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Background: The International Physical Activity Questionnaire-Short Form (IPAQ-S) has been evaluated against accelerometer-determined physical activity measures in small homogenous samples of adults in the United States. There is limited information about the validity of the IPAQ-S in diverse US samples. ***Methods:*** 142 Blacks residing in low-income housing completed the IPAQ-S and wore an accelerometer for up to 6 days. Both 1- and 10-minute accelerometer bouts were used to define time spent in light, moderate, and vigorous physical activity. ***Results:*** We found fair agreement between the IPAQ-S and accelerometer-determined physical activity (r = .26 for 10-minute bout, r = .36 for 1-minute bout). Correlations were higher among men than women. When we classified participants as meeting physical activity recommendations, agreement was low (kappa = .04, 10-minute; kappa = .21, 1-minute); only 25% of individuals were classified the same by both instruments (10-minute bout). ***Conclusions:*** In one of the few studies to assess the validity of a self-reported physical activity measure among Blacks, we found moderate correlations with accelerometer data, though correlations were weaker for women. Correlations were smaller when IPAQ-S data were compared using a 10- versus a 1-minute bout definition. There was limited evidence for agreement between the instruments when classifying participants as meeting physical activity recommendations.

Keywords: physical activity assessment, measurement, epidemiology, community-based research

Regular physical activity is associated with a reduced risk of numerous chronic conditions and premature mortality.[1–7] However, the accumulated research evidence has been challenged by the validity and reliability of self-reported

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physical activity measures. In response, a group of leading physical activity researchers developed the International Physical Activity Questionnaire (IPAQ) to facilitate surveillance comparisons across populations. Two versions, the IPAQ-Short Form (IPAQ-S) and the IPAQ-Long Form, were developed.

The IPAQ questionnaires were validated in 14 centers across 12 countries.[8] The IPAQ-S was found to have fair to moderate agreement with accelerometer-measured physical activity (pooled $r = .30$). However, among US participants, the study sample sizes were small (<30 participants each) and participant characteristics were not reported; however, the authors noted that the samples were not representative of the US population. This might limit the utility of the measure among US-based samples with significant representation of racial/ethnic minorities and/or those of low socioeconomic position (SEP). In fact, Craig et al called for an examination of population differences in the validity of the IPAQ, particularly those by SEP and culture.[8] Following the original validation, the IPAQ has been validated against accelerometry in several samples, but none have been US based.[9–12]

The methodological challenges associated with the valid measurement of physical activity using self-report measures might be magnified in studies involving sociodemographically diverse populations.[13,14] Individuals in racial/ethnic minority populations and lower SEP groups generally report lower levels of leisure-time physical activity (compared with Whites and higher SEP groups, respectively), but might achieve higher levels of occupational activity.[15] Some studies have suggested that the validity of physical activity instruments might be lower among some Black populations,[16] but few such investigations have been conducted.[17,18] As such, we sought to determine the validity of the IPAQ-S questionnaire in a sample of low-income Black adult men and women.

Materials and Methods

Sample

These data were gathered among Black residents of 2 public housing developments in metropolitan Boston, Massachusetts. In collaboration with the developments, participants were recruited through posted signs and distributed advertisements. Eligibility criteria included self-identification as Black or African American, age 24 to 70 years, and no restrictions to usual physical activity. Two hundred fifteen subjects responded and met eligibility criteria. All participants provided written informed consent. All study procedures were approved by the university's human subjects protection committee.

IPAQ

Self-reported physical activity data were collected using the IPAQ-S. We selected the IPAQ-S because of concerns that the length of the IPAQ-Long would result in significant participant burden. The IPAQ-S asks participants to report activities performed for at least 10 minutes during the last 7 days. Respondents are asked to report time spent in physical activity performed across leisure time, work, domestic activities, and transport at each of 3 intensities: walking, moderate, and vigorous.

Examples of activities that represent each intensity are provided; for example, participants are asked about vigorous activities such as "heavy lifting, digging, aerobics, or fast bicycling." Using the instrument's scoring protocol,[19] total weekly physical activity was estimated by weighting time spent in each activity intensity with its estimated metabolic equivalent (MET) energy expenditure.[8,19] The IPAQ scoring protocol assigns the following MET values to walking, moderate, and vigorous intensity activity: 3.3 METs, 4.0 METs, and 8.0 METs, respectively. Participants were considered to have met CDC/ACSM physical activity recommendations[20] if they reported at least 150 min/wk of walking, moderate, or vigorous intensity physical activity.

