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Comparison of hip and wrist accelerometers in a pre-adolescent population in free-living and semi-structured physical activity

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Comparison of hip and wrist accelerometers in a pre-adolescent population in free-living and semi-structured physical activity

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by

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ABSTRACT

COMPARISON OF HIP AND WRIST ACCELEROMETERS IN A PRE-ADOLESCENT POPULATION IN FREE-LIVING AND SEMI-STRUCTURED PHYSICAL ACTIVITY

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The dose-response relationship between physical activity (PA) and health is not well understood, which has been due in part to previously poor measures of free-living PA. The development of accelerometry has made it possible to quantify multiple components (i.e., intensity, duration) of free-living PA. Accelerometry devices have traditionally been worn on the hip, however there has been a recent trend to place these monitors on the wrist. Currently, there have been no studies that have compared wrist- and hip-worn accelerometry data in a pre-adolescent sample in a field-based setting. **PURPOSE**: The primary aim of this study was to examine the accuracy of a hip (Evenson algorithm) and wrist-worn (Crouter algorithm) accelerometer in assessing time spent in different intensity categories in pre-adolescent girls during semi-structured dance classes using direct observation (D.O.) as the criterion measure. The secondary aim of this study was to examine the validity of a wrist-worn accelerometer for dichotomizing pre-adolescent girls as meeting or not meeting different preselected doses of moderate-to-vigorous PA (1 – 2 day/60 minutes; 3 – 4 days/60 minutest; ≥5 days/60 minutes) compared to the hip-worn accelerometer. **METHODS**: Data were collected and analyzed on a total of 6 participants (age = 10.22 ± 2.38) for the primary aim. One day/week during a PA dance

intervention, one participant (n = 8) was randomly selected to be video recorded and wear hip and wrist accelerometers during the hour long dance class. Kruskal-Wallis Test was used to compare D.O. data with accelerometry data. Additionally, data was collected and analyzed on a total of 20 participants (age = 8.6 ± 1.6) for the secondary aim. Participants were asked to concurrently wear a hip and wrist accelerometer for seven consecutive days. Fisher Exact Test was used to compare similarity between wrist and hip accelerometry data. **RESULTS**: Compared to D.O., the wrist-worn accelerometer was inaccurate in measuring time spent in light PA (D.O.= 44.77 ± 6.82; wrist = 5.27 ± 4.98; $p< 0.01$), vigorous PA (D.O.= 0.50 ± 1.01; wrist = 27.65 ± 22.87; $p< 0.01$) and MVPA (D.O. = 6.59 ± 5.34; wrist = 44.14 ± 7.57; $p< 0.01$). Additionally, the hip-worn accelerometer was inaccurate in measuring time spent in sedentary time (D.O. = 1.39 ± 2.18; hip = 12.38 ± 8.25; $p< 0.05$), light PA (D.O. = 44.77 ± 6.82; hip = 30.23 ± 5.47; $p< 0.01$), vigorous PA (D.O. = 0.50 ± 1.01; hip = 4.05 ± 3.56; $p< 0.05$) and total PA (D.O. = 51.36 ± 2.19; hip = 40.46 ± 8.25; $p< 0.01$). Further, for the secondary aim, there was no difference between device location and meeting PA dosage for one day. However, there was a significant difference between device location and meeting PA dosage for three days (OR = 7.01, $p = 0.01$) and five days (OR = 7.01, $p = 0.01$). **CONCLUSION**: Traditional accelerometer algorithms rely on the activity count cut-point method which provides mixed to poor results of activity intensity classification regardless of wear location. Future research should move away from the activity count cut-point method and aim to develop algorithms that use more of the rich data available from the accelerometers' acceleration signal.

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CHAPTER I

INTRODUCTION

Background

The latest National Health and Nutrition Examination Survey (NHANES) data indicates that only 42% of children (6-11 years old) are meeting the physical activity (PA) recommendation of at least 60 minutes of moderate-to-vigorous PA (MVPA) per day (74). Low levels of PA in pre-adolescence has been shown to track into adulthood and has been correlated with several adverse health conditions, such as dyslipidemia, cardiometabolic syndrome, obesity, and cardiovascular disease (33, 85). The combination of low PA levels and the resultant health care cost ($190.2 billion to treat diabetes annually in the US) (4) associated with inactivity-related chronic diseases signify the importance for PA evaluation in pre-adolescent children. With better PA evaluation modalities, healthcare professional can effectively determine PA prescriptions to combat low PA levels.

