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Predictors of discordance in self-report versus device-measured physical activity measurement

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Abstract

Purpose: Accurate measurement of free-living physical activity is challenging in population-based research, whether using device-based or reported methods. Our purpose was to identify demographic predictors of discordance between physical activity assessment methods and to determine how these predictors modify the discordance between device-based and reported physical activity measurement methods.

Methods: Three hundred forty-seven adults from the Survey of the Health of Wisconsin wore the Acti-Graph accelerometer for 7 days and completed the Global Physical Activity Questionnaire. Multivariate linear regression was conducted to assess predictors of discordance including gender, education, body mass index, marital status, and other individual level characteristics in physical activity reporting.

Results: Seventy-seven percent of men and 72% of women self-reported meeting the U.S. Centers for Disease Control and Prevention guidelines for aerobic activity but when measured by accelerometer, only 21% of men and 17% of women met guidelines. Demographic characteristics that predicted discordance between methods in multivariate regression included greater educational attainment ($P < .001$) and partnered status ($P = .003$).

Conclusions: These varying levels of discordance imply that comparisons of self-reported activity among groups defined by (or substantially varying by) educational attainment or marital status should be done with considerable caution as observed differences may be due, in part, to systematic, differential measurement biases among groups.

Keywords

Accelerometry; Epidemiology; Methods; Population health; Physical activity assessment

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Introduction

Physical activity is a key determinant of health via reduced chronic disease risk, increased longevity, and improved quality of life [1]. Per the U.S. Centers for Disease Control and Prevention, the recommended amount of aerobic physical activity for healthy adults is 150 minutes per week of moderate-intensity physical activity, or 75 minutes of vigorous-intensity physical activity, or a combination of both collected in bouts of 10 minutes or more [2]. The guidelines focus on moderate-to-vigorous intensity physical activity (MVPA) because most health benefits are reaped at these intensities [3]. Physical activity comprises a complex and heterogeneous set of behaviors, including intentional exercise, lifestyle activity (e.g., housework, caregiving), walking or biking for transportation, and activity performed as part of work. This broad range of behavioral contexts, many of which can occur multiple times per day or may be performed on an irregular schedule, hinders the accurate and comprehensive measurement of physical activity both in individuals and across populations.

Self-report measures are particularly well-suited for population-based measurement of physical activity due to low cost and ease of implementation but subject to substantial measurement error—particularly over-reporting—and especially with recall periods longer than a few days [4]. On the other hand, devicemeasured measures of physical activity (i.e., accelerometers) have been found to be more precise and accurate than self-report measures [5] but are less widely used in population-based research due to limitations including comparatively higher cost and challenges to capturing some nonambulatory forms of locomotion. The most common physical activity at the population level is walking, and accelerometers are highly accurate for ambulatory activities, including walking, but less accurate for certain activities such as biking, and generally not used during swimming. Thus, in the typical U.S. sample, discrepancies between reported and devicebased methods of physical activity measurement likely reflect a substantial degree of self-report measurement error, as opposed to major underestimation from accelerometry. While completely reliable and valid physical activity assessment is not attainable outside of a laboratory, reasonably accurate physical activity assessment is needed in population-based and other research settings, particularly when considering new opportunities for intervention and prevention. To avoid misinterpretation, questionnaire- based physical activity is referred to as ‘reported’ activity, where activity captured by the accelerometer is referred to as ‘devicemeasured’ in this manuscript [6].

Few studies, however, have examined predictors of within-person discordance between device-based and reported measures of activity, especially in general population-based studies. Dyrstad et al. compared the International Physical Activity questionnaire with an ActiGraph accelerometer, assessing both sedentary time and physical activity. Overall, authors found that participants reported more vigorous activity and less sedentary time than device-measured accelerometry [7]. In that sample, men reported 47% more MVPA on the International Physical Activity questionnaire than did women, yet there were no gender differences in MVPA via accelerometry. This study provided some of the first indications that the consistency between reporting methods may be influenced by demographic characteristics such as age, sex, body mass index (BMI), and educational attainment;

however, it primarily used bivariate analyses such as correlations and absolute differences in reporting to determine the agreement between methods.