Actical Accelerometer

Actical activity monitors (Mini Mitter Co., Bend, OR) are small, lightweight, water resistant, and have a large data storage capacity. The Actical uses a single internal omnidirectional accelerometer that senses motion in all directions but is most sensitive within a single plane. The accelerometer detects low frequency (0.5 to 3.2 Hz) G-forces (0.05 to 2.0 Hz) common to human movement and generates an analog voltage signal that is filtered and amplified before being digitized by an A-to-D converter at 32 Hz. The digitized values are then summed over user-specified intervals of time (ie, an epoch). The raw data stored by the accelerometer are proportional to the magnitude and duration of the sensed accelerations that correlate to changes in whole-body motion and physical activity energy expenditure. A total of 40 Acticals, all of which were calibrated before testing, were randomly assigned to subjects and preprogrammed to record data over 60-second epochs.

Accelerometer Sampling Protocol

Participants provided informed consent and were subsequently oriented to the accelerometer data-collection protocol. Research staff recorded participant height in meters using a Seca floor scale 770 and weight in kilograms using a Seca Portable Stadiometer. Research staff then explained the function of the accelerometer, demonstrated proper accelerometer placement, and securely fastened the device to a hip clip for attachment to the participant's clothing. Participants were also provided with a waistband for use when wearing the hip clip was not possible or for added security. All participants were provided with an Actical, hip clip, safety lanyard, waistband, and an illustrated instruction pamphlet with support contacts.

Participants were instructed to wear the accelerometers for 6 consecutive days, with the option to remove the device for sleeping, bathing, or showering. Because the Actical is water resistant, it was not necessary to ask participants to complete a separate log of water-based physical activities. In addition, qualitative data collected in our early interactions with members of this population indicated the prevalence of water-based physical activities was quite low. After the 6-day monitoring period, accelerometers were collected and data were immediately downloaded and archived.

Accelerometer Data Screening and Processing

The raw accelerometer data files were visually inspected for wearing compliance and data integrity using the manufacturer's software (Actical V2.0, Mini Mitter Co., Inc.). Some participants did not wear the units continuously for 6 days as instructed. As such, each accelerometer file had to satisfy the following criteria before further processing: (1) the subject must have worn the monitor at least 4 full days during the specified wearing period, (2) a "full day of wearing" was defined as at least 10 hours of continuous monitoring from the first to last bursts of activity data, (3) the 10-hour minimum could include a single 2-hour period of no activity, (4) partial days (<10 hours) were not counted in the analyses regardless of the activity content for that day. Actual wearing time was inferred by the mild burst of activity associated with putting on and taking off the monitor in the morning and evening, respectively. Subsequent analyses performed on the accelerometer data were only performed on the full monitoring days. These procedures are consistent with recommendations for wearing compliance and reliability of physical activity variables derived from free-living accelerometry.[21]

The raw activity data for each subject were imported into a custom Visual Basic (Version 6.0) program for conversion to minute-by-minute activity energy expenditure (AEE, $kcals \cdot kg^{-1} \cdot min^{-1}$) using a modification of the validated "2R" hip monitor algorithm.[22] The program searched each activity file for minutes of activity that met or exceeded a given threshold intensity (ie, sedentary/light, moderate, or vigorous intensity). The AEE cut points corresponding to sedentary/light intensity (<3.0 METs), moderate intensity (≥3.0 METs and <8.0 METs), and vigorous intensity (≥8.0 METs) were defined as follows: sedentary/light intensity < $0.0385\ kcals \cdot kg^{-1} \cdot min^{-1}$; $0.0385\ kcals \cdot kg^{-1} \cdot min^{-1}$ ≤ moderate intensity < $0.1235\ kcals \cdot kg^{-1} \cdot min^{-1}$; vigorous intensity ≥$0.1235\ kcals \cdot kg^{-1} \cdot min^{-1}$. Our definition of the moderate-intensity physical activity range (≥3.0 METs and <8.0 METs) is consistent with that recommended by the published IPAQ-S scoring protocol,[19] although it differs from that used by the CDC/ACSM recommendations[20] (≥3.0 METs and <6.0 METs). Thus, the IPAQ-S recommended definition is more restrictive in the vigorous-intensity range. Furthermore, previous work with normal-weight White adults identified 0.0310 and $0.1181\ kcals \cdot kg^{-1} \cdot min^{-1}$ as AEE cut points corresponding to 3 and 8 METs, respectively.[22] More recent work determined that the higher cut points employed are more appropriate for a sample of largely overweight/obese Black adults.[23] To our knowledge, these more recent cut points specific to overweight/obese Black adults are the only current accelerometry cut point data specific to this population.

