Practice of Epidemiology

Age- and Sex-Specific Criterion Validity of the Health Survey for England Physical Activity and Sedentary Behavior Assessment Questionnaire as Compared With Accelerometry

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The criterion validity of the 2008 Physical Activity and Sedentary Behavior Assessment Questionnaire (PASBAQ) was examined in a nationally representative sample of 2,175 persons aged ≥16 years in England using accelerometry. Using accelerometer minutes/day greater than or equal to 200 counts as a criterion, Spearman's correlation coefficient (ρ) for PASBAQ-assessed total activity was 0.30 (95% confidence interval (CI): 0.25, 0.35) in women and 0.20 (95% CI: 0.15, 0.26) in men. Correlations between accelerometer counts/minute of wear time and questionnaire-assessed relative energy expenditure (metabolic equivalent-minutes/day) were higher in women ($\rho = 0.41$, 95% CI: 0.36, 0.46) than in men ($\rho = 0.32$, 95% CI: 0.26, 0.38). Similar correlations were observed for minutes/day spent in vigorous activity (women: $\rho = 0.39$, 95% CI: 0.33, 0.46; men: $\rho = 0.31$, 95% CI: 0.26, 0.36) and moderate-to-vigorous activity (women: $\rho = 0.42$, 95% CI: 0.36, 0.48; men: $\rho = 0.38$, 95% CI: 0.32, 0.45). Correlations for time spent being sedentary (<100 counts/minute) were 0.30 (95% CI: 0.24, 0.35) and 0.25 (95% CI: 0.19, 0.30) in women and men, respectively. Sedentary behavior correlations showed no sex difference. The validity of sedentary behavior and total physical activity was higher in older age groups, but validity was higher in younger persons for vigorous-intensity activity. The PASBAQ is a useful and valid instrument for ranking individuals according to levels of physical activity and sedentary behavior.

accelerometry; physical activity; questionnaires; sedentary behavior; validation

Both the outcomes and determinants of regular physical activity have been extensively investigated over the past several decades. By contrast, the epidemiology of sedentary behavior is an emerging field. While previous studies have focused on moderate-to-vigorous physical activity (MVPA), the primary focus of sedentary behavior research is on low-energy-expenditure activities that involve sitting, reclining, or lying down. Studies have shown associations between prolonged sitting and health outcomes independent of MVPA levels (1), drawing growing attention to sedentary behavior research. Both physical inactivity and prolonged sitting are prevalent in economically developed countries (2, 3), with

evidence that time spent being sedentary has recently increased (4).

Self-report questionnaires are frequently used to estimate levels of physical activity and sedentary behavior in national populations for reasons of economy, suitability for self-administration, and noninvasiveness (5–7). In addition, unlike objective data collected from motion sensors such as accelerometers, questionnaires facilitate data collection on specific types (e.g., bicycling, computer use) and domains (e.g., work, leisure time) of physical activity and sedentary behavior. However, questionnaires provide only a subjective estimate of overall levels of physical activity and sedentary

behavior during the reference period. Reliance on respondent recall is associated with potential measurement error, which may vary according to demographic characteristics such as sex and age (7). Self-reports may also be subject to social desirability bias (8).

Improvements in questionnaire design have been thought to ameliorate these limitations, although the changes have not generally reflected improved associations with accelerometer data collected from the same participants (9). Criterion validity studies provide an important source of information for researchers and practitioners when choosing an existing questionnaire or developing new instruments. Previous studies have shown that the degree of association between questionnaires and accelerometry can vary by age and sex (10, 11). Despite that, previous studies have typically utilized small samples, which limits the ability to examine subgroup differences in criterion validity (9). A recent review indicated a need for validation studies on large, representative samples in this field (12).

The Health Survey for England is the only nationally representative, population-based survey that collects multiple-domain physical activity data in England. Within the Health Survey for England, data on physical activity and sedentary behavior are regularly collected using the Physical Activity and Sedentary Behavior Assessment Questionnaire (PASBAQ). PASBAQ data have been extensively used to monitor adherence to the United Kingdom physical activity recommendations (13, 14) and for other epidemiologic research (15–24). However, evidence on the criterion validity of the most recent PASBAQ is limited, mainly because of a lack of generalizability and comprehensiveness of previous findings. Two small-scale studies assessed criterion validity using convenience samples: one among 77 older adults with a history of an acute cardiac event (25) and the other among 106 healthy adults (26). Both studies focused on MVPA, so no research has validated PASBAQ data for sedentary behavior and other physical activity indicators commonly used in epidemiologic studies, such as time spent walking, total

time spent being physically active, and relative energy expenditure. PASBAQ data have not been validated across different subgroups defined by age and body mass index (BMI). Therefore, the aim of the present study was to provide a comprehensive examination of the age-, sex-, and BMI-specific criterion validity of the PASBAQ in a large, nationally representative sample of persons aged ≥16 years in England.

