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The Utility of Shorter Epochs in Direct Motion Monitoring

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Abstract

This cross-sectional study using direct motion monitoring evaluated whether short epochs increased estimates of moderate or vigorous physical activity (MPA or VPA) and enhanced differences in daily VPA comparing overweight (OW) and nonoverweight (NOW) children. Seventy-seven children (ages 8–10 years) wore accelerometers for 7 days. We calculated two estimates (mean minutes per day) of MPA and VPA using motion counts based on a 15-s epoch and a calculated 60-s epoch produced by totaling each consecutive group of four 15-s motion counts. We compared estimates as a function of mean motion count$\cdot$min^{-1} for sex, age, and status as OW or NOW. The results showed that a 15-s epoch produced higher estimates of VPA (mean difference of 7 min per day, $p < .001$). The average number of VPA minutes added using the 15-s epoch vs. the 60-s epoch was 8.8 for more active children compared with 5.8 for less active children ($p < .001$). There was no difference in VPA minutes between OW and NOW children. These findings suggest modestly increased sensitivity to VPA using shorter epochs; this was particularly true for the most active children. Shorter epochs, however, might not be useful in clarifying the relationship between VPA and obesity in children.

Keywords

accelerometer; child; epoch; vigorous

The rise in childhood obesity has produced a wealth of studies describing the relationship between physical activity levels and body mass among U.S. children. Direct motion monitoring with accelerometers has become the preferred assessment method due to improved accuracy of physical activity estimates compared with self-reporting techniques (Trost, McIver, & Pate, 2005; Welk, 2000). Accelerometers quantify the intensity of body motion relative to gravitational forces over a predetermined period, traditionally 1 min, called a motion count. Depending on the value, each motion count may indicate vigorous, moderate, light, or sedentary physical activity intensity (Chen et al., 2005; Trost, McIver, & Pate, 2005). Totaling individual motion counts in each category helps determine how much

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moderate and vigorous physical activity (MPA and VPA) children routinely perform and how these levels relate to obesity (Ekelund et al., 2007; Pate et al., 2002).

Previous generations of accelerometers used a sampling interval of 60 s and generated a motion count·min^{-1} as the primary unit of measurement (Bray, Wong, Morrow, Butte, & Pivarnik, 1994; Chen et al., 2005; Coe, 2001; Masse et al., 2005; Puyau, Adolph, Vohra, Zakeri, & Butte, 2004; Puyau, Adolph, Vohra, & Butte, 2002). Numerous descriptive studies showed that these 60-s epochs captured less than 10 min of VPA in children in a typical day (Cradock et al., 2004; Mota, 2003; Pate et al., 2002). Observational and direct motion monitoring studies in schools and other settings also have shown that children tend to perform VPA in short bursts lasting fewer than 60 s (Bailey et al., 1995; Berman, Bailey, Barstow, & Cooper, 1998). Thus, 60-s epochs might miss these shorter bursts and underestimate VPA levels in children. Two recent studies supported this hypothesis, demonstrating that most VPA occurs in short bursts and that shorter epochs produce higher estimates of VPA (Baquet, Stratton, Van Praagh, & Berthoin, 2007, Nilsson, Ekelund, Yngve, & Stostrom, 2002). In addition, Trost et al. (2005) recommended that all researchers use an epoch of at least 15 s (currently the shortest epoch possible for a 7-day period on many commercially available monitoring devices) in future studies of physical activity in children as this may improve the ability to identify clinically important variations in VPA.

However, the available evidence supporting the utility of shorter epochs is limited in several ways. First, a small sample size in the Nilsson et al. (2002) study prohibited a complete analysis of the impact of variables that are known to influence VPA levels, such as overall physical activity levels and body mass index on the increased sensitivity of shorter epochs to high intensity physical activity. Second, few studies have examined the impact of shorter epochs on VPA estimates in Latino children living in urban settings within the United States, despite evidence that these populations of children perform relatively less VPA and have increased prevalence of obesity (Dwyer et al., 2000; Gordon-Larsen, Adair, & Popkin, 2002; Gordon-Larsen, McMurray, & Popkin, 1999; Motl et al., 2002; Trost et al., 2002). Finally, although commonly practiced, researchers have not validated the use of motion count thresholds established for 60-s epochs for classification of 15-s motion counts into MPA and VPA categories.