Activity counts (AC_{CNT}, counts/d) and time (AC_{TIME}, min/d) spent within light-, moderate-, and vigorous-intensity categories were averaged across all of each subject's "full monitoring days." To directly compare AC_{TIME} with the equivalent variable from the IPAQ, AC_{TIME} was transformed from min/d to min/wk by multiplying by 7 d/wk. In addition, participants were classified as having met the CDC/ACSM physical activity recommendations[20] if average AC_{TIME} was ≥30 min/d for the sum of time spent within the moderate- and vigorous-intensity categories. Lastly, because a preferred accelerometer bout length has not yet been established,[24] the AEE data were evaluated separately for 2 distinct bout definitions:

bouts lasting at least 1 minute and bouts of at least 10 minutes, without an allowance for bout interruptions. The 1-minute bout definition is consistent with how the IPAQ has been validated in previous studies,[8,10,11] and the 10-minute definition is consistent with the instructions provided in the IPAQ-S (ie, "Think only about those physical activities that you did for at least 10 minutes at a time") and the CDC/ACSM recommendations.[20]

Data Analysis

Of the 215 respondents, 142 (66%) had complete IPAQ and accelerometer data, consistent with our data-screening criteria. Three participants dropped out for personal reasons before the accelerometer protocol started, 6 lost their devices, and 2 returned devices that were not readable. Of the 204 participants providing accelerometer data, 34 subjects were excluded for not accumulating four, 10-hour days of wear. An additional 13 did not self-report physical activity data. According to the IPAQ-S scoring protocol, outliers (n = 15; defined as subjects reporting 960 min/wk or greater of activity) were excluded. The IPAQ-S scoring protocol also calls for the truncation of each intensity domain (moderate, vigorous, walking) at a duration of 180 minutes. Owing to the nonnormal distribution of the physical activity data, Spearman correlation coefficients were used to compare IPAQ-S (MET min/wk) and accelerometer-determined (count/d) physical activity estimates. In addition, the percent of participants similarly classified as meeting physical activity recommendations by the IPAQ-S and accelerometer were calculated, as were the corresponding kappa measures of agreement. All *P* values were two-sided. We also generated Bland-Altman plots for the 1- and 10-minute bout definitions. Finally, we examined gender differences in the validity of the IPAQ-S.

Results

Subjects were predominantly female (n = 91, 64%) and ranged in age from 24 to 67 years, with a mean (SD) of 44 (12; Table 1). Just over half of participants (n = 67, 54%) were obese (body mass index [BMI] ≥ 30 kg/m^2). Less than half (n = 59, 42%) of the sample was employed. Participants were low income, with 35% (n = 46) making less than $10,000 per year. However, over one-third (n = 55, 39%) reported having at least some college education, and 80% of subjects (n = 113) had at least a high school education.

IPAQ

Participants reported a mean (SD) of 5489 (4263) and a median (interquartile range, IQR) of 4512 (5637) MET min/wk of physical activity on the IPAQ-S (data processed according to the IPAQ scoring protocol). On average, this included 616 min/wk of walking, 312 min/wk of moderate-intensity physical activity, and 276 min/wk of vigorous-intensity activity (Table 2).