METHODS

Overview of the Health Survey for England

The Health Survey for England annually draws a nationally representative sample of persons aged ≥16 years living in English households using multistage stratified probability sampling (27). In the present analysis, we used data from the 2008 survey, which had a special focus on physical activity and fitness (13). The household response rate was 64%. Ethical approval for the survey was obtained from the Oxfordshire Research Ethics Committee. Trained interviewers assessed participants' demographic characteristics, self-reported health, and health behaviors using computer-assisted personal interviewing. Long-standing illness was assessed by asking participants whether they had "any long-standing illness, disability, or infirmity." Single measurements of height and weight were taken using standard protocols. BMI was computed as weight in kilograms (kg) divided by height in meters squared (m^2). Details on sampling procedures and the study design have been reported elsewhere (13).

A random subsample of participants were asked to wear a uniaxial accelerometer on the waist using an elastic belt (Manufacturing Technology, Inc., GT1M ActiGraph; ActiGraph LLC, Pensacola, Florida) during all waking hours for 7 consecutive days, except when swimming or showering/bathing. Our analytical sample consisted of 2,175 participants aged 16 years or older (992 men). Of these, 1,245 participants aged 16–74 years (615 men) reported doing

Table 1.   Characteristics of Participants With Complete Accelerometer and Questionnaire Data, by Sex, Health Survey for England, 2008

	Women (n = 1,183)		Men (n = 992)		P Value[a]
	%	Mean (SD)	%	Mean (SD)	
Current smoker	19.5		20.0		0.767
Manual occupation	33.3		45.0		<0.001
Long-standing illness	48.7		48.9		0.925
Very physically active at work[b]	16.0		25.9		<0.001
Age, years		51.8 (17.8)		52.7 (17.7)	0.281
Body mass index[c]		27.4 (5.6)		27.7 (4.5)	0.126
Accelerometer wear time, minutes/day[d]		827.3 (70.2)		845.0 (76.7)	<0.001

Abbreviation: SD, standard deviation.

[a] P value for comparison between men and women, calculated by means of the χ^2 test (categorical variables) or analysis of variance (continuous variables).

[b] Participants aged 16–74 years who had done any paid or unpaid work in the last 4 weeks (630 women, 615 men).

[c] Weight (kg)/height (m)^2.

[d] Average accelerometer wear time per day, where nonwear was defined by intervals of at least 60 minutes of zero activity counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute.

any paid or unpaid work in the last 4 weeks and so were asked additional questions on occupational activity. Table 1 and Web Table 1 (available at http://aje.oxfordjournals.org) present sample characteristics by sex and age group (16–44, 45–64, or ≥65 years), respectively. Differences between the full sample ($n = 15,054$) and the analytical sample ($n = 2,175$) in terms of sex ratio, age, BMI, current smoking status, socioeconomic position, presence of any long-standing illness, and participation in physically demanding jobs were not materially important (Web Table 2).

Objective measures of physical activity and sedentary behavior

Accelerometer data were processed using specialized software (KineSoft Software, Saskatoon, Saskatchewan, Canada). A 60-second epoch was used, and nonwear was defined by intervals of at least 60 minutes of zero activity counts with allowance for up to 2 consecutive minutes of 1–100 counts. For a day to be considered valid, accelerometers must have been worn for at least 600 minutes. Participants providing at least 3 valid days of accelerometer data were included in the analysis.

Accelerometer data are routinely processed to record the duration of time spent at different intensity levels. We used average daily minutes with 200 or more counts as the main indicator of total activity. Although there is uncertainty regarding the preferred cutoff for recording sedentary time (and hence time spent being physically active), we chose ≥200 counts/minute because 1) it has been used in previous Health Survey for England analyses to match the full range of light-, moderate-, and vigorous-intensity activities collected by the PASBAQ (28) and 2) it is less likely to contain sedentary behavior "noise" than alternative ≥50- and ≥100-counts/minute cutoffs. For sensitivity analyses, we used average accelerometer counts/minute of wear time as a secondary indicator of total activity, as was done recently in a major study in children (29).

