Difference Between Self-Reported and Accelerometer Measured Moderate-to-Vigorous Physical Activity in Youth

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We examined differences between objective (accelerometer) and subjective (self-report) measures of moderate-to-vigorous physical activity (MVPA) in youth. Participants included 2761 youth aged 12–19 years. Within each sex and race group, objective and self-reported measures of MVPA were poorly correlated ($R^2 = .01–.10$). Self-reported MVPA values were higher than objective values (median: 42.4 vs. 15.0 min/d). 65.4% of participants over-reported their MVPA by $\geq 5$ min/d. The difference between self-reported and objective measures was not influenced by sex, age, or race. There was, however, a systematic difference such that inactive participants over-reported their MVPA to the greatest extent.

Regular participation in moderate-to-vigorous intensity physical activity (MVPA) is associated with many health benefits in young people such as a decreased likelihood of obesity (18), an increased positive self-concept (24), and a more favorable cardiometabolic disease risk factor profile (3,10). Traditionally, observational studies in the physical activity sciences have assessed MVPA in a subjective manner, such as by self-reported questionnaire (7). However, even within larger epidemiological studies, researchers are increasingly relying on objective physical activity measures obtained by pedometers and accelerometers (23). Therefore, to put the emerging literature into historical context, it is essential to appreciate the difference between perceived (e.g., subjective reports) and objective measures of MVPA.

A recent systematic review by Adamo et al. (1) highlighted the discrepancies between self-reported and objective measures of MVPA within the pediatric population. Of the 83 studies reviewed, 72% reported that children and youth significantly over-reported their MVPA. A careful examination of the studies within this systematic review highlights key limitations in the existing literature and raises some additional questions. First, previous studies were based on relatively small and homogeneous samples. Thus, it is unclear as to whether the difference between self-reported and objective measures of MVPA varies according age, sex,
and race. Second, it is unknown as to whether the difference between self-reported and objective measures of MVPA varies across the physical activity scale. In other words, do both inactive and active youth over-report their level of MVPA, or is this issue limited to inactive youth?

This study has three objectives: 1) to quantify the magnitude of the difference between self-reported and objectively measured MVPA in youth, 2) to determine whether the difference between self-reported and objective measures varied across the MVPA spectrum, and 3) to determine whether the difference between self-reported and objective measures was influenced by sex, age, or race.

**Methods**

**Data Source**

The current study was based on 12–19 year old adolescents from the 2003/2004 and 2005/2006 cycles of the National Health and Nutrition Examination Survey (NHANES). NHANES is a representative cross-sectional survey of the United States. Participants were identified using a complex stratified, multistage probability sampling design (30). NHANES included a home interview and a physical exam that was completed in a mobile exam center. Informed consent was obtained from all participants and their parents or guardians if under the age of consent. The study protocol was approved by the National Center for Health Statistics. The secondary analysis presented here was approved by the Queen’s University Health Sciences Research Ethics Board.

**Objectively Measured Physical Activity by Accelerometry**

Physical activity was monitored objectively using Actigraph AM-7164 accelerometers (Actigraph, Ft. Walton Beach, FL, USA). These are uniaxial monitors that measure vertical accelerations between 0.05–2.00 G in magnitude at a frequency of 0.25–2.50 Hz. These parameters reduce spurious data caused by vibrations from outside sources and restrict monitoring to normal human movement (27). The filtered movement was stored as activity counts for one minute ‘epoch’ intervals.

Accelerometers were given out at the completion of the mobile exam center exam and were programmed to begin recording at 12:01 a.m. the following day. Monitors were worn for 7 consecutive days on the right hip (27). Thus, for each participant there were 10,080 epoch values (one for each minute of the week), with each of these values corresponding to their intensity of movement during that minute. Participants were asked to wear their accelerometer during all waking hours, except when it would get wet such as during water sports or while showering/bathing.

The 10,080 epoch values were downloaded from the accelerometers by the Centers for Disease Control and checked for biologically implausible data. Additional data reduction was completed by the authors before analyses. Specifically, participants were only included in the analyses if they had complete monitoring data for at least 4 days, including at least one weekend day. Days were considered complete if there was at least 10 hr of monitoring time (27). Periods of 20 min or more of zero counts were assumed to indicate nonwear time and did not count
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toward the total wear time. Within adolescents, four days of physical activity monitoring using uniaxial accelerometers has a test-retest reliability correlation coefficient of 0.70 (27).