Table 1 Participant Characteristics (N = 142)

	Total n (%)	Women (N = 91) n (%)	Men (N = 51) N (%)
Education			
less than high school	29 (20)	18 (20)	11 (22)
high school	58 (41)	35 (38)	23 (45)
some college or greater	55 (39)	38 (42)	17 (33)
Employed			
yes	59 (42)	36 (40)	23 (45)
no	83 (58)	55 (60)	28 (55)
Income			
less than $10,000	46 (35)	36 (42)	10 (23)
$10,000–19,999	31 (24)	17 (20)	14 (32)
$20,000–29,999	23 (18)	15 (17)	8 (18)
$30,000 and above	30 (23)	18 (21)	12 (27)
did not report	12	5	7
Body mass index[a]			
normal	29 (23)	18 (20)	11 (31)
overweight	28 (23)	20 (22)	8 (23)
obese	67 (54)	51 (58)	16 (46)

[a] Body mass index: normal (BMI < 25 kg/m^2), overweight (25 ≤ BMI < 30 kg/m^2), obese (BMI ≥ 30 kg/m^2).

Accelerometer

Participants recorded a mean (SD) activity count of 174,824 counts/d (86,705) and a median (IQR) of 157,237 (91,399) counts/d on the accelerometer with a 1-minute bout length and a mean (SD) of 33,761 (36,806) counts/d and median (IQR) of 20,857 (33,799) counts/d with a 10-minute bout length. This represents an 80% decrease in counts/d from the 1- to 10-minute bout length. Using a 1-minute bout definition, participants recorded 1657 min/wk of light-intensity physical activity, 683 min/wk of moderate-intensity physical activity, and 0 min/wk of vigorous-intensity physical activity. Using a 10-minute bout definition, participants recorded 155 min/wk of light-intensity physical activity, 101 min/wk of moderate-intensity physical activity, and 0 min/wk of vigorous-intensity physical activity.

Gender Differences in Physical Activity

Mean MET min/wk (5718 versus 5360) and activity counts/d (1-minute bout; 186,103 versus 168,503) were higher among men than women. Women recorded

Table 2 Mean and Median Minutes per Week of Physical Activity at Given Intensities by Instrument and Gender[a]

	Total		Women		Men	
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
IPAQ						
walking	616 (470)	510 (940)	650 (476)	630 (1080)	555 (459)	420 (795)
moderate	312 (395)	120 (530)	297 (385)	105 (465)	339 (415)	120 (600)
vigorous	276 (360)	120 (420)	253 (358)	90 (360)	316 (363)	150 (540)
Accelerometer (1-min bout)[b]						
light	1657 (431)	1657 (587)	1688 (427)	1703 (600)	1601 (436)	1568 (554)
moderate	683 (367)	590 (368)	660 (345)	635 (404)	725 (405)	581 (505)
vigorous	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Accelerometer (10-min bout)[b]						
light	155 (123)	123 (142)	153 (105)	124 (132)	157 (152)	116 (190)
moderate	101 (126)	54 (116)	91 (110)	61 (112)	119 (150)	50 (175)
vigorous	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Abbreviations: IQR, interquartile range; IPAQ, International Physical Activity Questionnaire.
[a] No significant differences between men and women on any of the mean min/wk values.
[b] Light activity is <3.0 metabolic equivalents (METs), moderate is between 3.0 and 7.9 METs, and vigorous is ≥ 8.0 METs.

more light activity and reported more walking than men. Men reported and recorded more moderate-intensity physical activity and reported more vigorous physical activity than women. However, there were no significant gender differences in reported or recorded physical activity.

1-Minute Bout Length

Overall, the Spearman correlation coefficient (r = .36, P < .001) revealed moderate agreement between IPAQ-S and accelerometer-determined activity counts with a 1-minute bout definition. The correlation (r = .58, P < .001) was higher among men than it was among women (r = .21, P = .05).

According to the accelerometer, 94% of participants met CDC/ACSM physical activity recommendations; the IPAQ reported 91% of participants as meeting recommendations (Table 3). Although 89% of participants were classified the same by both instruments, the agreement between the 2 was low (κ = .21, 95% CI: –.04 to .47).

10-Minute Bout Length

When employing a 10-minute bout definition, there was fair correlation between IPAQ-S and accelerometer-measured activity counts (r = .26, P = .002). The correlation was moderate among men (r = .48, P = .003) and poor among women (r = .07, P = .48).

Based on the accelerometer data, only 15% of participants were found to have met CDC/ACSM physical activity recommendations using the 10-minute bout length. Only 25% of participants were classified the same by both instruments, and the agreement was poor (κ = .04, 95% CI: .01 to .06).