There has been a lack of uniformity in the choice of accelerometer cutoffs for measuring duration of time spent in physical activities of at least moderate intensity (30). A 760 counts/minute cutoff based on combined information from laboratory- and field-based studies was developed by Matthew (31). In line with previous studies (32–34), 760–2,019 counts/minute was used to estimate duration of time spent in lower-range moderate-intensity physical activity. These thresholds potentially capture activities (such as gardening and vacuuming) that fall below the 2,020 counts/minute cutoff point commonly used (35–38) to estimate duration of time spent in moderate physical activity (2,020–5,998 counts/minute) and MVPA (≥2,020 counts/minute). MVPA using the 2,020 counts/minute threshold was analyzed in terms of both total accumulated time and bouts of at least 10 consecutive minutes ($MVPA_{10\text{-min bouts}}$) to enable comparison with physical activity recommendations in the United Kingdom, the United States, and elsewhere which stipulate that the achievement of health benefits requires undertaking MVPA in sustained bouts (39–41). Both MVPA and $MVPA_{10\text{-min bouts}}$ were grouped into one of 2 categories (<150 minutes/week or ≥150 minutes/week, with time spent in vigorous-intensity activities given twice the credit of time

spent in moderate-intensity activities) to indicate achievement of physical activity recommendations.

An accelerometer count below 100 per minute during wear time is the most common threshold denoting sedentary behavior among adults, but it is not universally accepted (42, 43). To examine the sensitivity of criterion validity, we derived the average minutes/day spent being sedentary using 3 different cutpoints—<50 counts/minute, <100 counts/minute, and <200 counts/minute—for comparison with self-reported data.

Measurement of physical activity in the Health Survey for England

Different versions of the Health Survey for England physical activity questionnaire have been used since 1991: version 1 in 1991–1993; version 2 in 1997–1998 and 2006; and version 3 in 1999, 2003, and 2004 (44). The 1998, 2003, and 2008–2010 Scottish Health Surveys used a questionnaire identical to version 2 (45–47). The 2008 version was a slight alteration of version 2, containing additional questions on occupational activity and sedentary behavior. Web Table 3 outlines the different versions of the questionnaire used between 1991 and 2008. The 2008 questionnaire is provided in the Web Appendix.

Physical activity questions included the frequency (number of days in the last 4 weeks) and duration (of an average episode) of participation in 4 domains: 1) "light" (e.g., general tidying) and "heavy" (e.g., spring cleaning) domestic activity; 2) "light" and "heavy" manual work/gardening/do-it-yourself activity; 3) light-intensity (slow/average pace) and moderate-intensity (fairly brisk/fast pace) walking; and 4) light, moderate, and vigorous sports/exercise. Intensity of sports/exercise was determined by the nature of the activity as indexed in the metabolic equivalent (MET) compendium (48, 49) and a follow-up question on whether the activity had made the participant "out of breath or sweaty." To reflect current recommendations (39–41), the PASBAQ asks participants to include only activities which lasted for at least 10 minutes; therefore, its physical activity estimates can be interpreted as estimates of activity that was performed in sustained bouts.

Sedentary behavior was assessed using a set of questions on the usual amount of time spent in 1) television viewing (including digital video discs (DVDs)) and 2) any other (non-television-viewing) sitting during leisure time, including reading and computer use ("In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekday/weekend day?"). For participants aged 16–74 years who had done any paid or unpaid work during the last 4 weeks, another set of questions assessed the usual amount of time spent sitting down or standing while at work.

Time spent being physically active, regardless of intensity, was calculated as the sum of amounts of time spent in the 4 domains listed above. To estimate relative energy expenditure, we multiplied the amounts of time spent in different activities by their MET values. As in previous studies (20, 21), light-intensity activities (i.e., "light" domestic activity, "light" manual/gardening activity, slow/average-paced walking, and a subset of sports/exercise) were assigned MET values of 1.5–2.9; moderate activities (i.e., "heavy" domestic/manual/

gardening activity, fairly brisk/fast-paced walking, and a sub-set of sports/exercise) were assigned MET values of 3.0–5.9; and vigorous activities (all other levels/activities) were assigned MET values of ≥ 6.0 (48, 49). Time spent in MVPA was calculated by summing amounts of time spent in moderate-intensity and vigorous-intensity activity. MVPA was calculated both including and excluding "heavy" domestic activity, as previous studies have shown this domain to be either negatively associated (50) or not associated (24, 45, 50, 51) with health outcomes, and thus studies often exclude "heavy" domestic activity from MVPA calculations (24, 28, 52). Sports participation was assessed both overall (i.e., any intensity) and for activities of at least moderate intensity (48). Using current recommendations, PASBAQ-assessed leisure-time MVPA was used to classify participants as aerobically active if they reported ≥ 150 minutes/week of moderate-intensity physical activity, ≥ 75 minutes/week of vigorous-intensity activity, or an equivalent combination of the two (53).