An epoch threshold of ≥3000 counts/minute was used to denote those minute where the participants were engaged in MVPA (25). This threshold is based on previous validation studies conducted in a similar age group and corresponds to a metabolic equivalent (MET) value of 3.0, which equates to brisk walking (26). As explained below in more detail, the moderate intensity activity threshold for the self-reported MVPA measures was also equivalent to brisk walking and MET values of 3 or higher. There is considerable discrepancy in the literature concerning the accelerometry threshold that should be used to classify MVPA, and the proposed thresholds often vary by age and sex (9). The thresholds used in this study were selected based on available evidence and best judgment of the authors. Although the thresholds used here were developed from a study conducted entirely in adolescent females, similar thresholds have been used for males and females and in youth ranging in age from 6 to 16 years (20).

For each complete day of monitoring, data were filtered to determine the number of minutes spent engaged in: 1) bouts of MVPA (≥5 min), and 2) sporadic MVPA (<5 min). To calculate a bout of MVPA, we determined the number of consecutive minutes in which participants spent at least 80% of the time above the threshold for MVPA (e.g., for a 10 min bout, 8 min would have to be above 3000 counts/minute and this would count as 10 min). The 80% threshold allowed us to account for the occasional rest period observed during bouts of physical activity (e.g., the short break between a goal and restart of game in football). Sporadic physical activity was calculated as those minutes outside of bouts in which participants achieved the 3000 counts/minute threshold. Total MVPA for each day was then calculated as the sum of bouts and sporadic activity. Total minutes of MVPA were then averaged over the 4–7 day monitoring period to create a final variable for each participant that reflected their average MVPA in minutes per day.

Self-Reported Physical Activity by Interview

MVPA was measured subjectively through self-report in a computer assisted interview. The physical activity questions were asked as part of a much larger health survey. The physical activity questionnaire used was developed using questions from previous NHANES surveys and other national health surveys conducted in the U.S. We are not aware of any studies that have tested the psychometric properties and validity of this particular physical activity questionnaire, although components of this questionnaire have been tested and validated.

Participants were asked about specific activities they had engaged in over the past 30 days. This included activities performed in leisure time, at school, and for transportation (e.g., walking, biking). For each activity that they reported engaging in, participants were queried about the frequency, typical intensity, and typical duration. If the frequency and duration of a single activity was implausible (e.g., over 12 hr/day) the time was assumed to be an error and was set as a missing value within the database. Time spent being physically active of least a moderate intensity was summed to create a total amount of time (in minutes) spent engaging in MVPA over the past 30 days. This value was then converted to give an average MVPA value
in minutes per day. Moderate intensity activity is equivalent to brisk walking and calculated by a value of at least 3 METs (2). MET intensities were based on the Compendium of Physical Activity developed by Ainsworth et al. (2,17). To assure that the questionnaires and accelerometers measured the same activities, all water activities (fishing, kayaking, rowing, swimming, and surfing) were removed from the self-reported physical activity measures for the this study.

**Statistical Analysis**

All statistical analysis was performed using SAS version 9.1 (SAS Institute, Cary, NC) and took into account the sample weights and complex sample design of the NHANES survey. Both the objective and self-reported physical activity measures were positively skewed and were log transformed before regression analyses. Initially, descriptive statistics were performed. Paired $t$ tests were used to compare the means of the objective and self-reported MVPA measures. A chi-square test was used to determine the difference in the proportion of youth meeting physical activity guidelines of $\geq 60$ min per day (19,24) according to the objective and self-reported MVPA measures. General linear models were run using the PROC SURVEYREG command to determine if the relationship between measures of MVPA was modified by age, sex, and race.

Bland Altman plots were used to further explore the nature of the relationship between MVPA measures (6). Bland Altman plots, as opposed to correlation, report on how close the linear relationship is by plotting the level of agreement between two measurements. This is done because two methods can have a high correlation without actually agreeing on the measurements (6). Finally, by plotting the difference between measures of self-reported and accelerometer measured MVPA, we determined if the difference between objective and self-reported measures was systematic in nature.

**Results**

**Descriptive Information**

From the 4591 eligible NHANES participants, 2761 (1428 boys and 1333 girls) had both self-reported and objective measures of MVPA and were considered in the analyses.