Important factors for researchers and clinicians to take into account when assessing an individual's PA level are the reliability, validity, and burden of the method used to assess PA (3, 22, 38, 53). PA can be assessed either through objective (i.e., accelerometers) or subjective (i.e., self-report questionnaires) measures. In field-based research, one of the most widely used methods to objectively assess PA is accelerometers. Based on a specified algorithm, using activity counts and population specific cut-points, accelerometers can categorize PA into sedentary, light, moderate, and vigorous intensity, in addition to step counts and activity counts per minute (CPM) (19). Accelerometers have the ability to provide reliable information on PA over several days (76). They can be programmed to measure PA over a specified time period; a practical capability when comparing PA during school-hours, after-school, and weekends (50,

62, 65). Furthermore, accelerometers are an important instrument in research because in addition to measuring total PA, they are able to quantify several components of PA (frequency, intensity, duration) (25, 55, 75).

Accelerometers are commonly worn on the right hip of participants. In 2004, Rowland and colleagues validated the use of a hip-worn triaxial accelerometer in a sample of 19 children (age: 9.5 ± 0.8 yr) during a series of laboratory tests (four different treadmill speeds and three free living activities). The researchers observed that the predicted energy expenditure derived from the accelerometer activity counts output worn on the hip was comparable to the energy expenditure output from their Douglas Bag analysis ($r=0.87$, $p<0.01$) (61).

However, there has recently been a trend to place the accelerometers on the participant's wrist (13, 28, 44). The benefits of wearing the monitor on the wrist are an increase in compliance (20), and the ability to assess sleep quality, quantity, and duration (7). Accelerometers worn on the wrist have been correlated with higher compliance by participants, making it a practical location to place accelerometers when attempting to measure a participant's habitual PA (2, 16)

In field-based PA research, direct observation is considered the gold standard for assessing PA in individuals (62). To date, there have been no studies that have compared wrist- and hip-worn accelerometry data with direct observation in a pre-adolescent sample in a field-based setting. Therefore, there is a need to determine the accuracy of the Actigraph accelerometers at different anatomical locations to assess PA levels in pre-adolescent children.

Purpose of the Study

The primary aim of this study was to examine the accuracy of a hip-worn and wrist-worn triaxial accelerometer in assessing time spent in different intensity categories in pre-adolescent

girls, using direct observation as the criterion measure during semi-structured dance classes. The secondary aim of this study was to examine the validity of a wrist-worn triaxial accelerometer for dichotomizing pre-adolescent girls as meeting or not meeting different preselected doses of PA compared to the hip-worn accelerometer.

Hypotheses

H_{1a}: The hip-worn triaxial accelerometer will accurately measure time spent in all PA intensity categories compared to directly measured PA.

H_{1b}: The wrist-worn triaxial accelerometer will accurately measure time spent in all PA intensity categories compared to directly measured PA.

H_2: The wrist-worn triaxial accelerometer will accurately dichotomize participants as meeting or not meeting different doses of PA.

Summary

Only 42% of U.S children are meeting PA recommendations (74). This presents a major public health concern, given that childhood PA habits track into adulthood and lack of PA has been correlated with several adverse health conditions (11, 14, 21, 23, 27). The lack of PA and associated health risks signifies the importance of accurate PA evaluation methods to identify individuals who would benefit from PA interventions. In selecting a method to assess PA, researchers and clinicians need to take into account the reliability and validity of the measurement method. Accelerometers are one type of instrument that is widely used for PA assessment. Although the literature indicates accelerometers have been extensively used, there is limited data on the validity of hip- and wrist-worn accelerometers for assessing PA in young

children in a field-based setting. This study will provide insightful information on the validity of both hip- and wrist-worn Actigraph accelerometers in assessing PA in pre-adolescent children.

CHAPTER II

LITERATURE REVIEW

Overview

Physical activity (PA) research encompasses the prevalence, distribution, and potential determinants of PA (and sedentary time), and its role in preventing and treating chronic diseases, such as obesity (80). Pediatric obesity (BMI $\geq 85^{th}$ percentile for age and gender) is a public health epidemic (47). In the past three decades, the prevalence of obesity has more than tripled among pre-adolescents (63). Currently, 34.2% of children between 6-11 years of age are overweight/obese (51). Obese children are at an increased risk for adult obesity (36, 71), in addition to significant adverse health risks (i.e., type 2 diabetes mellitus, sleep apnea, and cardiometabolic syndrome) (49). Therefore, PA research and its role in treatment and prevention of chronic diseases is dependent on the accurate measurement of this human behavior (80). Low levels of PA have been established as an important contributing factor to the development of obesity in children (12, 30, 70). Current PA recommendations stipulate that children should accumulate at least 60 minutes of moderate-to-vigorous physical activity (MVPA) on all days of the week (74). However, the latest NHANES data indicates only 42% of children (6-11 years old) are meeting PA recommendations (74). This is concerning because PA habits learned in childhood have been shown to carry over into adulthood (11, 36, 66) and potentially reduce obesity risk and its associated adverse health risks (8, 46). The high prevalence of physical inactivity among children, despite the substantial health benefits of PA signifies the need to address PA habits in children. In order to adequately address PA in children, researchers and healthcare providers need modalities that can accurately assess PA in this population in different settings (i.e., community and clinical settings).