Total sedentary time was calculated both including and excluding time spent sitting down or standing while at work. Our 3 chosen domain-specific sedentary measures were: 1) watching television, 2) any other nontelevision leisure-time sitting, and 3) occupational sitting/standing. As with the accelerometer data, all PASBAQ-derived variables were converted to minutes/day or MET-minutes/day.

Statistical analyses

Data were analyzed using SPSS, version 20.0 (SPSS Inc., Chicago, Illinois) and Stata, version 12.1 (StataCorp LP, College Station, Texas). Accelerometer and PASBAQ variables were analyzed as continuous variables. Differences by sex were analyzed using the χ^2 test and analysis of variance for categorical and continuous variables, respectively. All tests of statistical significance were based on 2-sided probability ($P < 0.05$).

A small-scale study of 106 healthy adults demonstrated strong test-retest reliability for both accelerometry (intraclass correlation coefficients were 0.81 and 0.90 in women and men, respectively) and the PASBAQ (intraclass correlation coefficients were 0.76 and 0.89, respectively) (26). Criterion validity was assessed using Spearman's rank-order correlation coefficient (ρ), as in most previous studies (9, 54). Bootstrapping methods were used to calculate 95% confidence intervals (55). Accelerometer-versus-PASBAQ estimates of median minute/day spent being physically active/sedentary were compared using the Wilcoxon signed-rank test. Nonparametric tests were used because of the highly positively skewed data distributions. The kappa statistic was used to compare accelerometer estimates of the proportion adhering to the current MVPA recommendations with PASBAQ estimates. To address our a priori hypothesis that validity coefficients would vary across subgroups, each analysis was stratified by sex, age group, and, additionally, BMI (normal weight: 18.5–24.9; overweight: 25.0–29.9; obesity: ≥ 30.0). Participants with BMIs less than 18.5 were excluded from BMI-specific analyses because of small numbers ($n = 22$). Differences in correlations across subgroups were tested using Fisher's z test. PASBAQ-derived total activity and duration of time spent in sports were compared against the

2 indicators of accelerometer-assessed total activity described above. As was done previously (56), PASBAQ-derived total MET-minutes/day were compared with average accelerometer counts/minute of wear time.

RESULTS

In our analytical sample, men were more likely than women to be in a manual social class ($P < 0.001$) and to report themselves to be very physically active at work ($P < 0.001$) (Table 1). No significant sex differences in BMI, smoking, or the presence of any long-standing illness were found. The prevalence of current smoking decreased in older age groups, while the proportions of participants with any long-standing illness and in a manual social class increased in older age groups ($P < 0.001$). Men wore accelerometers on average 17.7 minutes/day longer than did women ($P < 0.001$). Accelerometer wear time was highest in middle-aged persons and lowest in older persons (852.7 minutes/day and 817.9 minutes/day, respectively) but did not vary by BMI (Web Table 3).

Table 2 shows results from the comparison of accelerometer median minutes/day spent being physically active/sedentary with PASBAQ median minutes/day (see Web Tables 4 and 5 for results by age group and BMI, respectively). In each sex, age, and BMI category, the accelerometer-based median numbers of minutes/day spent in both total activity and MVPA (total accumulated time) were underestimated by self-report data. In women, differences ranged from 10.2 minutes/day for MVPA (including "heavy" domestic activity) to 188.6 minutes/day for total activity. The equivalent figures in men were 13.7 minutes/day and 178.0 minutes/day, respectively. In contrast, PASBAQ-assessed MVPA was slightly higher than accelerometer-assessed MVPA analyzed in bouts of ≥ 10 minutes, with differences of 5.8 minutes/day and 8.1 minutes/day in women and men, respectively.

In each sex, age, and BMI category, the PASBAQ underestimated the amount of time spent being sedentary. The median PASBAQ-assessed sedentary time was 145.0 minutes/day and 122.1 minutes/day lower than accelerometry-based estimates in women and men, respectively (using <100 counts/minute as the threshold). The largest difference in sedentary time between the 2 assessment methods was found among older persons, while the largest difference in the duration of physical activity was found in young persons. Absolute differences between median PASBAQ- and accelerometer-based physical activity and sedentary behavior estimates were similar across BMI categories.

According to self-reported data, the proportions of participants meeting current physical activity recommendations were 54.1% and 59.8% in women and men, respectively; equivalent figures using accelerometer-based MVPA were 45.0% and 59.3% (total accumulated time) and 11.7% and 16.6% (bouts of ≥ 10 minutes), respectively. The kappa statistic for agreement between PASBAQ- and accelerometer-based MVPA analyzed as total accumulated time was 0.27 (95% confidence interval (CI): 0.22, 0.33) in women and 0.32 (95% CI: 0.26, 0.39) in men. Equivalent figures for accelerometer-based MVPA analyzed in bouts of ≥ 10 minutes were 0.10 (95% CI: 0.07, 0.14) and 0.13 (95% CI: 0.09, 0.17), respectively.