Determining the role of individual characteristics that differentially influence physical activity reporting by population subgroups could identify predictors that are prone to over- or under-reporting their physical activity. Consequently, the predictors could then be used to guide future physical activity estimation protocols for research and surveillance. This study aimed to [1] measure the extent of disagreement between self-report questionnaire and waist-worn accelerometry in a general population-based sample and [2] examine potential predictors of discordance between methods, focusing on demographic characteristics and body habitus, measured using BMI (kg/m^2). We hypothesized that demographic characteristics would influence the amount of discordance between self-reported and device-measured activity from the accelerometer. Specifically, we expected that higher discordance would be observed among individuals with lower educational attainment, those with BMI ≥ 30.0 kg/m^2, and those who were unmarried/not living with a partner. These specific individual factors were expected to independently predict discordance due to their previously demonstrated effects on other types of health outcomes. These aims were assessed using a population-based sample of adults living in Wisconsin.

Methods

Participants and recruitment

Initiated in 2008, the Survey of the Health of Wisconsin (SHOW) is a series of annual population health examination surveys with a stratified, random cluster sampling design [8]. A detailed summary of the SHOW methods has been previously published [8]. All SHOW participants have provided self-reported assessment of physical activity collected via personal interview; accelerometry was added in 2014. A total of 531 adults 18+ years old participated in 2014 with 100% completing physical activity questionnaires. All participants were invited to complete the accelerometry portion unless they had walking impairments and/or limitations that would prevent wearing an accelerometer. The University of Wisconsin–Madison Health Sciences Institutional Review Board approved the survey protocols, and written informed consent was obtained for all participants.

Measures

Demographics—Participant responses were collected via self-report with the SHOW interviewer following a standardized script [8]. Questionnaires included information about demographic characteristics such as education, income, marital status, health history, employment, perceived health status, and health behaviors such as physical activity.

Anthropometrics—Trained interviewers measured height and weight using standardized protocols. Both height and weight were measured twice, and the average of the two measurements was recorded. BMI was calculated as weight in kilograms divided by the height in meters squared.

Accelerometry—Participants wore the ActiGraph wGT3X-BT (ActiGraph Corporation, Pensacola, FL) for 7 continuous days. The accelerometers were initialized to collect data in 1-second epochs and then were aggregated into 60-second epochs for wear time validation, scoring, and analysis. The device was worn on a belt on the right hip, and participants received verbal and written instructions on proper use. Participants were instructed to wear the accelerometer for all waking hours, removing it only for water activities (e.g., swimming, showering), and at night to sleep. Accelerometer data underwent multiple quality assessments for completeness and validity by SHOW staff including visual inspection and compliance checks with dates worn, and device assignment with study identification number [9]. Accelerometer data were processed using ActiLife version 6.11.0 (ActiGraph Corporation). For inclusion in this analysis, observations were restricted to those who had worn the accelerometer for at least 5 days with at least 10 hours of wear time per day, which has been shown to minimize intraindividual variance [9,10]. The Troiano Adult (2007) scoring algorithm was used for accelerometer data interpretation and for cut points for MVPA, with the Troiano cut points selected to establish consistency with National Health and Nutritional Examination Survey and other population-level estimates of accelerometer-measured physical activity [11].

Self-reported physical activity—Trained interviewers administered the Global Physical Activity Questionnaire (GPAQ) during the in-home visit using a computer-assisted personal interview program [8]. The GPAQ assesses different types of occupation, transportation, and recreational moderate-and vigorous-intensity physical activities [12] during a “typical week” [13,14]. Vigorous-intensity activity had the additional prompt of activity that causes large increases in breathing or heart rate, and moderate-intensity activity has the prompt of small increases in breathing or heart rate; both activities need to be collected in bouts of at least 10 minutes [12]. Moderate- and vigorous-intensity physical activities were assessed separately, and activity accumulated during transportation (walking, bicycling) was assumed to be of moderate intensity [15]. The total volume of selfreported physical activity was calculated by aggregating moderate- and vigorous-intensity categories into estimates of metabolic equivalent of task (MET)-minutes per week, as specified by the GPAQ scoring protocol. Moderate-intensity activities were assigned a value of 4 METs and vigorous activities were assigned 8 METs, as per the prespecified GPAQ scoring protocol MET values [16]. The validity of the GPAQ has been examined in multiple populations and has been shown to be a useful instrument to assess volume and changes of MVPA [16–19].

Data analysis—Statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). Both self-reported variables and accelerometer data were recorded as continuous variables (minutes per day). Preliminary data cleaning excluded any implausible values (e.g., greater than 23 hours of physical activity per day). The self-reported data distribution had a right skew with approximately 10% of the sample reporting a value greater than three times the 75th percentile of activity. To address the heavy-tailed distribution of data, extreme values of self-reported MVPA were rounded down to three times the 75th percentile (i.e., 6.8 hours per day for total moderate and vigorous physical activities) [20]. To make a valid comparison to match the 7-day time frame of the GPAQparticipants, those who had 5 days of accelerometer wear time were adjusted to the equivalent amount of physical activity over

7 days as to not artificially inflate the discordance outcome due to missing days of activity data.