We attempted to determine how epoch length (15-vs. 60-s) influences estimates of average daily MPA, VPA and high-vigorous physical activity (high-VPA) in a sample of mostly Latino 8–10-year-old children. High-VPA was defined as motion counts with a value above the median vigorous motion count for the sample. In addition, we examined the impact of interactions between epoch length and status as obese, overweight (OW), or nonoverweight (NOW), as well as interactions between epoch length and overall physical activity level, on estimates of average daily VPA or high-VPA and variation in VPA among participants. Specifically, we hypothesized that the improved detection of vigorous physical activity using shorter epochs might enhance differences in physical activity levels between more and less active children as well as between OW and NOW children (Berkey et al., 2000; Epstein & Goldfield, 1999; Goran & Treuth, 2001; Ruiz et al., 2006; Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003). If true, this might provide new information regarding the advantages and disadvantages of using short epochs in clinical outcomes and epidemiological studies examining physical activity in children. We also attempted to validate physical activity classification (into MPA and VPA categories) using 15-s epochs, by comparing the accuracy of classification according to fractions of validated thresholds for 60-s epochs (¼·[moderate 900–2,200 count·min^{-1} or vigorous ≥ 2,200 count·min^{-1}]) with observations during a series of choreographed physical activities (Puyau et al., 2002).

Method

Participants

At a community health center in New Haven, CT, we interviewed the parents of 168 children out of the 247 who were scheduled to visit the clinic from January 2005 to June 2005 (see Figure 1). Families who expressed interest in the study were referred to the onsite study investigator (n = 126 of 168). Children with acute illnesses, such as asthma, and those with developmental disorders, such as attention deficit hyperactivity disorder (n = 38), were excluded from consideration. We selected a final sample of 77 boys and girls between 8 and 10 years of age. We obtained written informed consent from parents and assent from the children before enrollment. We also obtained approval from the Human Investigation Committee at the Yale School of Medicine and the participating community health center's research committee.

Demographics and Body Size

Each participant was evaluated for eligibility using a screening questionnaire to assess sex, age, race, and ethnicity. Body mass was obtained using the Seca digital scale (Hamburg, Germany) to 0.1kg. Height was obtained using a portable scale-mounted stadiometer (Seca, Hamburg, Germany) to the nearest 0.1 cm. Height was measured twice and the values averaged for a final height value. Body mass index (BMI; $kg \cdot m^{-2}$) was calculated from height and body mass and used as an indicator of overall weight status. BMI percentile was determined using Centers for Disease Control and Prevention (CDC) reference values to characterize children as NOW (BMI < 85th percentile for sex and age), OW (BMI ≥ 85th% and < 95th percentile for age and sex), or obese (BMI ≥ 95th percentile for age and sex).

Physical Activity Assessment

The Actical accelerometer has been tested and validated for use in field studies with children (Puyau et al., 2002). Participants were fitted with accelerometers (Minimitter, Bend, OR), affixed on elastic belts around the waist, on the day of enrollment. A sample interval (epoch) of 15 s was used. The children were instructed to wear their monitors all day and all night, except for swimming and bathing, for at least 7 full days. Participants returned for a follow-up visit between Days 3 and 6 to determine adherence to the protocol. We reviewed accelerometer data for missing time intervals using graphic output from the Actical software. We also obtained self-reported data regarding the removal of the monitor, failure to replace the monitor, or missed school days.

Observation of Physical Activities

A subset of 7 participants completed a series of five directly observed physical activities while wearing the accelerometer on the final monitored day. Each child was observed sitting in a chair while watching a DVD for 4 min, standing at a table completing a puzzle for 4 min, tossing a football (6 tosses and 6 catches per minute) for 4 min, walking at 2.5 mph for 4 min, and performing 2 series of jumping jacks for 1 min each (range: 36–58 jumping jacks per minute), with a 2-min rest between exercises. The intensity classification for these activities (sedentary, light, moderate, and vigorous) has been established with direct observation and indirect calorimetry (Ainsworth et al., 2000).

Physical Activity Variables

Complete participant data contained at least 5 days with 12 hr or more of motion data between 7:00 a.m. and 11:00 p.m. on school days and between 6:00 a.m. and 11:00 p.m. on nonschool days. This quantity of motion data is sufficient to provide a valid estimate of habitual activity level (Trost, Pate, Freedson, Sallis, & Taylor, 2000). After applying this benchmark, only 75 of the 77 enrolled had sufficient data to be included in these analyses. A 15-s epoch was used to express motion data as count·epoch^{-1}—the primary unit of analysis. A 60-s motion count (count·min^{-1}) was calculated as the sum of each set of four consecutive counts·epoch^{-1} for each minute the monitor was worn.