Table 2. Absolute Differences Between Median Amounts of Time Spent in Physical Activity and Sedentary Behavior as Derived From the Physical Activity and Sedentary Behavior Assessment Questionnaire and Accelerometer Data, by Sex, Health Survey for England, 2008

PASBAQ		Accelerometer		Difference, minutes/day[a]	P Value[b]
Variable	Median Time, minutes/day (IQR[c])	Variable	Median Time, minutes/day (IQR)		
Women (n = 1,183)					
Total physical activity	63.2 (159.3)	Total physical activity[d]	251.9 (110.5)	−188.6	<0.001
VPA	0.0 (8.6)	VPA[e]	0.0 (0.0)	0.0	<0.001
MVPA[f]	8.6 (31.4)	MVPA[e]	18.8 (25.0)	−10.2	<0.001
MVPA[f]	8.6 (31.4)	MVPA$_{10-min\ bouts}$	2.9 (10.9)	5.8	<0.001
MVPA[g]	4.3 (30.0)	MVPA	18.8 (25.0)	−14.5	<0.001
MVPA[g]	4.3 (30.0)	MVPA$_{10-min\ bouts}$	2.9 (10.9)	1.4	<0.001
Heavy domestic activity	0.7 (3.7)	LRMPA[e]	63.9 (47.6)	−63.2	<0.001
Total sedentary activity[h]	364.3 (197.1)	<50 cpm	457.3 (113.4)	−93.0	<0.001
Total sedentary activity	364.3 (197.1)	<100 cpm	509.3 (112.4)	−145.0	<0.001
Total sedentary activity	364.3 (197.1)	<200 cpm	575.9 (111.5)	−211.6	<0.001
Men (n = 992)					
Total physical activity	64.8 (149.2)	Total physical activity	242.9 (124.4)	−178.0	<0.001
VPA	0.0 (27.1)	VPA	0.0 (0.6)	0.0	<0.001
MVPA[f]	13.2 (41.7)	MVPA	26.9 (34.1)	−13.7	<0.001
MVPA[f]	13.2 (41.7)	MVPA$_{10-min\ bouts}$	5.1 (15.3)	8.1	<0.001
MVPA[g]	8.6 (38.6)	MVPA	26.9 (34.1)	−18.4	<0.001
MVPA[g]	8.6 (38.6)	MVPA$_{10-min\ bouts}$	5.1 (15.3)	3.4	<0.001
Heavy domestic activity	1.1 (3.7)	LRMPA	65.3 (51.9)	−64.2	<0.001
Total sedentary activity	415.7 (207.5)	<50 cpm	485.0 (139.6)	−69.3	<0.001
Total sedentary activity	415.7 (207.5)	<100 cpm	537.8 (137.5)	−122.1	<0.001
Total sedentary activity	415.7 (207.5)	<200 cpm	598.8 (130.0)	−183.1	<0.001

Abbreviations: cpm, counts/minute; IQR, interquartile range; LRMPA, lower-range moderate-intensity physical activity; MVPA, moderate-to-vigorous physical activity; PASBAQ, Physical Activity and Sedentary Behavior Assessment Questionnaire; VPA, vigorous physical activity.

[a] Difference between PASBAQ- and accelerometer-assessed median estimates.

[b] *P* value for the difference between PASBAQ- and accelerometer-assessed estimates, according to the Wilcoxon signed-rank test.

[c] Difference between 25th and 75th percentiles.

[d] Average daily amount of time spent at ≥200 cpm.

[e] Accelerometer cutoff points for quantification of time in intensity band: VPA, ≥5,999 cpm; MVPA, ≥2,020 cpm; LRMPA, 760–2,019 cpm.

[f] MVPA calculations included heavy domestic activity.

[g] MVPA calculations excluded heavy domestic activity.

[h] Total included occupational sitting/standing.

Table 3 presents sex-specific estimates of criterion validity for PASBAQ-derived physical activity. Spearman rank-order correlations ranged from 0.12 to 0.42 in women and from 0.09 to 0.39 in men; most correlations exceeded 0.25. In both sexes, criterion validity was lowest for sports of any intensity and highest for MVPA including "heavy" domestic activity. Correlations between PASBAQ- and accelerometer-assessed total time spent in physical activity were 0.30 in women (95% CI: 0.25, 0.35) and 0.20 in men (95% CI: 0.15, 0.26). In the alternative analysis using average accelerometer counts/minute as the criterion, correlations were slightly higher for both women (ρ = 0.33, 95% CI: 0.28, 0.38) and men (ρ = 0.25, 95% CI: 0.20, 0.31).