Meeting physical activity guidelines—To assess proportion of adults accumulating sufficient physical activity, participants were classified as meeting versus not meeting the physical activity guideline separately for accelerometry data and self-reported data consistent with the physical activity guidelines for adults [2].

Multivariate regression—To better understand how associations may vary within subpopulations, linear regression models were used to look at linear associations between measures by education, marital status, and obesity status. Linear regression models were used to identify predictors of "discordance" measured as the difference between device-based accelerometer and GPAQ self-report in hours per week. Covariates included gender, age, education, BMI, and marital status that were selected based on previous literature showing the role of these variables in overall physical activity. Accelerometer wear time was tested in the model to determine if wear time independently predicted discordance and was found to be non-significant with inclusion, therefore for the sake of parsimony have been excluded from the final model presented. Model fit and assumptions for linear regression were checked and met for the model presented.

Results

Demographics and physical activity descriptive results

Table 1 summarizes the distribution of predictor variables for the analytic sample, which includes participants who satisfactorily completed both the self-report and device-based components. Of the 531 adults who participated in the 2014 survey, 500 (94%) consented to participate to accelerometry and 347 (65%) had sufficient valid accelerometer wear time to be included in the analysis. Overall, men self-reported an average of 17.2 (SD = 19.7) hours of MVPA per week, whereas women reported 13.4 (SD = 15.6) hours/ wk. Accelerometer-measured MVPA was 2.9 hours/wk (SD = 3.3) for men and 1.9 hours/wk (SD = 3.2) for women. The proportion of adults achieving recommended amounts of physical activity was significantly higher ($P = .002$) as measured by the GPAQ (77% of men, 72% of women) compared to the accelerometer (21% of men, 17% of women).

Descriptive levels of MVPA by level of education are presented in Table 2. Those in the lowest category of education attainment selfreported an average of 22.9 (SD = 24.6) hours/wk of MVPA, with the middle (college group) self-reporting an average of 15.0 (SD = 18.1), and the highest postgraduate education group self-reporting 9.1 (SD = 9.0) hours per week of MVPA ($P < .0001$). However, when comparing these same educational groups using accelerometry, the lowest category group achieved an average of 0.7 (SD = 2.2) hours/ wk of MVPA, with the middle group collecting an average of 0.9 (SD = 2.2) hours/wk of MVPA, and the highest educational group achieving 1.4 (SD = 2.2) hours of MVPA per week ($P = .12$).

Multivariate analysis of predictors of discordance

Table 3 shows the result of the modeling discordance outcome with demographic characteristics as predictors.

Education

Higher educational attainment was a significant predictor of lower levels of discordance ($P < .0001$) based on increasing levels from high school education or less to college and postcollege graduate studies.

Marriage

When treating marriage as a dichotomous variable, married/ partnered participants showed a significantly lower discordance between methods than unmarried participants ($P = .003$).

Age and gender

There were no significant associations between age ($P = .74$) or gender ($P = .43$) and discordance as the outcome measure.

Body mass index

BMI modeled as a continuous variable was not an independent predictor of discordance ($P = .80$). When analyzed as a dichotomous variable (nonobese: BMI<30 kg/m^2; obese: BMI ≥ 30 kg/m^2), BMI was also not associated with discordance ($P = .56$, not shown).

Moderate-to-vigorous intensity physical activity

Baseline physical activity using accelerometer estimates was included as a predictor during model selection to determine if device-measured physical activity levels significantly predicted discordance. Estimates were neither clinically nor statistically significant, so device-measured MVPA was excluded from the final model presented.

Discussion

This study presents new data regarding individual-level predictors of discordance between self-reported and accelerometer-measured physical activity data. In this large population-based sample of adults, there were much higher volumes of physical activity estimated via self-report compared to accelerometer. Approximately 75% of the sample self-reported meeting physical activity guidelines, but only 19% of those participants met guidelines when assessed via accelerometer. We found that obesity was not an independent predictor for discordance of reporting but being married and higher educational attainment were associated with significant reductions in discordance.

Although a majority of adults (77% of men and 72% of women) reported completing enough physical activity to meet recommended guidelines, a significantly smaller portion met these same guidelines when assessed via accelerometer (21% of men and 17% of women). Similar results were presented by Troiano et al. with a large proportion of the sample meeting guidelines via self-report, but when examining guideline adherence by accelerometry, the prevalence dropped to less than 5% of the adults in that sample [21]. On average, our sample had higher proportions of the sample meeting guidelines than found in National Health and Nutritional Examination Survey data by Troiano. This is consistent with selfreported data from the Centers for Disease Control and Prevention, which found Wisconsin has a slightly higher prevalence of meeting physical activity recommendations compared to the average prevalence of the United States [22].