Basic descriptive information on the study sample is shown in Table 1. Details on the physical activity measures are shown in Table 2. The median time engaged in MVPA was 15.0 min/d based on accelerometer measures and 42.4 min/d based on self-reported measures. The median difference between the two measures was 27.4 min/d ($p < .001$) with self-reported measures over-reporting MVPA by an average of 182.5%.

Most youth (65.4%) over-reported their time spent engaging in MVPA by at least 5 min/d. Twenty percent of youth under-reported their time spent engaging in MVPA by at least 5 min/d. In the remaining 14.6% of participants, the objective and self-reported measures were within $\pm 5$ min/d. Significantly fewer youth met international physical activity guidelines ($\geq 60$ min/d) based on objective measures of MVPA compared with self-reported measures (2.4% vs. 37.9%, $p < .001$).
Relation Between Objective and Self-Reported Measures of Physical Activity

Within the entire subject pool, the objective and self-reported measures of MVPA were poorly but significantly correlated ($R^2 = .04$, $p < .001$). As illustrated in Figure 1 (Panel A), the intercept of the regression line between the objective and self-reported MVPA measures was greater than 0 ($p < .0001$) and the slope was less than 1 ($p < .0001$). This indicates that the difference between the objective and self-reported MVPA measures was systematic in nature such that those at the low end of the physical activity scale tended to over-report their MVPA to a greater extent than moderately activity participants, while highly active participants tended to under-reported their MVPA.
Systematic differences between the objective and self-reported measured MVPA were further explored using a Bland-Altman Plot (Figure 1, Panel B). Analysis revealed that the difference between the objective and self-reported MVPA measures was significant ($p < .001$). The median difference between the two measures was 27.4 min/d. The Bland-Altman plot also shows a small but significant negative relation ($R^2 = .22$, $p < .001$) between the difference in objective and self-reported measures of MVPA, further illustrating the systematic nature of the relation.

**Sex, Age, and Race Differences**

Within each of the sex and race subgroups, the objective and self-reported measures of MVPA were poorly correlated ($R^2 = .02$ in boys, $R^2 = .04$ in girls, $R^2 = .04$ in non-Hispanic white, $R^2 = .09$ in Hispanic, and $R^2 = .06$ in non-Hispanic black). The relation between the objective and self-reported MVPA measures was not significantly modified by sex ($p > .1$, Figure 1, Panel A). In other words, the magnitude and direction of the differences between the objective and subjective measures of MVPA was not different in boys and girls. Similarly, the relation between objective and self-reported measures of MVPA was not significantly modified by age ($p > .2$, Figure 2, Panel A) or race ($p = .7$, Figure 2, Panel B).

**Discussion**

This study examined the relation between accelerometer and self-reported measures of MVPA in a large and representative sample of American youth. Two thirds of the participants over-reported their MVPA by at least 5 min/d. Although the self-reported and objective measures of MVPA were poorly correlated, the results suggest that over-reporting of MVPA was particularly problematic in inactive youth. The nature of the self-report bias was not influenced by sex, age, or race.

The observation that youth over-reported their MVPA is consistent with a large body of evidence that has recently been synthesized in a systematic review (1). The studies in this systematic review consistently reported low-to-modest correlations between self-reported and accelerometer measured physical activity with self-report measures overestimating activity in children and youth (1). Self-reported measures of MVPA overestimated accelerometry measures by an average of 147%. Within the current study we observed weak correlations between self-reported and accelerometer measures of MVPA. Self-reported MVPA was over-estimated by an average of 183%. These findings are consistent with the findings reported in the systematic review (1).

Past studies examining the relationship between self-reported and objectively measured MVPA in youth have relied on small and homogeneous samples (1). There have been limited attempts to determine whether key demographic characteristics (age, sex, race) influence the self-reporting bias. McMurray et al. (14) reported that girls over-reported their MVPA to a greater extent than boys, while Mota et al. (15) reported the opposite, and Basterfield et al. have reported no significant gender differences (5). In the current study we found no difference in the nature of the self-reporting bias in boys and girls. Past research provides limited insight as to
Figure 1 — Panel A: difference between self-reported and accelerometer MVPA in boys, girls, and for the total sample (youth 15 years of age). Dotted line represents line of identity which shows values if there was no difference between self-reported and accelerometer measurements. Panel B: Bland Altman plot showing difference between MVPA as measured by self-report questionnaire and accelerometer vs. average MVPA measured by the two methods for all subjects. Values above 0 on the y-axis indicate that the self-reported MVPA values were higher than the accelerometry values. Solid line, regression line; dotted line, average difference between the two methods; dashed line, 95% confidence interval for difference.
Figure 2 — Panel A: difference between self-reported and measured MVPA in youth 12, 15, and 19 years of age. Panel B: difference between self-reported and measured MVPA with respect to race for youth 15 years of age. Dotted line represents line of identity which shows values if there was no difference between self-reported and accelerometer measurements.
whether the miss-reporting of MVPA is consistent in children and youth of different ages. In this study we found no difference in the amount of over-reporting across different ages. To our knowledge, no previous studies have examined whether race influences the degree of over-reporting of MVPA in youth. Most of the research in this area has been conducted in predominately white population groups (1). The limited research conducted in other racial groups has also found that there is a tendency for MVPA to be over-reported (12,15,29). The findings from the current research suggest that the nature and extent of over-reporting is not modified by race within youth living in the same country.