Each 60-s epoch was assigned an intensity category (sedentary, light, moderate, and vigorous). These intensity categories were based on established thresholds from validation studies in children using the Actical accelerometer compared with indirect calorimetry (Puyau et al., 2004). According to these established thresholds, sedentary epochs are those with a count of < 100 (< 0.015 kcal·kg^{-1}·min^{-1}), light ≥ 100–900 (≥0.015 and < 0.05 kcal·kg^{-1}·min^{-1}), moderate ≥ 900–2,200 (≥ 0.05 and < 0.1 kcal·kg^{-1}·min^{-1}), and vigorous ≥ 2,200 (≥0.1 kcal·kg^{-1}·min^{-1}). Each 15-s epoch was also assigned an intensity category based on thresholds derived from those established for 60-s motion counts. Threshold values were divided by 4 (using the manufacturer's software), as there are four 15-s epochs per minute (< 25 count·15 s for sedentary, ≥ 25 and < 225 for light, ≥ 225 and < 550 for moderate, and ≥ 550 for vigorous). For the purpose of comparing estimates of high-VPA based on 15-s versus 60-s epochs, we determined that all minutes of VPA with a count·epoch^{-1} greater than the median vigorous count·min^{-1} (2,956.5 for the 60-s epoch and 765 for the 15-s epoch) would be classified as high-VPA.

Statistical Analysis

Descriptive statistics were calculated to describe personal characteristics of the participants including sex, age, BMI, height, weight, race or ethnicity, weight group (obese, OW, or NOW), and number of days monitored. The participants' race or ethnicity was classified as African American, Hispanic, White, or other (including one Arabic participant). We then created the mean and standard deviation of age. For the purposes of statistical analysis, we created two age groups: one composed of slightly more than half of the sample with an age at or above the sample's median age of 9.5 years and the other half with an age below the median.

We generated separate estimates of daily minutes of MPA, VPA, and high-VPA from 60-s epochs and from 15-s epochs. For each subject, one estimate of average daily MPA was calculated by totaling all minutes per day (using a 60-s epoch) with a motion count ≥ 900 and < 2,200, and averaging each daily sum over all monitored days. A second estimate was calculated by totaling all periods of 15 s per day (15-s epoch) that had a motion count ≥ 225 and < 550, and averaging daily sums over the monitored days. Using the same method, we calculated two estimates of average daily VPA (using the threshold of ≥ 2,200 for 60-s epochs and ≥ 550 for 15-s epochs) and of average daily high-VPA (using the threshold of the sample median VPA count of 2,956.5 for the 60-s epoch and 765 for the 15-s epoch). We classified each subject as either more or less active according to whether their average 60-s epoch activity count was above or below the median average for all participants. Children with an average count·min^{-1} ≥ 364 (the median average value for the sample) were classified as more active. Those with an average count·min^{-1} < 364 were classified as less active.

Next we compared the average daily number of minutes spent in MPA, VPA, and high-VPA, according to 15-s or 60-s epochs, across participants using paired *t* tests; we did this for all participants combined, as well as separately for less and more active participants. To assess whether the difference in average daily VPA and high-VPA minutes, as counted by 15- and 60-s epochs, varied significantly by subject characteristic, we calculated the difference in MPA, VPA, and high-VPA minutes as measured by each epoch for each subject, and regressed each average daily difference separately against each of the independent variables (weight category and overall physical activity level), reporting the *F* test for each categorical variable. We used an alpha of .05 to determine statistical significance for all tests. To explore whether the interaction between epoch size and these variables affected the observed variation in physical activity estimates, we examined the distribution of daily average VPA and high-VPA data (using the interquartile ranges (IQRs) and standard deviations) for obese, OW, and NOW children separately as well as for more and less active children separately.

Finally, we determined whether the approach to classifying 15-s motion counts into intensity categories using fractions of threshold values developed for 60-s epochs (threshold value$\cdot 4^{-1}$) provided valid estimates of minutes spent in each intensity category. We compared the sensitivity (number of minutes correctly classified into a single intensity category by motion count thresholds/total number of minutes observed at that intensity level), specificity (number of minutes correctly classified as not belonging to a given intensity category by motion count threshold/total number of minutes observed at that intensity level), and proportion of total minutes correctly classified as sedentary, light, moderate, or vigorous (according to direct observation of physical activities) for fractional thresholds (15-s epochs) and validated threshold values for 60-s epochs (Payau et al., 2002).

Results

Characteristics of participants are shown in Table 1. The average number of days monitored were 7.8 (range: 5–13 days), and the average number of hours per day of motion data was 14.4 (range: 12.6–16 hr). Overall, the average numbers of MPA, VPA, and high-VPA minutes determined from 15-s and 60-s epochs are shown in Table 2. Analysis with student *t* tests showed a difference of 2 min in daily MPA (with the lower estimate produced using the 15-s epoch and the higher estimate from the 60-s epoch) that was not statistically significant (p = .0545). Estimates of both average daily VPA and high-VPA were higher using the 15-s epoch compared to the 60-s epoch (M = 7.2 min and 3.4 min respectively, p < .001).