Hip-worn accelerometry

Accelerometers are the de-facto objective method used to assess PA in field-based research settings (19). They are lightweight devices that can quantify the frequency, intensity, and duration of PA. From these variables, an estimate of energy expenditure and the accumulation of time at different PA intensity (sedentary, light, moderate, and vigorous) categories can be determined (10, 78, 81). Traditionally, accelerometers have been worn on the hip to capture whole body acceleration in the medial/lateral, anterior/posterior, and vertical directions (35). There have been several studies that have examined the ability of a hip-worn accelerometer to assess PA in a pre-adolescent population. In 1998, Eston et al. examined the relationship between oxygen consumption (expressed as a ratio of body mass raised to the power of 0.75) and outputs from a CSA (Computer Science Application) uniaxial and triaxial accelerometer. In their sample of 30 children (age: 9.3 ± 0.8 yrs.), the researchers observed that the vector magnitude sum of the CSA triaxial accelerometer showed stronger correlations with oxygen consumption (r= 0.91) than the CSA unixaxial accelerometer (r= 0.78). Furthermore, they also observed during unregulated play activities (crayoning and playing catch), the largest accelerations were recorded in the anteroposterior plane and not the vertical plane. From their findings, Eston and colleagues concluded that a CSA triaxial accelerometer provides the best assessment of activity in children (14). In 2000, Ott et al. tested the validity of a triaxial accelerometer (Tritrac-R3D) in assessing children's free-play PA. In a sample of pre-adolescent children (age: 9.7 ± 0.6 yrs) the Tritrac-R3D produced activity counts that were significantly correlated with predicted MET levels ($r = 0.66$, $p < 0.001$), heart rate ($r = 0.73$, $p < 0.001$), and intensity classification ($r = 0.73$, $p < 0.001$) using the Polar Vantage XL Heart Rate Monitor as the criterion measure. Further, Rowlands et al. (2004) tested the validity of two triaxial

accelerometers (RT3 and Tritrac) in 19 children (age: 9.5 ± 0.8 yr). Using oxygen consumption expressed as a ratio of body mass raised to the power of 0.75 (SVO_2) as the criterion measure, researchers observed that both the RT3 ($r = 0.87$, $p < 0.01$) and Tritrac ($r = 0.87$, $p < 0.01$) counts correlated significantly with SVO_2 in their sample. These studies provide evidence that the hip is a suitable anatomical location for measuring activity intensities in pre-adolescent children.

Despite their ability to objectively assess PA, hip-worn accelerometers are not without limitations. One such limitation is participant wear time noncompliance (i.e., participant not wearing the monitor as instructed for the determined required period of time) and limited ability to assess sedentary times (37, 42). Due to these limitations, there has recently been a trend to place the accelerometers on research participants' wrist (7).

Wrist-worn accelerometry

Prior accelerometer use in large cohort studies has shown higher compliance with wrist-worn verses hip-worn accelerometers, indicating that wrist-worn may be an adequate alternative for assessing PA (44, 86). In a sample of 8-10 year olds (n = 22), Ekblom et al. examined the validity of a wrist-worn accelerometer (uniaxial ActiWatch) compared to indirect calorimetry and a hip-worn accelerometer (uniaxial, Actigraph 7164) (10). Authors demonstrated that wrist-worn accelerometers provide at least equally valid ($r = 0.80$) PA data compared to hip-worn accelerometers, with indirect calorimetry as the criterion measure. Currently, there are three studies that have used a wrist-worn triaxial accelerometer in pre-adolescent children. Crouter and colleagues developed and validated methods for analyzing wrist-worn accelerometer data in children (n = 181; age = 12.0 ± 1.5) using an Actigraph accelerometer (7). The researchers reported that their developed regression equation for vector magnitude (Reg-VM) and vertical

axis (Reg-VA) did not yield significantly different measurement values for child-METs or time spent in sedentary time (ST), light PA (LPA), moderate PA (MPA), and vigorous PA (VPA) when compared against indirect calorimetry (Cosmed Kb4[2]). Further, because the dataset used to develop the Reg-VM and Reg-VA for wrist placement is the same dataset that was used to develop a 2-regression model for hip placement, Crouter and colleagues were able to directly compare how the model developed for the hip compared to those developed for the wrist. They observed that the wrist regression equations yielded smaller errors than the hip regression equations in energy expenditure and time spent in different PA intensities. This would suggest that placing an accelerometer on the wrist could potentially be a better location than the hip for estimating time spent in different PA intensities in children using the developed regression methods.