Using average accelerometer counts/minute as the criterion, PASBAQ-derived MET-minutes/day showed higher correlations than PASBAQ-derived total time spent in activity in both women (ρ = 0.41, 95% CI: 0.36, 0.46) and men (ρ = 0.32, 95% CI: 0.26, 0.38). Positive correlations of similar magnitude were found for vigorous-intensity physical activity (women: ρ = 0.39, 95% CI: 0.33, 0.46; men: ρ = 0.31, 95% CI: 0.26, 0.36) and MVPA analyzed as total accumulated time (women: ρ = 0.42, 95% CI: 0.36, 0.48; men: ρ = 0.38,

Table 3. Rank-Order Correlations (Spearman's ρ) Between the Physical Activity and Sedentary Behavior Assessment Questionnaire and Accelerometer Data for Physical Activity Variables, by Sex, Health Survey for England, 2008

Accelerometer Measure, by PASBAQ Measure	Women (n = 1,183)		Men (n = 992)		P Value[a]
	ρ[b]	95% CI[c]	ρ[b]	95% CI[c]	
Total activity (defined as minutes with ≥200 counts)					
Total activity (in minutes/day)	0.30	0.25, 0.35	0.20	0.15, 0.26	0.013
Sports of any intensity (in minutes/day)	0.12	0.07, 0.17	0.09	0.03, 0.15	0.484
Total activity (defined as average cpm)					
Total activity (in minutes/day)	0.33	0.28, 0.38	0.25	0.20, 0.31	0.042
Total activity (in MET-minutes/day)	0.41	0.36, 0.46	0.32	0.26, 0.38	0.016
VPA (≥5,999 cpm)					
VPA	0.39	0.33, 0.46	0.31	0.26, 0.36	0.034
MVPA (≥2,020 cpm)					
MVPA[d]	0.42	0.36, 0.48	0.38	0.32, 0.45	0.271
MVPA[e]	0.40	0.35, 0.44	0.37	0.31, 0.43	0.412
MVPA in sports	0.26	0.21, 0.31	0.24	0.18, 0.30	0.624
Fairly brisk/fast walking	0.35	0.31, 0.40	0.28	0.23, 0.34	0.072
MVPA (≥2,020 cpm) in 10-minute bouts					
MVPA[d]	0.36	0.30, 0.43	0.39	0.33, 0.46	0.418
MVPA[e]	0.35	0.29, 0.41	0.38	0.33, 0.44	0.424
LRMPA (760–2,019 cpm)					
Heavy domestic activity	0.28	0.21, 0.34	0.24	0.17, 0.32	0.317

Abbreviations: CI, confidence interval; cpm, counts/minute; LRMPA, lower-range moderate-intensity physical activity; MET, metabolic equivalent; MVPA, moderate-to-vigorous physical activity; PASBAQ, Physical Activity and Sedentary Behavior Assessment Questionnaire; VPA, vigorous physical activity.

[a] P value for the difference between Spearman's ρ for women and men, calculated using Fisher's z test.
[b] Spearman's rank-order correlation coefficient.
[c] Confidence intervals were computed using a bootstrapping procedure.
[d] MVPA calculations included heavy domestic activity.
[e] MVPA calculations excluded heavy domestic activity.

95% CI: 0.32, 0.45). Correlations were similar using accelerometer-based MVPA analyzed in bouts of ≥10 minutes (women: ρ = 0.36, 95% CI: 0.30, 0.43; men: ρ = 0.39, 95% CI: 0.33, 0.46). Excluding "heavy" domestic activities from PASBAQ-assessed MVPA produced similar correlations.

Criterion validity was significantly higher in women than in men for: 1) total activity time using both average accelerometer minutes greater than or equal to 200 counts (P = 0.013) and accelerometer counts/minute (P = 0.042); 2) MET-minutes/day versus counts/minute (P = 0.016); and 3) time spent in vigorous-intensity physical activity (P = 0.034). Validity coefficients showed an age-related trend for total time spent in activity and "heavy" domestic activity, with correlations increasing in older age groups (Web Table 6). For example, correlations for total time spent in activity (versus average accelerometer counts/minute) ranged from 0.15 (95% CI: 0.08, 0.23) in persons aged 16–44 years to 0.46 (95% CI: 0.38, 0.53) in persons aged 65 years or older. Similarly, higher criterion validity for MVPA (total accumulated time), sports of any intensity, and time spent walking at a fairly brisk/fast pace was found in older persons, while validity for vigorous-intensity physical activity was highest in young persons. Validity coefficients across BMI categories

failed to show any consistent pattern, with the exception of lower correlations among persons classified as obese for time spent in vigorous-intensity physical activity (Web Table 7).