Social desirability bias and a misinterpretation of the level of perceived exertion may account for some of the discrepancy between self-reported and objective measures of MVPA. Social desirability bias describes the tendency for respondents to distort their answer toward the more socially acceptable and desirable behavior. Klesges et al. (11) found that youth with higher levels of social desirability, measured using a modified version of the Children’s Manifest Anxiety Scale (21), over-reported their physical activity to the greatest extent. This argument is supported by the fact that the greatest level of over reporting was present in the least active youth in the current study. Misinterpretation of the level of perceived exertion during a bout of physical activity may also lead to over-reporting of MVPA. In particular, children and youth that have a history of uncomfortable experiences during exercise are more likely to have higher perceptions of their levels of exertion. This may lead to a skewed perception of time and intensity spent engaging in physical activity, resulting in over-reporting (22).

The manner in which children and youth accumulate their MVPA over the course of a day may account for some of the over-reporting and the poor relations between objective and subjective MVPA measures. Unlike physically active adults, who may accumulate most or all of their daily activity in a single session, children and youth tend to accumulate their activity in short, sporadic sessions (e.g., a couple of minutes of activity here and there over the day; 4). Sporadic physical activity may be difficult to quantify in a questionnaires (4). It was recently reported that sporadic sessions of MVPA, defined as physical activity session less than 5 min in length, accounted for 66% of total daily MVPA in American youngsters, with bouts of activity accounting for the remaining 44% (13). Thus, youth may be inadvertently over-reporting their time spent being physically active by considering many separate sporadic bursts of activity as one longer bout. For example, a 60 min physical education class may be perceived as 60 min of MVPA by a young person, however, in addition to activity time, this 60 min time period would typically be filled with instruction and demonstration by the teacher, time on the sidelines watching others participate, and time standing in line waiting to participate.

As with any study, this study has a number of limitations. Although accelerometers are objective in nature, they are not a perfect measure of MVPA. Accelerometers are an insensitive measure when body movement in the hip region is independent of physical activity intensity (such as weight lifting or bicycling which accounted for <2% of the self-reported MVPA; 25). There are also discrepancies among researchers as to the appropriate accelerometry thresholds that defines MVPA (25,28). If different thresholds were used, the overall volume of objectively measured MVPA would have changed. It should also be noted that the NHANES questionnaire asked participants about activities they engaged in over the past 30
days, whereas the accelerometers measured activities in the week following the mobile exam center visit. The lack of congruency between measurement time periods for the self-reported and objective measures may account for some of the observed differences. In addition, the physical activation questionnaire that was use was rather simple, and had a more comprehensive and validated questionnaire been employed the relations between the objective and subjective MVPA measures may have been stronger and the amount of self-report bias may have been reduced. Finally, this study employed uniaxial accelerometers to obtain the objective MVPA measures. Uniaxial accelerometers are not the criterion measure of MVPA in free-living conditions, as triaxial accelerometers provide more valid measures (8). Nonetheless, studies within youth have shown excellent agreement \((r \geq .86)\) between physical activity measures obtained by triaxial and uniaxial accelerometry implying that uniaxial accelerometry measures are themselves quite valid (16; 31).

**Conclusion**

This study has helped clarify the relationship between self-reported and objective measures of MVPA in 12–19 year old youth. While the relationship between self-reported and objectively measured MVPA was not influenced by basic demographic characteristics (sex, age, and race), the issue of over-reporting was particularly problematic in inactive youth. These findings may reflect a social desirability bias, a misunderstanding of what constitutes MVPA, and the sporadic nature in which inactive children accumulate their activity.

**References**