Similarly, Schaefer et al. demonstrated that a triaxial accelerometer (Actical) worn on the wrist could accurately classify ST and PA intensities in a sample of 6-11 year old children (n = 22) using indirect calorimetry as the criterion measure (64). Area under the curve analysis resulted in values of: 0.95 (sedentary), 0.93 (moderate), 0.97 (vigorous) (64), indicating excellent agreement between the PA intensities observed from the wrist-worn accelerometer and indirect calorimetry. Hildebrand and colleagues used a wrist-worn Geneactiv accelerometer in a sample of 7-11 year old children (n = 30) and reported strong correlation ($r^2 = 0.71$) between energy expenditure (measured by indirect calorimetry) and raw accelerometer data (31).

Direct Observation as a criterion measure

Direct observation (D.O.) of an individual's movement is considered a gold standard in PA assessment (67). Two of the most commonly used D.O. methods in children are the Child

Activity Rating Scale (CARS) and System for Observing Fitness Instruction Time (SOFIT). CARS is designed to categorize PA on a 1-5 rating scale at 15 second intervals and discriminate levels of energy expenditure (9). SOFIT was designed to assess PA in children during physical education class. Similar to CARS, it utilizes a 1-5 categorical scoring system, but at ten second intervals (59).

Similar to other forms of measurement, D.O. is not without its own limitations. A major limitation to D.O. is the labor-intensive data collection and analysis process. In addition, to maintain high reliability and validity, data collection can only be completed by highly trained observers. This limitation has reduced the utilization of D.O. as the criterion measure in field-based PA research. Due to this, researchers have proposed an alternative form of D.O. (video monitoring) that could potentially reduce the time burden for researchers. This form of D.O. utilizes a hand-held digital personal assistant (PDA) with custom software to analyze the recordings and has been validated against indirect calorimetry. Lyden et al. validated the Noldus video-monitoring software to quantify PA using indirect calorimetry (oxycon mobile) as their criterion measure in a sample of 15 participants (age: 25±4.8 yrs) (41). In their study, the authors used a PDA device to record participants' behavior and then uploaded the recordings to the Noldus software. As part of their procedure, researchers recorded a participant's activity type from a menu of activities with their corresponding MET value. Participants completed three separate 2-hour visits. During each visit, participants were allowed to perform any activity of their choice within a designated area, for any duration to preserve the sporadic nature of free-living behavior (41). In order to effectively use the PDA and Noldus software, the researchers had to complete extensive verbal, written, and video training and testing before the D.O. trials. The authors observed an intraclass correlation coefficient that ranged between 0.80 - 1.00 for

METs and different PA intensities. Based on their findings, the authors concluded that D..O using video monitoring could be used as a criterion measure in free-living settings. The low researcher burden of video monitoring makes it an ideal measurement tool to assess free-living PA. The current proposed study will be the first to use the Noldus video-monitoring and software to directly observe and analyze the PA of pre-adolescent girls in a free-living setting. In the proposed study, directly observed PA using the Noldus system will be used as the criterion measure in assessing the accuracy of a wrist- and hip-worn Actigraph accelerometer in a pre-adolescent sample in a field-based setting.

Summary

Over the past three decades, there has been a global decline in pediatric PA and concomitant increase in obesity (51). While the causal relationship between PA and obesity are complex and bidirectional, low PA levels have been attributed as a modifiable risk factor. This signifies the need to address low levels of PA in children in the hope of reversing the current pediatric health trend. In order to adequately address PA in children, researchers and healthcare professionals need modalities that can accurately assess PA in this population in both community and clinical settings. This review of literature suggested that there is an immediate need for accurate data processing methods for raw accelerometer data that can accurately assess PA levels in children in order for clinicians and researchers to effectively prescribe PA promotion and test the efficacy of behavior change techniques in children. Therefore, it is essential to identify methods and modalities that can accurately assess PA levels in children. This study will contribute to gaps in the literature by providing insight into objective (i.e., accelerometers) PA assessment tools that can be used to examine PA levels in pre-adolescent children.

