physical activity (MVPA). Agreement between the accelerometer outputs and the IPAQ was assessed using the Bland-Altman analysis,[23] plotted as the difference between accelerometer outputs and the IPAQ against the mean of both.

This plot demonstrated the relationship between measurement error and mean values from the Kenz Lifecorder e-Step accelerometer and the IPAQ. The limits of agreement were taken to be the mean difference ± 1.96 SDs between the accelerometer outputs and the IPAQ. Paired sample t-tests were conducted to test differences in the time spent on moderate-to-vigorous intensity physical activity detected by the two instruments. Sensitivity (ability of the IPAQ to identify inadequately active individuals) and specificity (ability of the IPAQ to identify adequately active individuals) was computed. Statistical significance was set at an alpha level of 0.05. Statistical analyses were conducted using SPSS version 20.

RESULTS

Participants' baseline characteristics and descriptive statistics from IPAQ and accelerometer measures are set out in Table 1.

Table 1 Participant baseline characteristics and descriptive statistics of IPAQ and accelerometer measures

Variables	Mean ± Standard deviation
Age	34.8±8.4
Height (cm)	157.2±8.2
Weight (kg)	69.3±14.0
BMI (kg/m^2)	28.0±4.8
Accelerometer	
Mean MVPA 1 (minutes per day)	3.6±3.0
Mean MVPA 2(minutes per day)	10.0±10.3
Mean MVPA 3(minutes per day)	4.0±5.5
IPAQ	
Mean MVPA 1(minutes per day)	34.7±29.3
Mean MVPA 2(minutes per day)	34.7±29.3
Mean MVPA 3(minutes per day)	34.7±29.3

Note: MVPA 1 refers to moderate-to-vigorous intensity physical activity at first assessment
MVPA 2 refers to moderate-to-vigorous intensity physical activity at second assessment
MVPA 3 refers to moderate-to-vigorous intensity physical activity at third assessment

Figures 1, 2 and 3 (Bland-Altman plots) demonstrate the differences between IPAQ- and accelerometer-minutes per day for MVPA, plotted against the mean of IPAQ- and accelerometer-minutes per day for MVPA at first assessment, second assessment (four-month interval) and third assessment (six-month interval), respectively.