Bland-Altman Plots

Bland-Altman plots (Figures 1 and 2) further demonstrate the fair performance of the IPAQ-S. A sizeable positive trend, demonstrating systematic overestimation

Table 3 Classification of Meeting Physical Activity Recommendations by IPAQ and Accelerometer Activity Assessments (N)

	IPAQ	
	Did not meet recommendations Total (N = 13)	Met recommendations Total (N = 129)
Accelerometer (1-min bout)		
Did not meet recommendations	3	6
Met recommendations	10	123
Accelerometer (10-min bout)		
Did not meet recommendations	13	107
Met recommendations	0	22

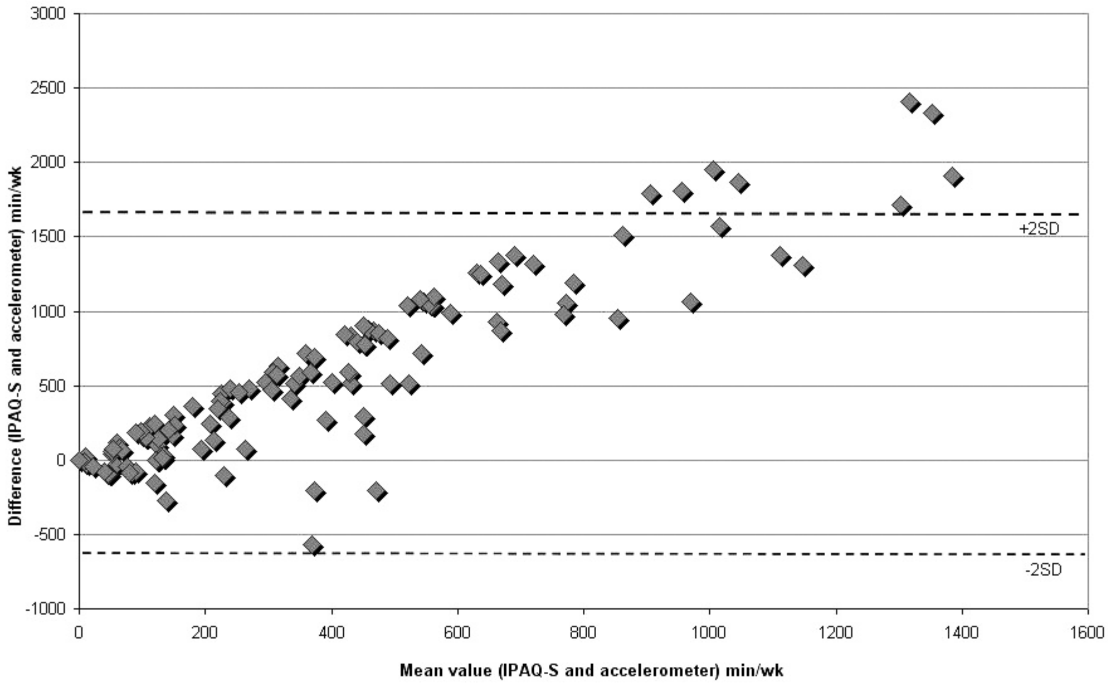

Figure 1 — Bland-Altman plot of IPAQ-S versus accelerometer (10-minute bout) measured physical activity.