The VPA estimates were higher when shorter epochs were used for both the more active (50.4 min, SD = 19.2, with a 60-s epoch and 59.2, SD = 18.3, with a 15-s epoch) and less active children (15.0 min, SD = 9.2, with a 60-s epoch and 20.8 min, SD = 10.2, with a 15-s epoch). Student *t* tests showed that epoch size had a statistically significant impact on the difference in daily estimates of VPA and high-VPA comparing the two groups (see Table 2). For example, more active children had 38.4 more minutes of VPA estimated from the 15-s epoch and only 35.4 more minutes based on the 60-s epoch (p < .001). A similar finding for high-VPA estimates showed a difference of 22.1 min based on the 15-s epoch and only 19.7 min based on the 60-s epoch (p < .001). The relative increase in VPA estimates using the shorter epoch, however, was larger for less active children, 39% (5.8 additional minutes using the 15-s epoch/15.0 VPA minutes using the 60-s epoch), compared with the more active children, 18% (8.8 additional minutes using the 15-s epoch/50.4 min of VPA using the 60-s epoch).

Regression analysis showed that weight group had no statistically significant association with the difference in VPA and high-VPA estimates (15-s vs. the 60-s epoch; see Table 3). For example, the difference in VPA estimates comparing 15-s and 60-s epochs was 7.0 min per day for NOW children, 7.6 for OW children, and 7.1 for obese children (between group difference *F*test, p= .87). There was also no significant difference between 15-s and 60-s epoch estimates of average daily high-VPA among weight groups (p=.78). Variation in VPA and high-VPA estimates was greater when the shorter epoch was used regardless of weight group. For example, the IQR for daily VPA was 28.9 (SD= 22.3) for obese children using the 15-s epoch compared with an IQR of 24.6 (SD = 20.8) in the same group when the 60-s epoch was used. Among children in the obese group, the IQR for daily high-VPA was 16.7 (*SD*= 13.5) using the 15-s epoch compared with an IQR of 13.4 (*SD*= 11.8) when the 60-s epoch was used. Similar trends were observed between OW and NOW children (see Table 3 and Figure 2).

The sensitivity and specificity of fractional thresholds (15-s epochs) and validated 60-s epoch threshold values were similar compared with direct observation of sedentary and light physical activities (see Table 4). For example, the sensitivity and specificity for distinguishing sedentary from light physical activity for 15-s epochs were 99% and 96%, respectively, compared with those for 60-s epoch thresholds, 100% and 98%, respectively. Sensitivity and specificity for the threshold between light and moderate activity were also similar for 15-s epochs (91% vs. 87%) compared with 60-s epochs (83% vs. 86%). Sensitivity was low for separating moderate from vigorous physical activity, although the 15-s epoch was more sensitive (40.3%) compared with the 60-s epoch (18.8%). The proportion of epochs classified correctly (according to direct observation) was similar for fractional thresholds (15-s epochs) compared with 60-s epochs for all levels of physical activity.

Discussion

Our findings suggest that the use of shorter epochs increased the sensitivity of direct motion monitoring for detection of VPA. The increase in estimates of total daily time spent in VPA was modest, however, for the children in our sample. Furthermore, the total number of minutes by which the estimates increased was affected by overall physical activity levels with more active children having a larger increase in VPA estimates using 15-s epochs compared with less active children. Thus, the use of shorter epoch lengths provided a greater distinction in daily amounts of VPA between more and less active children. The 15-s epochs failed, however, to show increased differences in VPA between obese, OW, and NOW children despite the finding that obese and OW children performed less vigorous activity compared with NOW peers overall. These findings suggest that the use of shorter epochs may improve our ability to distinguish between states of relative inactivity and high physical activity among children but may have more limited utility in distinguishing between clinical states according to personal characteristics such as body mass or adiposity.

The use of shorter epoch lengths adds to the complexity of motion data analysis by quadrupling the amount of raw data generated and introducing the need to estimate appropriate activity category thresholds for epochs of different lengths (Chen et al., 2005; Trost et al., 2005). Yet, only a few studies demonstrate the greater sensitivity of shorter epochs, and no studies examined their utility in providing a better indicator of the connection between VPA and health outcomes including obesity. Our findings indicate that the gains achieved with the use of short epochs may be modest with respect to estimating overall daily VPA minutes. Furthermore, the increase in VPA appeared to depend on the overall activity level of the children in our sample. Due to their smaller sample size, previous studies have not fully described this interaction between overall physical activity level and increased sensitivity to VPA using shorter epochs (Nilsson et al., 2002). Our results show that the interaction between the sensitivity of shorter epochs and overall physical activity level resulted in a larger observed difference in daily VPA levels comparing more active with less active children. This occurred due to both a larger gain in VPA minutes and a decrease in between-participant variation of VPA estimates, as measured by the standard deviation, among more active children when the shorter epoch length was used.

