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# Differentiating Sedentary Time from Light Activity: A Secondary Analysis Exploring Accelerometer Cut Points with Young Obese Children

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## Abstract

**Introduction and Statement of the Problem:** Physical activity and its measurement have become a focus for many researchers studying the pediatric obesity crisis. Identifying rigorous measures to use with young children and their caregivers is complex due to a child's cognitive, developmental and verbal abilities. Some physical activity measures rely on parent reports, which have been found to be largely inaccurate. Another objective measure of physical activity, direct observation of children by researchers, may threaten the internal validity of a study by altering children's normal levels of physical activity as well as adding significant expense to a research study. Accelerometry is considered one gold standard, objective measure of a child's physical activity and sedentariness and its use is increasing.

**Purpose:** This secondary data analysis of accelerometer data has been conducted to understand the differential effect of the data reduction process on the outcome variable: minutes of different intensities of physical activity (sedentariness and light PA) of overweight/obese children, 4-8 years of age. Determination and application of the point that distinguishes sedentariness from light physical activity is critical when studying interventions intended to reduce sedentary time and/or increase daily physical activity; however, limited rigorous validation research has been conducted regarding this distinctive cut off value.

**Method:** To examine the effect of applying different cut points, we reduced the raw accelerometry data from 53 overweight/obese young children two ways by sequentially applying different sets of published cut points to the data, those identified by Pate et al. (threshold level of 200 activity counts/15-second epoch) and those of Pfeiffer et al. (37.5 activity counts/15-second epoch).

**Results:** The difference in average minutes of sedentary activity ( $M_{diff} = 257.14$  minutes or 4 hours and 17.12 minutes) was significant ( $t = 16.71$ ,  $p = .00$ ) resulting in a significant decrease in the percentage of time spent in sedentary activity ( $t = 44.25$ ,  $p = .00$ ). Additionally, the average minutes of light activity was significantly increased given the two different cut points ( $t = -16.71$ ,  $p = .00$ ). The resultant effect of increasing the average minutes of light physical activity is important as this contributes significantly to the total or mean daily minutes a child is determined to be physically active.

**Discussion:** New commercially available methods facilitate the process of accelerometer data reduction. Care should be used when making decisions regarding the identification and application of cut points during the data reduction process. The characterization of a study sample and outcomes of a study may be significantly different with the application of different cut points. Therefore, justification of the cut points applied should be provided (e.g. methods of calibration and validation) for all studies that involve accelerometry data.

**Keywords:** Accelerometer; Physical activity; Preschool child

## Introduction

Physical Activity (PA) and its measurement have quickly become a focus for many researchers who target the childhood obesity crisis that faces this nation. Psychometrically sound measures are critical for research efforts designed to evaluate the effects of interventions. Experts have identified three categories of activity measures: self-reported measures (e.g., Physical Activity Questionnaire - Child [PAQ-C]; [1]; direct observation methods (e.g., Child Activity Rating System [CARS]; [2]; and motion monitors (e.g., pedometers, accelerometers).

Identifying valid and reliable measures of PA with young children is a complicated task because children younger than 10 years old are unable to accurately recall and report this information; [3,4] as a result parents are often called upon to report the child's activity. Just as self-reported data may be biased, the accuracy of second-hand reports or parent reports is suspect [5]. Moreover, direct observational methods of children's PA are costly and time-intensive and thus not optimal to use with moderate to large samples in appropriately powered full-scale intervention studies. Thus, researchers may rule out the use of parent reports and direct observation and opt to use motion monitors. The valid use of motion monitors in young children should be initiated by trained experts because of the physiologic differences that exist in children as compared with adults which directly affect which monitors are used and how data is interpreted.

The body size and leg length of young children (3-4 years of age) may affect the function of the internal mechanisms of pedometers, rendering data with questionable reliability and validity [6]. The use of accelerometers, on the other hand, has increased dramatically as a way to assess the PA of young children largely because they provide a feasible, valid and reliable objective measure of habitual activity (activity over time [7]. Unlike parent report and direct observation, they measure the frequency of PA in addition to the intensity [8]. Software programs have significantly reduced the time and cost involved in the process of data reduction, necessary step when using accelerometers, thereby facilitating their use. This paper describes the variation in outcomes researchers can anticipate using different approaches to the data reduction process.