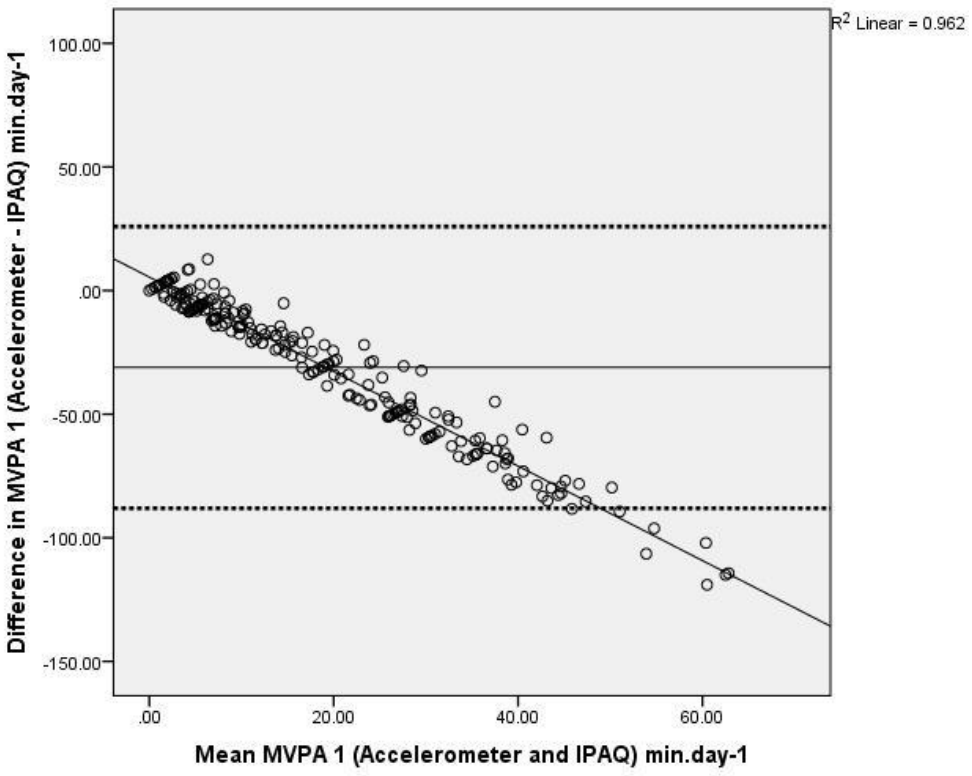

Figure 1. First assessment Bland-Altman plot for min.day^{-1} reported in MVPA from accelerometer and IPAQ. Mean error scores are indicated by a solid horizontal line and limits of agreement (±1.96 SDs from the mean) are shown as dashed horizontal lines.

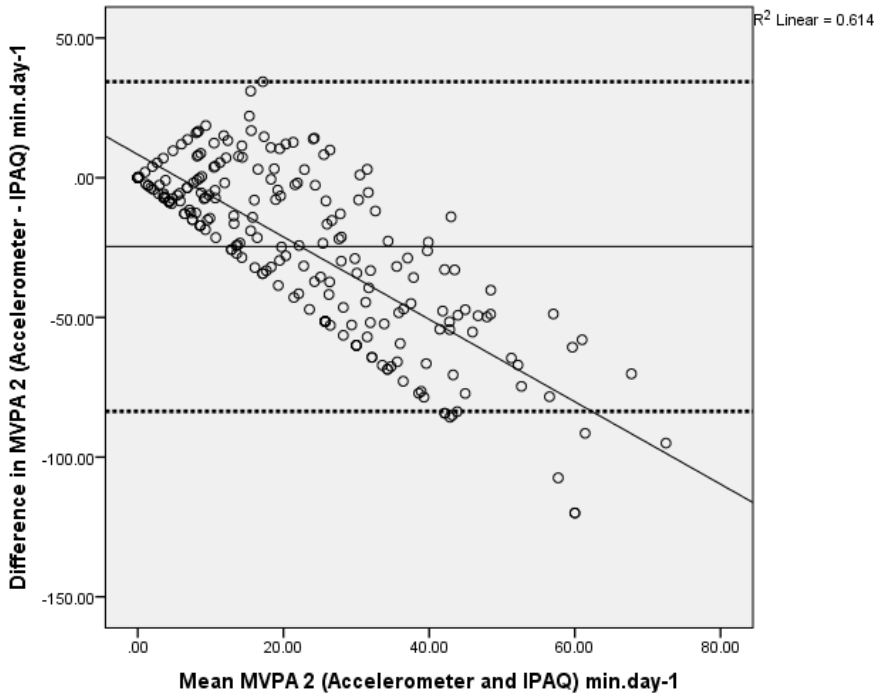

Figure 2. Second assessment Bland-Altman plot for min.day^{-1} reported in MVPA from accelerometer and IPAQ. Mean error scores are indicated by a solid horizontal line and limits of agreement (±1.96 SDs from the mean) are shown as dashed horizontal lines.