CHAPTER III

METHODS AND PROCEDURES

Introduction

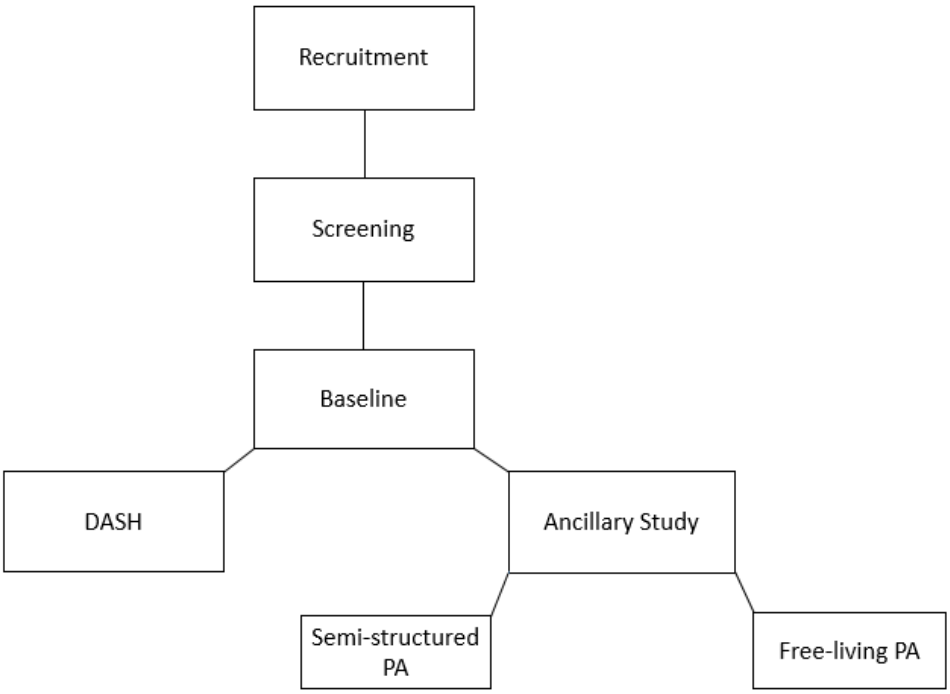
The purpose of this study was to examine the accuracy of hip-worn and wrist-worn Actigraph accelerometers in assessing time spent in different intensity categories in pre-adolescent girls, using direct observation as the criterion measure during semi-structured dance classes. The secondary aim of this study was to examine the validity of a wrist-worn Actigraph accelerometer for dichotomizing pre-adolescent girls as meeting or not meeting different doses of PA compared to waist-worn accelerometer.

The sample for this study was drawn from an after-school PA and sleep intervention study [Girls Dancing and Sleeping for Health (DASH)]. After a successful screening procedure, a baseline visit was scheduled in the participants' home or at the intervention site. Baseline visits consisted of informed consent and assent documentation, anthropometric measures, and survey/questionnaire completion. PA was assessed with wrist- and waist-worn Actigraph accelerometers simultaneously for seven consecutive days, including two weekend days during baseline assessment. PA was also assessed with D.O., as well as wrist- and hip-worn accelerometers one day per week during the dance portion of the 8-week intervention.

To assess the primary aim of this study, participants wore both a wrist and hip Actigraph accelerometer one day per week during the 1 hour dance portion of the intervention. One participant was randomly selected t be videotaped during the dance class using a GoPro Hero, which was later used for D.O. analysis. As previously stated, the D.O. was used as the criterion measure in assessing the secondary aim. To assess the secondary aim of this study, participants wore an Actigraph wrist accelerometer for 7 consecutive days during baseline assessment. In

addition, they also wore a Actigraph hip accelerometer for the same 7 consecutive days. As previously stated, the hip-worn accelerometer was used as the reference measure in assessing the primary aim. The study design is presented in Figure 1.

Figure 1: Study Design



Participants and Randomization

Participants

Participants for this study were pre-adolescent girls from the greater Springfield, MA area who were participating in the DASH program. Girls were eligible for this study if they were between the ages of 7-12 years old at the start of the intervention protocol. Participants were excluded if they had conditions or injuries preventing them from completing PA assessments (wearing accelerometers), were unable to read and write in English, or had a condition limiting

their ability to participate in the PA (i.e., developmental or physical disabilities, inability to increase PA levels for any reason, or musculoskeletal injury or disorder) portion of the study.

Recruitment and Screening

Recruitment consisted of strategies previously employed by the Pediatric Physical Activity Laboratory. This includes face-to-face recruiting at the Greater Springfield YMCA, the Boys and Girls Club, and community events. Flyers (Appendix 1) were distributed at local elementary schools and community centers, and placed in newspaper advertisements. In addition, participants were recruited through social media (Facebook) using a targeted messaging campaign. After completing the screening procedure (Appendix 2) for study inclusion criteria, a baseline visit was scheduled. The baseline visit was scheduled to take place at the participants' home or at the intervention site. After the completion of the baseline visit, participants were assigned a participant ID.