Table 4 presents sex-specific coefficients for PASBAQ-derived sedentary behavior. Correlations ranged from 0.11 to 0.31 in women and from 0.11 to 0.26 in men. The correlations with accelerometer data (<100 counts/minute) were highest for total sedentary time (women: ρ = 0.30, 95% CI: 0.24, 0.35; men: ρ = 0.25, 95% CI: 0.19, 0.30) and lowest for time spent watching television. Correlations did not show significant differences by sex. However, correlations for total sedentary time (excluding occupational sitting/standing) and television viewing did increase in older age groups (Web Table 8). Correlations with accelerometry for PASBAQ-assessed television viewing were higher for overweight persons than for those of normal weight (Web Table 9). Criterion validity was not highly sensitive to the choice of accelerometer cutpoint for recording amount of time spent being sedentary.

DISCUSSION

To our knowledge, this was the first study to examine the validity of the 2008 PASBAQ in a nationally representative

Table 4. Rank-Order Correlations (Spearman's ρ) Between the Physical Activity and Sedentary Behavior Assessment Questionnaire and Accelerometer Data for Sedentary Behavior Variables, by Sex, Health Survey for England, 2008

PASBAQ Measure, by Accelerometer Cutoff Point for Sedentary Behavior[a]	Women (n = 1,183)		Men (n = 992)		P Value[b]
	ρ[c]	95% CI[d]	ρ[c]	95% CI[d]	
Total sedentary activity[e]					
<50 cpm	0.31	0.25, 0.37	0.25	0.19, 0.31	0.131
<100 cpm	0.30	0.24, 0.35	0.25	0.19, 0.30	0.208
<200 cpm	0.27	0.21, 0.32	0.23	0.17, 0.29	0.322
Total sedentary activity[f]					
<50 cpm	0.27	0.22, 0.32	0.26	0.20, 0.32	0.803
<100 cpm	0.24	0.19, 0.29	0.23	0.16, 0.29	0.803
<200 cpm	0.21	0.16, 0.26	0.20	0.14, 0.26	0.810
Television viewing					
<50 cpm	0.16	0.11, 0.22	0.16	0.10, 0.21	>0.999
<100 cpm	0.14	0.08, 0.19	0.13	0.07, 0.19	0.810
<200 cpm	0.11	0.06, 0.17	0.11	0.05, 0.18	>0.999
Nontelevision sitting					
<50 cpm	0.20	0.15, 0.26	0.18	0.12, 0.24	0.631
<100 cpm	0.20	0.14, 0.25	0.17	0.11, 0.22	0.472
<200 cpm	0.18	0.12, 0.23	0.15	0.09, 0.21	0.472
Occupational sitting/standing[g]					
<50 cpm	0.19	0.11, 0.27	0.17	0.09, 0.25	0.740
<100 cpm	0.20	0.10, 0.30	0.19	0.11, 0.27	0.865
<200 cpm	0.18	0.11, 0.26	0.19	0.11, 0.27	0.865

Abbreviations: CI, confidence interval; cpm, counts/minute; PASBAQ, Physical Activity and Sedentary Behavior Assessment Questionnaire.

[a] Accelerometer-assessed sedentary time was calculated using 3 different thresholds (<50 cpm, <100 cpm, and <200 cpm).

[b] P value for the difference between Spearman's ρ for women and men, calculated using Fisher's z test.

[c] Spearman's rank-order correlation coefficient.

[d] Confidence intervals were computed using a bootstrapping procedure.

[e] Total included occupational sitting/standing.

[f] Total excluded occupational sitting/standing.

[g] Time spent sitting/standing while at work, among participants aged 16–74 years who reported doing any paid or unpaid work in the last 4 weeks and had complete information on sedentary time (559 women, 556 men).

sample of persons aged ≥16 years in England using accelerometer data as the criterion method. The magnitude of validity coefficients differed across indicators of physical activity and sedentary behavior. We also found important differences in the validity coefficients by age. The correlations with accelerometer data showed that the PASBAQ is a useful instrument for ranking individuals according to levels of physical activity and sedentary behavior. However, the average number of minutes/day spent being physically active and sedentary were both underestimated by self-report data, suggesting that absolute estimates derived from the questionnaire in its present form should be interpreted with caution.

There is no universally acceptable level for the magnitude of criterion validity coefficients for questionnaires versus accelerometry, but several reviews have indicated that correlations rarely exceed 0.40 (6, 11, 57, 58). The recent systematic review by Helmerhorst et al. (9) showed an average correla-

tion of 0.30, similar to those found in our study and elsewhere (59). The same review also showed an average correlation of 0.23 for estimates of time spent being sedentary (9). Therefore, the rank-order correlations for total sedentary time in our study (0.30 in women and 0.25 in men) indicated above-average criterion validity of the PASBAQ.