Variation in VPA estimates between participants increased among less active children when the shorter epoch was used. One possible explanation for this finding is that the shorter epoch corrected mistakes made when using the 60-s epoch to assign activity category classification. For example, consider two consecutive 15-s epochs with VPA counts indicating 564 and 620 and two subsequent 15-s epoch counts indicating sedentary behavior, 4 and 12. The sum for all four is 1,200. Using the 15-s epoch we would conclude that the participant had 30 s of VPA and 30 seconds of sedentary physical activity. Using the 60-s epoch the whole period (of 1 min) would be considered MPA. In this example we would conclude that the 15-s epoch was the more precise measure of VPA and the 60-s epoch underestimated VPA. In a separate period of time we may find two 15-s counts of 1,100, and find 2 subsequent counts of 0. Using the 60-s epoch the entire minute would be classified as vigorous. Using the 15-s epoch only 30 seconds of this period would be counted as time spent in VPA. Thus, we would conclude here that the 60-s epoch overestimated the VPA compared with the 15-s epoch. The reduction in between subject variation in daily VPA among more active children using the 15-s epoch may be a reflection of these types of discrepancies in classification of motion counts using shorter and longer epochs. There may not be the same amount of error correction among less active children, or the same number of discrepancies between 15- and 60-s motion count classifications (perhaps due to less moment-by-moment variation in motion intensity).

It is possible that the lower thresholds applied to 15-s epochs are inaccurate and cause misclassification of motion, specifically classification of epochs spent in MPA and VPA The results of our direct observation study, however, appear to contradict this hypothesis. By comparing established thresholds for activity category classification during observed physical activities using the 15- and 60-s epochs, we found that the shorter 15-s epoch provided a more sensitive measure of VPA. Although the 15-s epoch estimates were higher, the sensitivity for detection of VPA was low overall using both the 15- and 60-s epoch. This may have been due to either inappropriately high thresholds for vigorous physical activity (for both measures) or the transient nature of VPA in children even under conditions of observation. The degree of specificity and of correct classification of epochs into the VPA category was similar using both epoch lengths. Both epoch lengths also produced similar sensitivity for distinguishing sedentary from light activity and light from moderate activity. Our finding of comparable classification of motion counts from 15- and 60-s threshold values indicates that there is little error in physical activity classification and greater sensitivity to VPA using shorter epochs. Validation studies using indirect calorimetry may yield more accurate threshold values and demonstrate whether prediction equations based on shorter epochs provide more accurate estimates of activity energy expenditure. This study, however, is one of the first to provide data supporting the use of derived thresholds for categorizing motion data from short sampling intervals (< 60 s).

The average increase in VPA and high-VPA estimates we observed was more modest than increases reported in previous studies despite the relatively high amount of VPA performed by children in our sample (Baquet et al., 2007; Nilsson et al., 2002). The most compelling evidence for increased sensitivity of shorter epochs was presented by Nilsson et al. (2002) in a study of sixteen 7-year-old Swedish children who wore the CSA (WAM7164, MTI, Inc.) accelerometer for 4 days (Nilsson et al., 2002). A primary epoch of 5-s was used and 10-, 20-, and 60-s epochs were calculated. For example, children in the Nilsson et al. (2002) study performed 30.8 min of daily VPA using the 10-s epoch and only 22.0 min of VPA according to the 20-s epoch. These represented a one- and twofold increase in daily VPA compared with the 9.9 min of VPA detected using the 60-s epoch (211%, or 20.9/9.9·100 for the 10-s epoch and 122%, or 12.1/9.9·100 for the 20-s epoch). In our study, the relative increase in daily VPA comparing the 15-s to the 60-s epoch was only 23% [additional VPA minutes (15-s)/total VPA (60-s epoch) × 100]. The number of additional minutes of high

VPA added using the 15-s epoch in this study (3.4 min) did, however, fall within the expected range between the 10-s epoch and 20-s epoch estimates of high-VPA reported in the Nilsson et al. (2002) study (2.7 and 6.1 min, respectively).

The small relative increase in VPA (23%) using the 15-s compared with 60-s epoch in our study compared with larger increases reported in other studies might indicate a ceiling affect at higher overall physical activity levels. For example, when children in a sample are relatively inactive a small increase in VPA estimates may result in a larger relative increase or a doubling of total VPA minutes using shorter epochs. Once children reach the highest levels of daily physical activity; however, even a larger absolute increase in VPA minutes may produce a smaller relative increase in daily VPA. This hypothesis is supported by our finding that although less active children in our sample had a smaller number of VPA minutes added (using the 15-s epoch) they had a larger proportional increase in the total VPA estimate relative to the 60-s epoch estimate compared with more active children.