This study showed that higher levels of education were associated with lower discordance. Because accelerometer-measured physical activity was not different by educational level, those with lower education were either over-reporting more activity, or those with lower education had higher occupational activity that was not sufficiently captured by the accelerometer. For example, accelerometers may not register all workplace upper body movements, some of which may be moderate or vigorous intensity (e.g., heavy lifting) or intermittent, or those from activities such as swimming, resistance training, and stationary cycling [10]. It is possible that those with more education may have a better understanding of activity definitions as presented in the GPAQ. Partnered marital status was significant for reduced discordance between methods, which may be because those who are partnered are more acutely aware of their health or their activity habits, or partnered status could be a proxy assessment for having a secondary person to whom they are held accountable, which increases honesty of reporting from the self-report of physical activity assessment.

Strengths and limitations

The strengths of this investigation are the large sample size and the use of a population-based sample. Additional strengths include the use of multiple baseline characteristics to predict discordance between physical activity measurement methods. The potential for participation bias was limited by the high proportion (94%) of SHOW participants who elected to wear the accelerometer. Strengths of the GPAQ include the ability to ask about domain-specific activity such as activity accumulated during work compared to leisure time. In addition, the GPAQ differentiates between moderate and vigorous-intensity activity allowing for respondents to separately report moderate and vigorous activities.

In addition, while our investigation was premised on measurement limitations of self-reported physical activity, in fact, both methods of physical activity measurement have specific sources of error. As shown in the literature, self-reported instrument measures are prone to recall bias (depending on study design) and social desirability bias [15,23–25]. Although we had multiple measures of physical activity, having an additional measure for aerobic fitness of the individual would have improved the present study. Having a physiologic measurement of an individual’s fitness could potentially help explain some misclassification of activity, such as activity that the device classifies as moderate that an individual with limited aerobic fitness would determine as vigorous.

Conclusions

This study adds important new information about physical activity measurement and the role of predictors in discordance across physical activity methods. Significant predictors of lower discordance include marriage and higher educational attainment. The present study shows that self-reported measures lead to an overestimation of physical activity, but that the discrepancy in reporting is not differential by BMI or by obesity status. Therefore, our study supports the important conclusion that subgroups with obesity are not prone to substantial differential reporting, but we have identified other important predictors, including education and marital status.

On a population level, using self-reported data to assess proportion of adults meeting activity guidelines will lead to a significant over-estimation. Reducing over-reporting would provide a more accurate depiction of physical inactivity and insufficient activity in the United States, thus strengthening the case for policy changes and public health interventions. If our findings are found to be robust between samples and across geographic regions of the United States, researchers could develop a demographic correction factor for physical activity reporting. This could be used to adjust the physical activity estimates from large epidemiologic studies that rely on self-report to minimize differential measurement error between participants. While a demographic correction factor would have high utility for surveillance efforts, using accelerometry at the population level provides objective, comparable estimates of physical activity. Although the opportunity and logistical costs of deploying accelerometers at the population level are higher than using self-report methods, the more precise estimates of activity may be worth the costs. While the accelerometer is not without limitations, caution is warranted when assessing population-level physical activity only via self-report measures for healthy adults.

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Table 1

Selected demographic characteristics for analytic sample of those who participated in accelerometry, stratified by gender (*n* = 347)

Characteristic	Overall	Males	Females
Total n (%)	347 (100.0)	162 (46.7)	185 (53.3)
Age, y, mean (SD)	50.7 (16.9)	50.2 (17.8)	51.2 (16.1)
BMI, kg/m^2 mean (SD)	28.9 (6.3)	29.0 (5.8)	28.9 (6.8)
BMI category, n (%)			
Healthy (BMI < 24.9)	108 (31.1)	44 (27.2)	64 (34.6)
Overweight (25–29.9)	111 (32.0)	57 (35.2)	54 (29.2)
Obese I (30–34.9)	79 (22.8)	37 (22.8)	42 (22.7)
Obese II (35+)	49(14.1)	24 (14.8)	25 (13.5)
Marital status [*], n (%)			
Married/partnered	243 (70.0)	120 (74.0)	123 (66.5)
Not married/unpartnered	104 (30.0)	42 (26.0)	62 (33.5)
High school education [†], n (%)			
High school or less	84 (24.2)	45 (27.8)	39 (21.1)
Some college, college degree	211 (60.8)	87 (53.7)	124 (67.0)
Postbaccalaureate education	52 (15)	30 (18.5)	22 (17.9)

[*] Married includes those who are legally married or living with partner, as compared to those who are unmarried such as those who are divorced, never married, currently single, or widowed.