## Background

Accelerometers function by measuring change in velocity or acceleration, identified as an activity count, over a specified time

interval (epoch), thus enabling intensity of PA to be quantified [9]. The ability of researchers to determine the epoch length when using accelerometers with young children is critical because young children frequently have short bouts of high-level activity (i.e., Moderate-To-Vigorous Physical Activity [MVPA]) which should not be averaged into long periods of time with less activity. If one calculates PA with epochs greater than 15 seconds the result may be a finding of low cumulative amounts of time spent in MVPA intensity and large amounts of time spent in lower levels of PA (i.e., sedentary and light activity). A Metabolic Equivalent of Task (MET) is a standard physiological measure expressing the energy cost of PA (1 MET = 1 kcal/kg/hour; [10]. The activity count/epoch that results from accelerometer use can be translated into energy expenditure (METs) using the following calculation: 1 MET = 1 kcal/kg of body weight \* height [11], making this a helpful tool for obesity investigators.

Several researchers have conducted calibration and validation studies specifically with young children using accelerometry to determine PA intensity levels (i.e., sedentary, light, or MVPA [12-15]. These studies have resulted in thresholds of activity counts/epoch that equate to child-specific intensities of PA [16-25] and thus energy expenditure. These differences may be attributable to the use of different brands of accelerometers; however, controversy remains over what the thresholds or cut points should be and the best methodology to establish the validity of those threshold levels [12,13,22,26,27].

Sirard and colleagues [22] conducted a study with 281 preschool aged children in which accelerometers were placed on the children, and the CARS was the criterion PA measure [2]. The children were asked to complete activities representative of the PA intensity categories of CARS for specific time intervals; then the data from the accelerometers were temporally matched with the activities performed. This validation study yielded threshold levels for sedentary, light and MVPA for the children (Table 1). Shortly thereafter, Pate et al. [17] completed an accelerometer validation study with 29 preschool-aged children. The researchers asked the children to wear Actigraph® accelerometers and complete some structured and unstructured activities; in this study, however, the children's energy expenditure was concurrently assessed by a metabolic criterion measure, Vo2 or oxygen consumption, an indirect calorimetry assessment regarded as a more valid assessment of energy expenditure than direct observation (e.g., the CARS). The findings of this study resulted in very different PA cut points than those identified by Sirard et al. (Table 1) [22] but many experts agree that this method of criterion validity testing was more rigorous than that of Sirard et al. [22].

Study Authors	Cut Point Validation Method	Sedentary	Light	Moderate-to-Vigorous
[14]	Criterion validity with Child Activity Rating System (CARS)	0-398 (0-1592)	399-890 (1596-3560)	>891 (>3564)
[17]	Criterion validity with metabolic measures (Vo2)	0-199.8* (0-799)	200-419.8 (800-1679)	>420 (>1680)
[28]	No validation methodology referenced	0-37.5 (0-148)	38-419 (149-1679)	>420 (>1680)
*The sedentary/light threshold value was determined by visual inspection of the data.				

**Table 1:** Published Physical Activity Cut Points Delineating Physical Activity Intensity Categories for Preschool Children per 15 Second Epoch (counts per minute).

Some data reduction software products use the Pate, et al. [17] reference to designate PA thresholds for different activity intensity levels, including light activity, even though Pate and colleagues did not publish a validated threshold distinguishing light and sedentary activity using the metabolic criterion method mentioned previously. The light threshold estimation from the Pate 2006 research was based on visual inspection of the data rather than indirect calorimetry [29]. A later study published by a group of researchers [28] identified a different threshold that distinguished sedentary from light activity differently, but they did not indicate the validation process used to identify this new threshold value for the Actigraph accelerometer®. Thus, researchers have derived activity-level thresholds that distinguish different activity levels that have been developed from various validation methods. These discrepancies have resulted in differences in reported amounts of cumulative daily time children spend in light and sedentary PA levels. The application of different cut points may significantly affect the study PA outcomes of research investigations.