We found no difference in sensitivity of shorter epochs for detection of VPA according to status as obese, OW, or NOW. Although OW and obese children had less daily VPA on average, a large proportion of NOW children were as inactive or more inactive compared with obese and OW peers. This high variation in VPA among NOW children made it difficult to detect differences according to status as OW or NOW. This finding indicates that shorter epochs may have limited utility in clinical or epidemiological studies examining the interaction between physical activity and obesity, although comparison of shorter epochs with 60-s epochs should be done using longitudinal data to clarify this issue.

There are several factors to consider when interpreting the results of this study. First, we compared shorter 15-s epochs with 60-s epochs rather than using two devices (one using a 15-s epoch and the other using a 60-s epoch). Thus, we cannot be certain that the differences observed in VPA estimates are due to actual differences in sensitivity when devices are set to 60-s epochs or 15-s epochs. Differences in the sensitivity of the accelerometers themselves or the methods used (monitoring protocols, data inclusion, or algorithms used to re-integrate epochs) may contribute to the discrepancies between our study and the findings of other investigators (Baquet et al., 2007; Nilsson et al., 2002). These differences may impact our ability to fairly compare these results with other studies. Our larger sample size, however, allowed for a comparison of differences in VPA estimates using shorter and longer epochs according to overall physical activity level and weight group. We were also able to conduct a limited validation of the use of fractional threshold in a subset of participants. Thus, we believe that this study expands on previous work and that our findings indicate a more limited utility of shorter epochs than has been suggested in previous studies. Also, prediction equations that estimate activity energy expenditure (AEE) from motion counts in validation studies (using the Actical accelerometer) have been based on a 60-s epoch (Puyau et al., 2004). Thus, we could not determine whether shorter epochs improve the accuracy of AEE predicted from motion data compared with longer epochs or to be certain that fractional thresholds accurately reflect levels of energy expended in sedentary, light, moderate, or vigorous physical activity.

In summary, 15-s epochs provided only modestly larger estimates of VPA compared with longer 60-s epochs in our sample. Such a small difference in VPA estimates likely would not substantially improve the validity of studies or provide a clinically meaningful increase in VPA estimates in children. Whereas, shorter epochs enhanced detection of differences in VPA between more active and less active children, they did not enhance detection of differences in VPA between OW and NOW children. This suggests limited utility of shorter epochs in obesity-related research, although longitudinal studies would clarify this issue. We also found that fractional threshold values for classification of 15-s motion counts into activity categories were as accurate as the validated 60-s epoch threshold values when compared with direct observation of physical activities. Future studies may demonstrate whether shorter epochs also more accurately identify VPA compared with the gold standard of calorimetry.

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References

Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: An update of activity codes and MET intensities. Medicine & Science in Sports & Exercise. 2000; 32 Suppl. 2:S498–S516. [PubMed: 10993420]

Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children#x002019;s physical activities: An observational study. Medicine & Science in Sports & Exercise. 1995; 27:1033–1041. [PubMed: 7564970]

Baquet G, Stratton G, Van Praagh E, Berthoin S. Improving physical activity assessment in pre-pubertal children with high-frequency accelerometry monitoring: A methodological issue. Preventive Medicine. 2007; 44:143–147. [PubMed: 17157370]

Berkey CS, Rockett HR, Field AE, Gillman MW, Frazier AL, Camargo CA Jr, et al. Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. Pediatrics. 2000; 105:E56. [PubMed: 10742377]

Berman N, Bailey R, Barstow TJ, Cooper DM. Spectral and bout detection analysis of physical activity patterns in healthy, pre-pubertal boys and girls. American Journal of Human Biology. 1998; 10:289–297.

Bray MS, Wong WW, Morrow JR Jr, Butte NF, Pivarnik JM. Caltrac versus calorimeter determination of 24-hr energy expenditure in female children and adolescents. Medicine & Science in Sports & Exercise. 1994; 26:1524–1530. [PubMed: 7869888]

Chen KY, Bassett R Jr, Welk GJ, Matthew CE, Freedson P, Pober D, et al. The technology of accelerometry-based activity monitors: Current and future. Medicine & Science in Sports & Exercise. 2005; 37 Suppl. 11:S490–S500. [PubMed: 16294112]

Coe D. Validation of the CSA accelerometer in adolescent boys during basketball practice. Pediatric Exercise Science. 2001; 13:373–379.