Correlations with accelerometer-based total activity (expressed as average counts/minute of wear time) were slightly higher using MET-minutes/day, indicating the value of incorporating standardized estimates of the energy costs associated with habitual physical activity. Lower criterion validity was found for domain- and type-specific physical activity (e.g., PASBAQ-assessed sports of any intensity vs. accelerometer-assessed total activity). Similar low levels of criterion validity were found for domain- and type-specific sedentary behavior (e.g., PASBAQ-assessed time spent watching television vs. accelerometer counts/minute below 100).

Although this was expected due to the lack of capacity for accelerometers to produce domain- and type-specific data, it remains an important finding, because many epidemiologic studies using self-report data capture only some domains of physical activity (leisure time) or sedentary behavior (television viewing) to assess the effects of physical activity/sedentary behavior on health (60, 61) or to adjust for potential confounding.

Previous validation studies have shown that questionnaires typically overestimate time spent being physically active and/or time spent in MVPA while underestimating sedentary time (62). Our study has shown that the PASBAQ underestimates both the absolute amount of time spent being physically active (total activity and MVPA analyzed as total accumulated time) and the absolute amount of time spent being sedentary. Explanations for possible underestimation of the actual validity of the PASBAQ include: 1) the exclusion of water-based activities from accelerometry; 2) differences in reference periods (7 days of accelerometer wear vs. 28 days of respondent recall) between the PASBAQ and the accelerometer (accelerometer data were collected the week after participants completed the questionnaire); and 3) the inability of uniaxial accelerometers in particular to capture nonambulatory activities and bicycling (31). However, our study showed that differences in absolute duration may depend to a large extent on whether accelerometer data are analyzed using total accumulated time or sustained bouts. Consistent with previous research (36, 43, 63), durations of accelerometer-assessed MVPA were considerably shorter and more similar to PASBAQ estimates when analyzed in sustained bouts of ≥10 minutes.

Our study had several strengths. The findings are generalizable to the English adult population living in private households, whereas the large majority of previous validation studies relied on small convenience samples (9, 11). Rank-order correlations were sex- and age-specific, which has been rare in previous studies (9, 11). Previous validation studies of the PASBAQ have focused exclusively on physical activity (25, 26). In contrast, our study provides additional data on both total and domain-specific sedentary behavior. Most participants were compliant with the measurement procedures. The minimum number of valid days of accelerometer wear for inclusion in the analysis was set at 3, but overall, 91% of persons in the analytical sample had 5 or more valid days of accelerometer wear. Furthermore, while a minimum of 600 minutes was set, the average accelerometer wear time was 835 minutes/day.

Interpretation of our findings is subject to several limitations. First, there has been a lack of uniformity in the choice of accelerometer cutoff for measuring duration of time spent in physical activity of at least moderate intensity (30). In line with other studies (33, 35–38), we calculated objectively assessed MVPA using the threshold of ≥2,020 counts/minute, but this threshold was based on calibration studies primarily carried out under laboratory conditions, not in free-living conditions (34). We acknowledge that a fuller range (e.g., 760–5,998 counts/minute, ≥760 counts/minute) has been used in other studies and that this range would potentially capture both ambulatory and nonambulatory activities. Second, accelerometer-versus-PASBAQ estimates of the proportion of participants meeting current physical activity recommendations can be misleading, since accelerometer data are compared against recommendations based on epidemiologic studies of the associations between self-reported physical activity and health outcomes (34, 53). Third, neither assessment method can capture all activity that participants engage in during waking hours. The PASBAQ asks about the most common types of physical activity/sedentary behavior, while waist-worn accelerometers cannot capture water-based activity, bicycling, or upper-body or resistance exercise such as walking uphill or carrying loads (5, 58). Fourth, differences in behavior during the 2 different reference periods would have weakened the degree of association between the assessment methods. Finally, by definition, questionnaires such as the PASBAQ capture relative intensity (e.g., an individual's perceived level of exertion), whereas accelerometers capture absolute intensity.

In conclusion, our results showed that in comparison with accelerometry, most PASBAQ variables had criterion validity similar to that of other questionnaires widely used in national and international surveys. However, the PASBAQ in its current form underestimated the absolute amounts of time spent being physically active (total accumulated time) and sedentary but overestimated time spent in sustained bouts of MVPA. Our study also showed that criterion validity was highest for estimates of total activity/sedentary time and that it also varied by age, which will necessitate age-specific reporting in future studies.

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