Randomization

A total of 34 girls were recruited for this study. Once girls completed the baseline assessment, they were randomized into one of three groups. In order to maintain an even distribution of girls who had a BMI above and below the 85^{th} percentile in all three intervention groups, randomization was stratified by BMI percentile. Participants' BMI percentile was determined by inputting their recorded baseline height, weight, and date of birth information into the Center for Disease Control (CDC) spreadsheet for BMI percentile. Participants with a BMI $\geq$ 85^{th} percentile were randomized into one of the three intervention groups separately from the

randomization of participants with a BMI < 85th percentile. A member of the research staff who was not involved with the data analysis performed the randomization procedure.

Study Procedures

Overview

The primary aim of this study was to examine the accuracy of the wrist- and hip-worn Actigraph accelerometer in assessing time spent in different PA intensity categories. To answer this question, D.O. was used as the criterion measure. The secondary aim of this study was to examine the validity of an Actigraph wrist-worn accelerometer for dichotomizing participants (pre-adolescent girls) in meeting or not meeting PA recommendations. To answer this question, the Actigraph GT3X+ accelerometer was used as the criterion measure. To address these aims, data obtained from baseline assessment and the DASH dance lessons were used. One day per week during the DASH dance lessons, participants were asked to wear a wrist- and hip-worn Actigraph accelerometer. During this time, the participants' PA was recorded using a handheld GoPro Hero. These recordings were then uploaded to the Noldus Media Module System for D.O. coding. Information on the Actigraph accelerometer and D.O. are presented in the measurement section of this document.

Measurements

Overview

This study used baseline data from DASH as well as data collected during the dance classes. All assessments took place at the participants' homes or at the intervention site. Trained

data collectors completed all data collection. During Baseline data collection, the order of data collection was as follows: physical measures and then PA assessment.

Data Collector Training

Prior to the start of the study, all data collectors underwent a data collection training session, and had to perform mock measurement assessments. Data collector trainees had to demonstrate to senior lab members that they could adequately collect data from participants using subjective (questionnaires) and objective (placement of GT3X+, ActiSleep, and anthropometric) measurement methods. In order to be approved for collecting data, trainees had to collect anthropometric (height and weight) measurements on three randomly selected lab members. A senior lab member then recorded the same measurements on the same three lab members and compared results. If the height or weight measurements differed by more than 0.5 cm or 0.3 kg, respectively, the trainee was assigned three new randomly selected lab members to assess. In addition, trainees had to demonstrate to senior lab members their ability to deliver and record questionnaire data from participants through mock interviews and that they could explain accelerometer (hip and wrist) use guidelines to participants. Once the trainees adequately performed all these tasks to senior lab members, then they were certified to collect data in the study.

Anthropometrics

To assess height and weight, participants were asked to remove their shoes and excess clothing (e.g. jackets or sweaters). Height was measured twice using a portable stadiometer (Shorr Height Measuring Board, Olney, MD) to the nearest 0.1 cm. If the two values differed by

> 0.5 cm, a third measurement was obtained. Weight was measured twice using a digital scale (Scaletronix 5125, White Plains, NY) on an uncarpeted flat floor. If carpeted flooring was the only option at the location, a 2x2 piece of plywood was placed underneath the scale to ensure accuracy. If the two weight values differed by > 0.3 kg, a third measurement was obtained. For both height and weight, the mean of the recorded values was used in data analysis. BMI was calculated as weight (kg) / [height (m)]^2. Calculated BMI was used to determine their CDC age and gender predicted BMI percentile (34).

Physical Activity

Objective Assessment

Hip-Worn

The GT3X+ Actigraph accelerometer (Actigraph, LLC, Pensacola, FL) was used to objectively measure participants' PA levels. Previous studies have shown the Actigraph accelerometer to be reliable in measuring activity counts and differentiating between PA intensities in children in a free-living environment (19, 23, 31) This Actigraph accelerometer measures and records accelerations ranging in magnitude from 0.05 - 2.00 G and a band limited frequency response from 0.05 - 2 G's. Within these parameters, the Actigraph GT3X+ is capable of detecting normal human motion and eliminates high frequency vibrations with an electronic filter. Initialization of the accelerometer occurred prior to each use and results were downloaded to a computer using Actilife software (Version 6.9.1). Accelerometers were programmed to store data in 15-second epochs for this study. Initialization was completed at least two days prior to

data collection. The accelerometers were programmed to start collecting data on the first day of data collection (baseline assessment) at 7:00 a.m.

Accelerometers were worn on an elastic belt placed over the participant's right hip. Participants were asked to wear the accelerometers for seven days including two weekend days. They were instructed to fill out a PA log book and wear the accelerometer at all times except when the unit could become completely wet (i.e., swimming or bathing). Participants received reminder calls throughout the week to ensure proper wear time and instructions regarding when to stop wearing the accelerometer. After wearing the accelerometer for seven consecutive days, participants were instructed to place the accelerometers in a pre-paid self-addressed envelope (provided to them during data collection visit) and to mail it back to the Pediatric PA lab at UMass Amherst. Evenson et al. (2008) counts per minute (CPM) cut points was used to reduce participants accelerometer data into PA intensity [sedentary time (ST) = 0 - 100 CPM; light PA (LPA) = 101 - 2295 CPM; moderate PA (MPA) = 2296 - 4011 CPM; and vigorous PA (VPA) ≥ 4012 CPM)] (15).