Cradock AL, Wiecha JL, Peterson KE, Sobol AM, Colditz GA, Gortmaker SL. Youth recall and TriTrac accelerometer estimates of physical activity. Medicine & Science in Sports & Exercise. 2004; 36:525–532. [PubMed: 15076797]

Dwyer JT, Stone EJ, Yang M, Webber LS, Must A, Feldman HA, et al. Prevalence of marked overweight and obesity in a multiethnic pediatric population: Findings from the Child and Adolescent Trial for Cardiovascular Health (CATCH) study. Journal of the American Dietetic Association. 2000; 100:1149–1156. [PubMed: 11043699]

Ekelund U, Sarnblad S, Brage S, Ryberg J, Wareham NJ, Aman J. Does physical activity equally predict gain in fat mass among obese and non-obese young adults? International Journal of Obesity. 2007; 31:65–71. [PubMed: 16652123]

Epstein LH, Goldfield GS. Physical activity in the treatment of childhood overweight and obesity: Current evidence and research issues. Medicine & Science in Sports & Exercise. 1999; 31 Suppl. 11:S553–S559. [PubMed: 10593527]

Goran MI, Treuth MS. Energy expenditure, physical activity, and obesity in children. Pediatric Clinics of North America. 2001; 48:931–953. [PubMed: 11494644]

Gordon-Larsen P, Adair LS, Popkin BM. Ethnic differences in physical activity and inactivity patterns and overweight status. Obesity Research. 2002; 10:141–149. [PubMed: 11886936]

Gordon-Larsen P, McMurray RG, Popkin BM. Adolescent physical activity and inactivity vary by ethnicity: The National Longitudinal Study of Adolescent Health. Journal of Pediatrics. 1999; 135:301–306. [PubMed: 10484793]

Janz KF, Burns TL, Levy SM. Tracking of activity and sedentary behaviors in childhood: The Iowa Bone Development Study. American journal of Preventive Medicine. 2005; 29:171–178. [PubMed: 16168865]

Masse LC, Fuemmeler BF, Anderson CB, Matthews CE, Trost SG, Catellier DJ, et al. Accelerometer data reduction: A comparison of four reduction algorithms on select outcome variables. Medicine & Science in Sports & Exercise. 2005; 37 Suppl. 11:S544–S554. [PubMed: 16294117]

Mota J. Differences of daily physical activity levels of children according to body mass index. Pediatric Exercise Science. 2003; 15:296–301.

Motl RW, Dishman RK, Ward DS, Saunders RP, Dowda M, Felton G, et al. Examining social-cognitive determinants of intention and physical activity among black and white adolescent girls using structural equation modeling. Health Psychology. 2002; 21:459–467. [PubMed: 12211513]

Nilsson A, Ekelund U, Yngve A, Stostrom A. Assessing physical activity among children with accelerometers using different time sampling intervals and placement. Pediatric Exercise Science. 2002; 14:87–96.

Pate RR, Freedson PS, Sallis JF, Taylor WC, Sirard JR, Trost SG, et al. Compliance with physical activity guidelines: Prevalence in a population of children and youth. Annals of Epidemiology. 2002; 12:303–308. [PubMed: 12062916]

Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. Obesity Research. 2002; 10:150–157. [PubMed: 11886937]

Puyau M, Adolph AL, Vohra FA, Zakeri I, Butte NF. Prediction of activity energy expenditure using accelerometers in children. Medicine & Science in Sports & Exercise. 2004; 36:1625–1631. [PubMed: 15354047]

Ruiz JR, Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjöström M. Relations of total physical activity and intensity to fitness and fatness in children: The European Youth Heart Study. American Journal of Clinical Nutrition. 2006; 84:299–303. [PubMed: 16895875]

Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. Medicine & Science in Sports & Exercise. 2005; 37 Suppl. 11:S531–S543. [PubMed: 16294116]

Trost SG, Pate RR, Dowda M, Ward DS, Felton G, Saunders R. Psychosocial correlates of physical activity in white and African-American girls. Journal of Adolescent Health. 2002; 31:226–233. [PubMed: 12225734]

Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective PA measures with youth: How many days of monitoring are needed? Medicine and Science in Sports & Exercise. 2000; 32:426–431. [PubMed: 10694127]

Trost SG, Sirard JR, Dowda M, Pfeiffer KA, Pate RR. Physical activity in overweight and non-overweight preschool children. International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity. 2003; 27:834–839. [PubMed: 12821970]

Welk GJ. Measurement issues in the assessment of physical activity in children. Research Quarterly for Exercise & Sport. 2000; 71 Suppl. 2:S59–S73. [PubMed: 10925827]

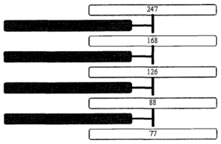

Figure 1.

Sample selection.

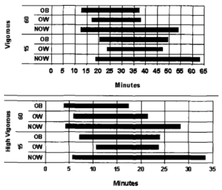

Figure 2.

Interquartile range of daily vigorous physical activity (VPA) and high VPA (count·min^{-1} > median vigorous count for the group) minutes among obese (OB; i.e., a body mass index percentile ≥ 95th for age and sex), overweight (OW; i.e., a body mass index percentile ≥ 85th and < 95th percentiles for age and sex), and nonoverweight (NOW; i.e., a body mass index percentile < 85th for age and sex) children: 15- and 60-s epochs.