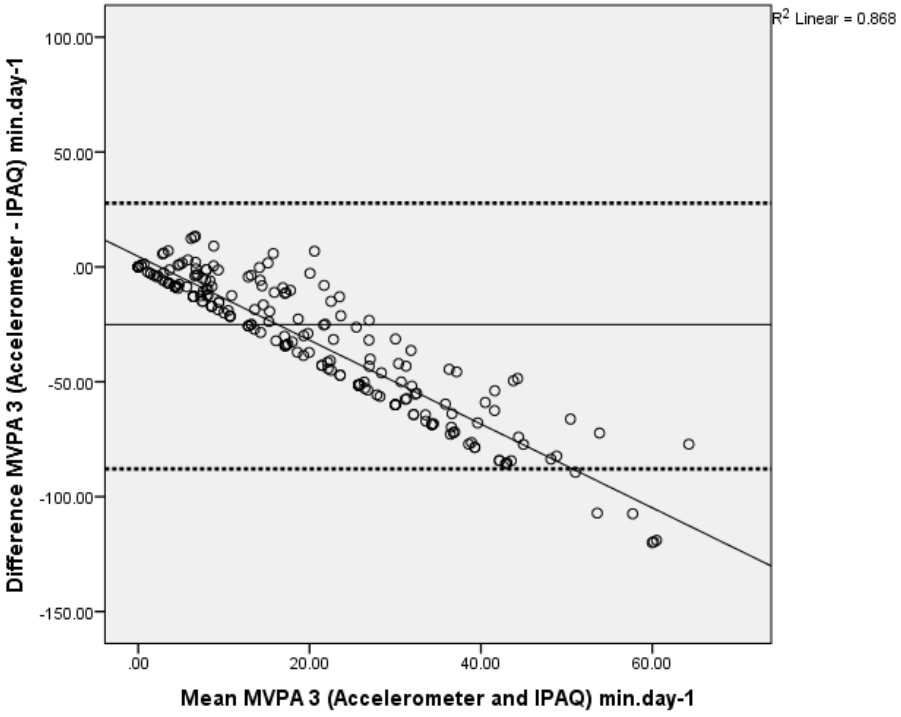

Figure 3. Third assessment Bland-Altman plot for min.day^{-1} reported in MVPA from accelerometer and IPAQ. Mean error scores are indicated by a solid horizontal line and limits of agreement (±1.96 SDs from the mean) are shown as dashed horizontal lines.

The mean difference was 31 min.day^{-1}($p<0.001$), and the 95% limits of agreement were within a reasonable range (-88 to 26 min.day^{-1}) for MVPA at first assessment. Differences or errors between IPAQ- and accelerometer-minutes per day in MVPA decreased as the mean minutes per day in MVPA increased (R^2=0.962).

The mean difference was 25 min.day^{-1}($p<0.001$), and the 95% limits of agreement were within a reasonable range (-84 to 34 min.day^{-1}) for MVPA at second assessment. Differences or errors between IPAQ- and accelerometer-minutes per day in MVPA decreased as the mean minutes per day in MVPA increased (R^2=0.614). The mean

difference was 31 min.day^{-1} ($p<0.001$), and the 95% limits of agreement were within a reasonable range (-88 to 28 min.day^{-1}) for MVPA at third assessment. Differences or errors between IPAQ- and accelerometer-minutes per day in MVPA decreased as the mean minutes per day in MVPA increased (R^2=0.868).

Table 2 Distribution of participants based on physical activity category at first assessment (n=225)

Accelerometer 1	IPAQ 1	
	Low	Moderate/High
Basal/Limited/Low	76 (33.8%)	146 (64.9%)
Somewhat active/Active/Very active	1 (0.4%)	2 (0.9%)

Table 3 Distribution of participants based on physical activity category at second assessment (n=225)

Accelerometer 2	IPAQ 2	
	Low	Moderate/High
Basal/Limited/Low	22 (9.8%)	135 (60.0%)
Somewhat active/Active/Very active	1 (0.4%)	67 ((29.8%)

Table 4 Distribution of participants based on physical activity category at third assessment (n=225)

Accelerometer 3	IPAQ 3	
	Low	Moderate/High
Basal/Limited/Low	55 (24.4%)	151 (67.1%)
Somewhat active/Active/Very active	3 (1.3%)	16 (7.1%)

The sensitivity of the IPAQ (ability to correctly classify inadequately active individuals) at first assessment, second assessment and third assessment was 34.2%, 16.1% and 26.7%, respectively. In relation to the specificity measure, 66.7%, 98.5% and 84.2% of those achieving somewhat active/active/very active level (as ascertained by the accelerometer) were captured by the IPAQ at first assessment, second assessment and third assessment, respectively.

DISCUSSION

The present study compared objective (accelerometer) and subjective (IPAQ) measures of physical activity among Malaysian government employees. The findings indicate that significantly more time in MVPA was reported on the IPAQ than was assessed with the accelerometer. The wide prediction intervals between the two instruments, highlighted in the Bland-Altman plots, imply that the criterion validity of the IPAQ is modest.