Wrist-Worn

Actigraph wrist-worn accelerometers were used to objectively measure participants' PA levels. Actigraph accelerometers are capable of detecting normal human motion and eliminates high frequency vibrations with an electronic filter. Actigraph accelerometers that have been validated for use on the wrist have shown strong sensitivity and specificity (ranging between 60 - 100%) (7). Likewise, wrist-worn accelerometers have demonstrated strong agreement between both D.O. and hip-worn accelerometer measurements (R^2 = 0.70 - 0.77) (5). However results are mixed when comparing vigorous PA and light PA against indirect calorimetry (5, 7, 32, 68).

Initialization of the accelerometer occurred prior to each use and results were downloaded to a computer using ActiLife software. Accelerometers were programmed to store data in 15-second epochs for this study. The Actigraph accelerometer was placed on a watchstrap around the child's non-dominant wrist. Participants were asked to wear the accelerometers seven days including two weekend days. They were instructed to wear the accelerometer at all times. Initialization protocol, PA log book procedure, and return mailing instructions for the wrist-worn Actigraph accelerometers were the same as for the hip-worn Actigraph accelerometers. Crouter et al. (7) cut points were used to reduce participant accelerometer data PA intensity (ST = 0 - 275 counts/5 sec.; LPA = 276 - 415 counts/5 sec.; MPA = 416 - 777 counts/5 sec., and VPA $\geq$ 778 counts/5 sec.).

Direct Observation

This study used the Noldus customized software and hardware D.O. system (Noldus Information Technology; Netherlands) to directly observe participants' PA. At the beginning of each week, one participant was randomly selected to be video recorded (via GoPro Hero+) during the dance portion of the intervention on one randomly selected day during that week. The randomly selected participant was followed with the GoPro Hero+ in order to capture every movement. If a participant used the restroom during D.O. video recording, the researcher (male) followed them up to the restroom door but did not enter the restroom with the participant. Start and end time of each video observation day was recorded. During data processing, these time stamps were used to exclude accelerometer data not recorded during the dance class, and to compare D.O. data with accelerometer data. Video recordings were uploaded to the Noldus Media Module and then imported to the Noldus Observer for coding of duration, and intensity.

In addition, the Noldus External Data Module was utilized for purposes of synchronizing observation data with the accelerometer data. The software was programmed to include a dropdown menu of commonly performed activities. Each activity was assigned a numeric code corresponding to an intensity category. In the current study, ST was defined by posture (seated or reclined) (26) and intensity ratings were coded using the youth MET compendium as a guide (56) The Noldus system provided the ability to label activity time precisely and synch these time intervals with the accelerometers, and accurately estimate absolute intensity. The Noldus system has been shown to be a valid system for estimating PA levels in free-living conditions in adults (41). Currently, research is being conducted to determine the applicability of this software in a pre-adolescent population during free-living conditions.

Data cleaning

To assess the primary aim of the study, a numerical coding scheme (1 – 4) was used (1 = ST, 2 = LPA, 3 = MPA, 4 = VPA). Every movement the participant made during the dance class was given an intensity rating. If a participant had to use the restroom during the observation period, this time frame was coded as private time and excluded from data analysis. All accelerometry data not collected during the dance class was excluded from analysis. The Noldus Software gave a D.O. output of minutes spent in each respective intensity category for all the observations. Similarly, the Actilife Software gave a similar output of minutes spent in each respective intensity category for both the hip and wrist Actigraph data.

To assess the secondary aim of the study, the Troiano algorithm (74) was used for wear time validation for both the wrist- and hip- worn Actigraph accelerometers. If a participant did not meet the minimum wear time requirement of eight hours per day for at least three days, they

were asked to wear both monitors for another seven days. In addition, time spent in different PA intensities were determined using Evenson cut points (15) for the hip accelerometer and Crouter cut points (7) for the wrist accelerometer. A participant was defined as meeting PA recommendations for PA_{5days} if they had at least 60 minutes of MVPA data for 5 days or more. Likewise, a participant was defined as meeting PA recommendations for PA_{3days} if they had at least 60 minutes of MVPA data for 3 days but less then 5 days. Further, a participant was defined as meeting PA recommendations for PA_{1day} if they had at least 60 minutes of MVPA data for 1 day but less than 3 days.