Table 1

Participant characteristics (*N* = 75)

	M	***SD***
Girls: *n* (%)	42	56.0
Age (years)	9.4	0.9
BMI (kg·m^2)	21.1	5.1
Height (cm)	136.6	8.0
Weight (kg)	40.0	13.2
Race/ethnicity: *n* (%)		
African American	10	17.8
Hispanic	48	85.3
White	4	7.1
Other	2	3.6
Unknown	11	19.6
Weight group: *n* (%)		
Nonoverweight	31	41.3
Overweight	14	18.7
Obese	30	40.0
Days monitored:		
median (range)	8	(6–10)

Note. M = mean; *SD* = standard deviation; BMI = body mass index.

Table 2

Differences in daily minutes of moderate, vigorous, and high vigorous physical activity using 15- versus 60-s epochs for all participants and for more versus less active children

All participants	**15-s epoch**		**60-s epoch**		**Difference**		p^a
	M	***SD***	***M***	***SD***	***M***	***SD***	
Moderate activity	103.1	35.6	105.1	41.8	−2.0	8.7	.0545
Vigorous activity	38.2	24.2	31.0	22.9	7.2	3.2	<.0001
High vigorous activity	18.7	14.4	15.3	13.5	3.4	2.0	<.0001
More versus less active children[b]							
Vigorous activity							
Less active	20.8	10.8	15.0	9.2	5.8	2.8	<.0001
More active	59.2	18.3	50.4	19.2	8.8	2.8	<.0001
Difference	38.4		35.4		3.0		< .0001
High vigorous activity							
Less active	8.7	5.6	6.4	4.9	2.4	1.6	<.0001
More active	30.8	12.4	26.1	12.7	4.7	1.7	<.0001
Difference	22.1		19.7		2.4		<.0001

Note. M = mean; *SD* = standard deviation.

[a] Student *t* tests were used to evaluate differences in moderate, vigorous, and high vigorous minutes comparing 15- with 60-s epochs.

[b] More active children were those with an average motion count·min^{-1} ≥ median count·min^{-1} for the whole sample (364); less active children had an average count·min^{-1} below the median value.

[c] Student *t* tests were also used to measure the differences in vigorous physical activity and high vigorous physical activity estimates between groups (more active vs. low active).

Table 3

Differences in daily minutes of vigorous and high vigorous physical activity using 15- and 60-s epochs according to weight group[a]

All	**15s**		**60s**		**Difference**		***p***
participants	***M***	***SD***	***M***	***SD***	***M***	***SD***	
Daily min. VPA							
Weight group							.868
NOW	43.3	27.7	36.3	26.5	7.0	3.0	
OW	35.9	18.2	28.4	16.8	7.6	2.9	
Obese	33.9	22.3	26.8	20.8	7.1	3.5	
Daily min. HVPA							
Weight group							.779
NOW	21.5	16.6	18.2	16.0	3.3	1.8	
OW	17.0	10.6	13.3	10.2	3.7	1.7	
Obese	16.7	13.5	13.3	11.8	3.4	2.3	

Note. *M* = mean; *SD* = standard deviation; Min. = minutes; VPA = vigorous physical activity; NOW = nonoverweight; OW = overweight; HVPA = high vigorous physical activity.

[a] Regression was used to test the contribution of weight group to the observed variance of the difference between mean daily vigorous and high vigorous physical activity minutes using the 15-s compared with the 60-s epochs.

Table 4

Sensitivity, specificity, and correct classification of motion counts into activity categories using 15 versus 60-s epoch thresholds for motion data collected during observed physical activities ($n = 7$)[a]

Threshold	**Sen. (%)**		**Spec. (%)**		**CC (%)**	
	15-s	**60-s**	**15-s**	**60-s**	**15-s**	**60-s**
Sedentary → light	98.5	100.0	96.1	98.0	97.5	99.2
Light → moderate	91.1	83.3	86.8	85.9	88.3	85.0
Moderate → vigorous	40.3	18.8	95.0	98.1	87.9	87.5

Note. Sen. = sensitivity; Spec. = specificity; *CC* = classified correctly.

[a] The sensitivity ({number of minutes correctly classified into a single intensity category by motion count thresholds}/{total number of minutes observed at that intensity level}$^{-1}$), specificity ({number of minutes correctly classified as not belonging to a given intensity category by motion count threshold}/{total number of minutes observed at that intensity level}$^{-1}$), and proportion of total minutes correctly classified as sedentary, light, moderate, or vigorous (according to direct observation of physical activities) for fractional thresholds (15-s epochs) and validated threshold values for 60-s epochs.