## Objective

The purpose of this report is to bring attention to the critical phase of data reduction (i.e., applying PA cut points when summing the number of minutes spent in different intensities of PA) when using accelerometers, with a focus on the Actigraph® accelerometer, and the effect of data reduction on reports of sample characteristics and PA outcome variables of interest, specifically time spent in sedentary and light PA. This secondary data analysis of accelerometer data has been conducted to understand the differential effect of the data reduction process on the outcome variable: minutes of sedentary and light PA of overweight/obese children, 4-8 years of age, an age group for whom the Actigraph® accelerometer is validated for use.

## Analysis

Data were analyzed using SPSS (Version 20; [30]). Significance was set at  $p = .05$ . Descriptive characteristics of the parents and children are presented as means and standard deviations. Paired samples *t*-tests were conducted to compare the means of PA levels of two cut points within subjects [17,28].

## Methods

### Methods of the Primary Study

The primary study from which baseline data for this study was extracted was an obesity treatment intervention Randomized Controlled Trial (RCT). We recruited parents of 60 overweight or obese (> 85<sup>th</sup> BMI percentile) children, 4-8 years, from 14 primary care provider offices in the Southwestern United States [31]. Following IRB approval and completion of the formal consenting procedure, we undertook several baseline assessments and then randomly assigned the parent-child dyads to treatment or control conditions. For this secondary data analysis, we extracted raw baseline Actigraph® accelerometry data collected in 15-second epochs over two days from the original dataset.

### Methods of this Secondary Data Analysis

To examine the effect of applying different cut points to the raw, extracted accelerometry data, we used the same process to reduce the data using a commercially available software program, [32] but we sequentially applied two different sets of cut points to the data, those identified by Pate, et al. [17] and those of Pfeiffer et al. [28]. We were most interested in appreciating the different cut points found in the literature that distinguish light from sedentary levels of PA intensity.

To complete the data reduction, we used the raw accelerometer data from participant children ( $N = 53$ ; demographic data were missing from 2 dyads) who completed up to 2 days of activity with at least 4 hours of recorded time each day but not more than 18 hours of recorded active time each day, which we defined as a “Valid” day of data collection. To assure measurement of actual active time identified, we assessed “Nonwear Time” as no activity counts recorded on the accelerometer for 60 or more continuous minutes [7], and we removed these data. We defined “Spurious Data” (i.e., abnormally high activity counts and perhaps erroneous activity) as activity that exceeded 10,000 counts per 15-second epoch or more than 9 standard deviations from the median [33]. We also removed these data from the final dataset.

The first set of cut points we applied to the data was published in a 2006 [17] Actigraph® accelerometer validation study, in which indirect calorimetry (Vo2), a gold standard, was used as the criterion measure that distinguished light PA from MVPA using the threshold of 420 activity counts/15-second epoch. This group of researchers specified the threshold level of 200 activity counts/15-second epoch that separated sedentary and light PA intensities based upon visual inspection of the data, a less rigorous method of validation. Using threshold values determined by Pfeiffer, et al. [28], a research team that also using the Actigraph® accelerometer, we then applied the cut point of 420 activity counts/15-second epoch as the threshold that distinguishes light from MVPA. Pfeiffer’s research team identified the threshold of 37.5 activity counts/15-second epoch to differentiate sedentary from light PA; although the validation method for that threshold level is unclear. This threshold was subsequently validated through the work of Fischer and Yıldırım [16] and Trost et al. [15], both using direct observation as the method of validation. After we applied the two sets of thresholds, we summed the time spent in each activity level.

**Sample**

Sixty participants were enrolled in the primary study [31]; of those, 7 did not have baseline accelerometry data, and of the remaining 53 participants 2 did not have fully completed demographic information. We extracted and used all participant data when baseline accelerometry data were present. Demographic information is depicted in (Table 2).