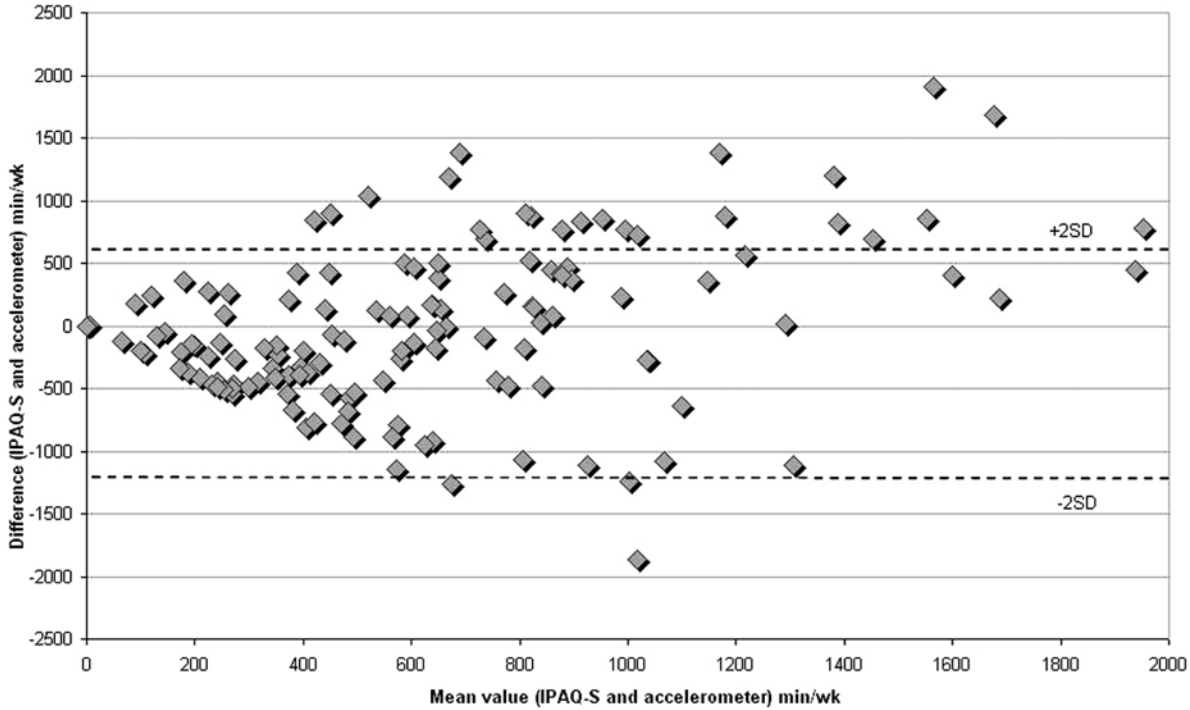

Figure 2 — Bland-Altman plot of IPAQ-S versus accelerometer (1-minute bout) measured physical activity.

with increasing physical activity (assessed using a 10-minute bout), is shown in Figure 1. In Figure 2, we see high variability in both directions. Bland-Altman plots for men and women looked similar (data not shown).

Discussion

In our sample of Blacks residing in low-income housing, we found fair correlations overall between the IPAQ-S and accelerometer-determined physical activity. In addition, we observed low agreement between the 2 measures in the proportion of individuals classified as meeting CDC/ACSM physical activity recommendations. It appears that the IPAQ-S is an acceptable instrument for the measurement of physical activity as a continuous scale variable in samples of low SEP Black men. However, the low correlation between the IPAQ-S and accelerometer-measured physical activity among Black women suggests that additional work might be necessary to enhance the validity of the measure when used in such populations. Similarly, caution should be employed when using the IPAQ-S for classifying physical activity in lower SEP Blacks.

Consistent with studies of other physical activity questionnaires,[17,25] we found that the IPAQ-S performed substantially better in men than in women. Explanations for this are unclear. One hypothesis is that occupational status contributes to the gender difference. In exploratory analysis, we found no differences in the results by employment status within each gender (data not shown). Together the accumulated evidence indicates that measurement of physical activity through self-report in women remains a challenge. Several recent investigations have similarly shown, in both adults and children,[26,27] poor agreement between accelerometers and self-report physical activity questionnaires. Again, the results of our study and other investigations demonstrate the challenges of measuring physical activity by self-report, particularly when classifying physical activity levels.

An important contribution of this study is the use of both a 1- and 10-minute bout definition to characterize accelerometer-measured physical activity. Use of a 10-minute bout definition more closely matches the IPAQ-S instructions suggesting that individuals report "only those physical activities that you did for at least 10 minutes at a time." We found that the choice of activity-bout definition had a substantial effect on the correlation between IPAQ-S and accelerometer-determined physical activity, particularly among women. We also found substantial differences in the classification of physical activity, depending on the activity-bout definition. When individuals' activity was classified using a 10-minute bout, only a quarter of participants were similarly classified by the IPAQ-S and accelerometer. These differences suggest that participants in our study accumulated physical activity in very short bouts (<10 minutes). Given the influence of bout length on the accuracy of the IPAQ-S in classifying participants' physical activity levels, we advocate that future validation studies provide detailed information on the bout length chosen. Given that the IPAQ asks participants only to report physical activity that was of 10 minutes or more, the 10-minute bout might be more appropriate for the validation of the IPAQ instruments. In addition, given the implication that few participants are accumulating physical activity in bouts of at least 10 minutes, intervention and policy efforts might address this when promoting physical activity.