[†] Education category is a three-level variable with high school completion or less as the reference category, some college up to bachelor's degree as the second category, and postcollege education (graduate school) was the third category.

Table 2

Total hours per week of self-reported physical activity and accelerometer-measured physical activity, stratified by educational status (n = 347)

Type of physical actiivty	Overall Mean (SD)	High school Mean (SD)	College Mean (SD)	Postcollege Mean (SD)
Self-reported PA				
PA by domain (hr/wk)				
Occupational	16.8* (18.7)	23.7 (25.1)	15.1 (16.4)	7.1 (8.2)
Transportation	4.2* (5.9)	6.3 (9.5)	3.8 (4.3)	2.6 (2.5)
Recreational	4.6 (4.6)	5.0 (4.6)	4.5 (5.0)	4.7 (3.6)
MET†-hr/wk of PA				
Moderate	35.0* (49.9)	43.7 (55.9)	34.1 (50.3)	22.0 (28.9)
Vigorous	31.6* (73.1)	52.8 (101)	25.7 (62.8)	14.9 (23.4)
MVPA	70.8* (107)	102 (140)	63.4 (95.4)	40.9 (42.7)
PA by intensity (hr/wk)				
Moderate	12.2* (13.7)	15.8 (15.7)	11.8 (13.5)	7.6 (8.3)
Vigorous	8.3* (11.8)	14.2 (15.4)	6.9 (10.4)	3.6 (3.2)
MVPA	16.2* (19.6)	22.9 (24.6)	15.0(18.1)	9.1 (9.0)
Accelerometer-measured PA				
PA by intensity (hr/wk)				
Light	26.2* (15.1)	24.0 (15.9)	27.7 (15.2)	23.8 (12.3)
Moderate	2.3 (3.1)	2.1 (3.4)	2.3 (3.1)	2.4 (2.6)
Vigorous	0.1 (0.5)	0.0 (0.0)	0.1 (0.5)	0.2 (0.6)
MVPA (in bouts)	0.9 (2.2)	0.7 (2.2)	0.9 (2.2)	1.4 (2.2)
MVPA (accumulated)	2.4 (3.3)	2.1 (3.5)	2.4 (3.3)	2.6 (2.9)
Percentage of wear time by intensity				
% Time in light PA	28.1 (14.3)	26.5 (15.7)	29.4 (14.0)	25.6 (12.0)
% Time in moderate PA	2.3 (2.8)	2.2 (3.4)	2.3 (2.5)	2.5 (2.4)
% Time in vigorous PA	0.1* (0.4)	0.0 (0.0)	0.1 (0.4)	0.2 (0.6)
% Time in MVPA (in bouts)	2.5 (2.9)	2.2 (3.5)	2.5 (2.7)	2.7 (2.7)

Type of physical actiivty	Overall Mean (SD)	High school Mean (SD)	College Mean (SD)	Postcollege Mean (SD)
% Time in MVPA (accumulated)	2.4 (2.9)	2.2 (3.5)	2.5 (2.7)	2.7 (2.7)

*Denotes statistically significant differences ($P < .05$) in group means.

†MET is metabolic equivalent of task approximated to 1 kcal/kg of body weight per hour, for example, resting quietly is approximately 1 MET.

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Table 3

Linear regression model for discordance of total MVPA (hr/wk) between self-report* and accelerometer

Parameter	Estimate (95% confidence interval)	*P* value
Intercept	24.7 (19.6, 29.7)	<.0001
Female (vs. male)	−1.1 (−4.0, 1.7)	.43
Age† (y)	0.0(−0.1,0.1)	.74
Married/partnered (vs. not)	−4.6 (−7.7, −1.6)	.003
BMI‡ (kg/m^2)	−0.0 (−0.3, 0.2)	.80
Education level§ (per level)	−5.3 (−7.6, −3.0)	<.0001

*Self-report values greater than 6.8 hr MVPA per week (values 3 times greater than the 75th percentile of MVPA) were rounded down to 6.8 hours (3 times the 75th percentile of MVPA).

†Age is centered at the mean of 50 years.

‡BMI is centered at the mean of 29.4.

§Education is a three-level variable with high school or less as the reference category, college as level two, and the third level is postcollege graduate school.