Demographics	Full Sample (N = 51)
Child Gender: n (%)	
Boys	22 (43%)
Girls	29 (57%)
Child Age in years: M (SD)	5.71 (1.45)
Range	03-Aug
Child Body Mass Index: M (SD)	21.45 (3.25)
Mean BMI Percentile	96.34 percentile
% Obese	70.60%
Mothers’ Age in years: M (SD)	36.31 (6.91)

Range	23-61 years
Mothers’ Education n (%)	
High school degree or less	13 (25.5%)
At least some college	38 (74.5%)
Mothers’ Marital Status: n (%)	
Married	40 (78.4%)
Single/Divorced/Widowed	11 (21.6%)
Ethnicity: n (%)	
White	35 (68.5%)
Black	1 (2%)
Hispanic	13 (25.5%)
Other	2 (4%)
*Two child participants were lacking some baseline demographic and accelerometry information and their data were excluded from this table	

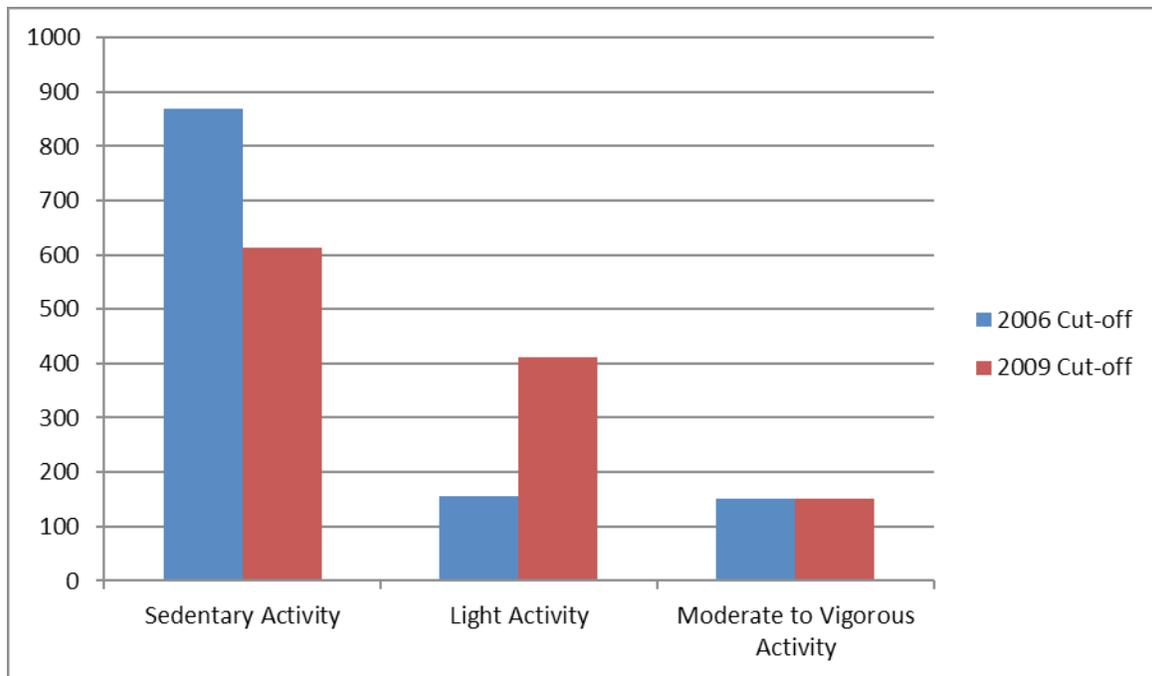
**Table 2:** Sample Demographic Information (N = 51)\*.

**Results**

To examine the difference in PA levels between the 2006 and 2009 cut points, we computed paired samples t tests to compare the average minutes of sedentary, light, and MVPA in preschool-aged children across different cut points (Table 3). The difference in average minutes of sedentary activity ( $M_{diff} = 257.14$  minutes or 4 hours and 17.12 minutes) was significant, with lower levels of sedentary activity found when using the 2009 cut point than when using the 2006 cut point ( $t = 16.71, p = .00$ ); the average minutes of light activity was significantly higher when using the 2009 cut point than when using the 2006 cut point ( $t = -16.71, p = .00$ ). The average percentage time spent in sedentary activity was significantly lower using the 2009 cut point compared to the 2006 cut point ( $t = 44.25, p = .00$ ). The average minutes of MVPA was unchanged across the 2006 and 2009 cut points because the threshold values were the same in both studies (Figure 1).