Accurate evaluation is crucial for epidemiological research on physical activity behaviour. Comparing the widely-used IPAQ with the objective accelerometer measure for 225 government employees (160 women), although strong to very strong correlation coefficients with accelerometer data supported the use of IPAQ (r=0.981 at first assessment; r=0.784 at second assessment; r=0.932 at third assessment), the wide limits of agreement from Bland-Altman plots emphasised discrepancies between the instruments, specifically in relation to MVPA. These findings illustrate the limitations of correlation coefficients in validation studies and the inaccuracy of self-report instruments such as the IPAQ in assessing physical activity. However, the correlation between outputs from the two instruments for time spent in MVPA supports the interchange ability of the outputs, if only relative values are required.

The present findings indicate the likelihood of over-reporting or inability to accurately recall activities in self-report measures of physical activity.[6, 24-25] Coding errors and social desirability bias have been documented with IPAQ,[14-15, 18, 25] but it is also probable that the accelerometer was not capable of capturing or otherwise underestimated physical activities such as cycling, swimming, heavy lifting and household tasks that may have been completed by these participants.

The IPAQ long form requires recall of physical activity at moderate-to-vigorous intensity for occupational, transport, household and leisure domains for a period of seven days. Because planned physical activities and those conducted at moderate-to-vigorous intensity are more memorable, they may be more accurately recalled. However, the present study has in accordance with previous research indicating a modest agreement between self-reported and

accelerometer-derived physical activity behaviour, specifically MVPA[5, 9].

Following international collaboration, the IPAQ was developed as the appropriate standardised self-report measure for population-wide measurements of physical activity, on which comparisons between countries might be made.[12] Studies of the numerous available self-report instruments have assessed their validity using the accelerometer as the criterion measure of physical activity, and differences between objective and subjective measures of physical activity have been demonstrated among adults.[5, 9]

Given the propensity of studies to employ non-validated approaches in evaluating physical activity behaviour, future research should make an effort to incorporate only valid and reliable self-report measures of physical activity and, where feasible, should use these in combination with an objective measure of physical activity (e.g. step counts). There is evidence to suggest that use of a pedometer or accelerometer may act as an intervention in itself, making it more difficult to establish what components of an intervention may have prompted any behaviour change. [26-28]

A total of four-month period was applied in previous studies. [29-30]Another two-month follow-up duration is in line with a previous study carried out by Tudor-Locke and colleagues.[31]

Maturation or history factor might play the role for the any said changes between first assessment, second assessment and third assessment. In other words, events that occur between assessments period and changes in the participants that occur as a function of the passage of time might lead to the said changes. Nevertheless, it should be stressed that the present study is more inclined towards comparing the accelerometer-based measurement with the International Physical Activity Questionnaire (long form) in the assessment of physical activity level.

The limitation of the study include the limited generalizability. Participants in the present study were employees, who may have potentially higher recall ability and comprehension than may be observed in the general population. Hence, the findings may not be applied to the general population.

CONCLUSION

Physical activity is an essential behavioural component in achieving good health and disease prevention.[32] While there is some merit in this as a population-level goal, the application of self-report tools to determine health outcomes of physical activity behaviour is inappropriate. This study demonstrates the need for valid measures of physical activity in assessing physical activity levels. Although modest evidence of criterion validity was observed for the IPAQ, the instrument overestimated time spent in MVPA and was likely to incorrectly classify Malaysian adults into the adequately active category.

These findings have implications for the appropriateness of using the IPAQ for physical activity monitoring and for creating public health recommendations in Malaysia. Further research is warranted on the validity of the IPAQ, and of other self-report physical activity instruments, in other Malaysian populations, to ensure more accurate assessment of physical activity data, and ultimately to support implementation of effective prevention and intervention programmes to combat the increase in chronic non-communicable diseases in the region.

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AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: CHP HAS BNMY MNMT. Performed the experiments: CHP HAS. Analyzed the data: CHP HAS. Wrote the paper: CHP HAS

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