Although the IPAQ-S has been found to have acceptable validity across a range of countries for population surveillance purposes, relatively few self-report physical activity measures have been validated among sociodemographically diverse samples in the United States. The correlation coefficients between self-reported physical activity using the IPAQ-S and accelerometer-measured physical activity are comparable with those previously found for the IPAQ-S instrument, both in the United States and internationally.[8–11] We found that the IPAQ-S had a better correlation with accelerometer assessment than did the CHAMPS questionnaire, one of the few self-report instruments to be validated in a Black sample (r = .32 versus .17; although the accelerometer model and cut points differed from those we used).[17] Because researchers have criticized the sole use of correlation coefficients in validation studies,[28] and given the public health priority of determining success in meeting physical activity guidelines, we also investigated the utility of the IPAQ-S in classifying individuals' physical activity. Indeed, although we found fair to moderate correlations between the continuous physical activity scores, we found that the IPAQ-S performed poorly at classifying individuals as meeting recommendations.

As with other validation studies, our findings are dependent on the choice of accelerometer cut points; we employed a conservative approach in the current study, using cut points based on modifications of published algorithms that are specifically tailored for the target population. As noted by Mâsse et al, the accelerometer data-processing algorithm employed can substantially affect outcome variables.[24] Given the potential influence of the data-reduction algorithm on interpretations of our findings, we have attempted to provide greater detail (compared with previous studies) of our analytic approach to facilitate future comparisons across studies. We also chose to use 8.0 METs to define vigorous physical activity in our accelerometer data (instead of the 6.0 MET cut point specified in the CDC/ACSM physical activity recommendations) to directly correspond to the IPAQ-S scoring protocol.[19] Given the low proportion of individuals with physical activity >6.0 METs, use of the 6.0 MET cut point in place of the 8.0 MET cut point in the accelerometer data is unlikely to have changed our findings on the utility of the IPAQ-S for classifying individuals as meeting physical activity recommendations. Future research might evaluate how the use of the higher cut point influences the correlations between the IPAQ-S and accelerometer data. We also analyzed the data using the raw IPAQ-S data (data not shown) without processing it as called for in the scoring protocol. We found comparable correlations to the data presented earlier, but kappa scores were lower for the raw data. When accounting for intensity of physical activity in categorizing data as was done in the original validation study (by doubling time in vigorous physical activity), we also found similar results (data not shown), likely because of the small amount of time spent in vigorous activities by the study participants. Our finding of a lack of vigorous physical activity accumulated by participants is not surprising given that Blacks are consistently reported to be less active than Whites. In fact, we found less than 1% of participants recorded vigorous physical activity on the accelerometer, and it lasted for less than 3 minutes in duration (data not shown).

Both self-reported and accelerometer-assessment techniques have limitations. Error in accelerometer measurement can occur because hip-worn devices do not accurately assess activities produced by upper-body movement.[29] Existing accelerometer data-processing algorithms might have reduced validity in obese individuals. To account for this, we used data-processing algorithms that were specifically tailored for overweight and obese Black adults and were based on published algorithms.[22] Given the high prevalence of overweight and obesity in this sample, using cut points specifically developed for these populations seemed most appropriate. Self-reported physical activity measurement error arises from participant misclassification of physical activity intensity, inability to recall non-routine activities, and difficulty recalling physical activity duration. The validity of the IPAQ in nonurban or higher SEP Blacks requires separate evaluation. Future studies should also examine the reliability of the instrument in Blacks. We cannot rule out the influence of accelerometer brand choice on our results. However, studies that have concurrently evaluated multiple accelerometer brands have found high correlations.[22,30] Finally, the generalizability of the sample might be limited both by the study sample size and the recruitment approach.

This study evaluated the validity of the IPAQ-S against accelerometer assessment in Black men and women. It is the largest US validation of the IPAQ-S instrument to date and suggests that the questionnaire may be appropriate for use in measuring physical activity with a continuous scale variable among similar low-income Black men; among women, the IPAQ-S performed less well. Before widespread use of the IPAQ-S is employed, its validity for classifying individuals' activity should be further assessed because our study indicates compromised performance, particularly in women.

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