	2006 PA Cut-offs	2009 PA Cut-offs	T-test Results	
	M (SD)	M (SD)	T value	Sig
Percent Time in Sedentary Activity	.74 (.08)	.53 (.09)	44.25	0
Average Sedentary Activity Minutes/day	869.32 (349.99)	612.18 (253.63)	16.71	0
Average Light Activity Minutes/day	154.91 (71.85)	412.05 (180.69)	-16.71	0
Average Moderate to Vigorous Activity Minutes/day	150.75 (81.07)	150.75 (81.07)	----	----

**Table 3:** Paired Samples T-test Results Comparing 2006 PA Intensity Cut Point Values and 2009 PA Cut Point Values (N = 53).



**Figure 1:** Shift in Daily Average Minutes of Physical Activity with the Application of Different Cut Points.

## Discussion

We identified the Pate research team’s [17] validation study that distinguished different levels of physical activity intensity using Actigraph® accelerometers with young children to be a high-level criterion validation study due to the use of indirect calorimetry (Vo2). However, upon closer review we identified the threshold demarcating light PA from sedentary time (200 activity counts/15 second epoch) by the Pate team [17] was determined by visual inspection of the data. To identify the best threshold that distinguishes light PA from sedentary time we continued to review validation studies that included Actigraph accelerometers® and young children. Pfeiffer’s research team [28] identified that threshold as 37.5 activity counts/15 second epoch although it was unclear how this threshold was determined this was validated by the work of Fischer and Yildirim [16] and Trost, et al. [15], both using direct observation as the method of validation.

Our research team had specific interest in the sedentary and light physical activity of the overweight/obese child participants, especially in light of the limited effects of previously conducted intensive PA interventions on children [34-38]. Additionally, light activity has recently been reported as a distinct category for intensity of activity [22,28,39], and its positive contribution to health has been recognized in the research literature over the last 25 years [40-45]. We believe that 37.5 activity counts/15 second epoch is the most valid threshold to apply to Actigraph® accelerometry data gained from young children given our investigation to date. However, we acknowledge that differences in child age may confound our findings similar to the findings of other researchers [46-48].

The change in the percentage of reported sedentary time that resulted with the different cut points, a change from 74% to 53%, was also important. Several researchers have commented about the significant amount of time that preschool children

spend in sedentary activities: estimates range from 53% to 86% of total activity time [31,49-51]; however, if those research teams reevaluated their data and applied the different threshold values, their reported findings would likely be significantly different. Moreover, if researchers apply different cut points during the data reduction phase, accelerometer findings will not be comparable across studies, and sample characteristics and outcomes may appear unique or unusual (e.g., samples are reported to be more active than those in other studies), suggesting that data from that study may have limited generalizability, when in fact the external validity of the study has not been compromised.

Identifying and applying cut points during the data reduction process are critical steps that have been facilitated by new software products, allowing researchers to select cut points by author or manuscript title or by specifying select thresholds for each intensity level. The predetermined threshold values offered may not be based on the most current research (e.g., validation studies using the best methods). The thresholds applied during the data reduction process should be taken from the most rigorously conducted validation studies (e.g., criterion validation studies). Furthermore, researchers should carefully review and appraise the original validation studies to be certain that each threshold value was validated similarly. It is critical, therefore, that researchers appreciate the importance of the application of thresholds in the data reduction step, continue to stay up-to-date with current research (i.e., validation studies) and remain closely involved with all data decisions.

## Conclusions

Accelerometer use requires data reduction, during which the minutes of different PA intensities are accumulated and represented as aggregate daily group means. The critical decisions that researchers make with this increasingly used measure affect the data reduction process and likely have direct effects on reported sample characteristics and study findings; therefore, researchers' decisions need to be intentional, justified, and clearly presented when the study findings are disseminated [33]. Individuals evaluating research that has used accelerometer measurement should be knowledgeable about the data reduction process and application of cut points. This knowledge will enhance the ability to critically analyze and synthesize results across studies and develop practice-related decisions.

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## Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to authorship and/or publication of this manuscript.

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