Statistical Analyses

The primary aim of this study was to examine the accuracy of a hip-worn and wrist-worn Actigraph accelerometer in assessing time spent in different intensity categories in pre-adolescent girls, using D.O. as the criterion measure during semi-structured dance classes. The secondary aim of this study was to examine the validity of a wrist-worn Actigraph accelerometer for dichotomizing pre-adolescent girls as meeting or not meeting different doses of PA compared to waist-worn accelerometer. Based on this purpose statement, the following hypotheses was be tested:

H_{1a}: The wrist-worn Actigraph accelerometer will accurately measure time spent in different PA intensity categories compared to directly observed PA (Noldus customized direct observation system).

Analysis plan for H_{1a}: Due to the non-parametric nature of the data, Kruskal-Wallis Test was used to determine the ability of the wrist-worn ActiSleep to measure PA intensity

levels (Total PA, MVPA, vigorous PA, moderate PA, light PA, and sedentary time), using direct observation as the criterion measure.

H_{1b}: The hip-worn Actigraph accelerometer will accurately measure time spent in different PA intensity categories compared to directly measured PA (Noldus customized direct observation system).

Analysis plan for H_{1b}: Due to the non-parametric nature of the data, Kruska-Wallis Test was used to determine the ability of the hip-worn Actigraph accelerometer to measure PA intensity levels (Total PA, MVPA, vigorous PA, moderate PA, light PA, and sedentary time), using direct observation as the criterion measure.

H_2: The wrist-worn Actigraph accelerometer will accurately dichotomize participants as meeting or not meeting different doses of PA compared to the hip-worn Actigraph accelerometer.

Analysis plan for H_2: Due to a small sample size, Fisher Exact Test was used to determine if participants meet or do not meet different doses of PA based on the wrist-worn accelerometer data.

CHAPTER IV

RESULTS

Baseline characteristics

The purpose of this study was to examine the accuracy of a hip-worn and wrist-worn triaxial accelerometer in assessing time spent in different intensity categories in pre-adolescent girls, using direct observation as the criterion measure during semi-structured dance classes. The secondary aim of this study was to assess the similarity between device location and number of days a participant met different doses (days, minutes/day) of PA using hip location as the reference measure. For the primary aim, data was collected on a total of eight participants. Participants' (n = 8) mean BMI percentile placed them within the normal weight range (82.4 ± 12.4) for their age (9.8 ± 1.8 yrs.). Participants' data was excluded (n = 2; age = 9.5 ± 2.1; BMI% = 87.0 ± 1.4) if they did not return the accelerometers. Therefore, the final sample size for the primary aim consisted of six participants with viable data. Participant characteristics are reported in Table 1. For the secondary aim, data was collected on a total of 33 participants. Participants' mean BMI percentile placed them within the normal weight range (74.5 ± 30.4) for their age (8.8 ± 1.6 yrs). Participants' baseline accelerometer data was excluded (n = 5; age = 10.0 ± 2.0; BMI% = 86.0 ± 17.9) if they did not meet the Troiano wear time criterion (74) for both monitor locations. In addition, baseline accelerometer data was excluded (n = 8; age = 8.6 ± 1.6; BMI% = 72.9 ± 37.1) if participants did not wear the wrist and hip monitors simultaneously. Therefore, the final sample size consisted of 20 participants with viable data. Participant characteristics are reported in Table 1. Accelerometer data revealed that participants spent most of their time in sedentary activity. Additionally, accelerometer data revealed a significant difference between the

two monitor locations for baseline time spent in sedentary activity, MVPA, total PA, and monitor wear time/day.

Table 1a. Participant descriptive characteristics

Variable	**Participant (N = 6)**	**Participant (N = 20)**
Age (years)	10.2 ± 2.3	8.6 ± 1.6
BMI percentile	77.4 ± 21.7	72.3 ± 30.7
African-American	5 (83%)	12 (60%)
Hispanic	0 (0%)	6 (30%)
White	1 (17%)	2 (10%)

Table 1b. Baseline characteristics (aim 2; N = 20)

Hip	
Sedentary activity (min/day)	578.56 ± 55.95
MVPA (min/day)	37.68 ± 15.71
Total PA (min/day)	157.36 ± 55.47
Wear Time/Day (min/day)	735.92 ± 134.89
Total Wear Days (days/week)	5.80 ± 1.06
Wrist	
Sedentary activity (min/day)	655.80 ± 80.42
MVPA (min/day)	128.88 ± 75.66
Total PA (min/day)	233.16 ± 80.33
Wear Time/Day (min/day)	888.97 ± 140.81

Total Wear Days (days/week)	6.55 ± 3.30

BMI= body mass index, PA= physical activity, MVPA= moderate to vigorous physical activity

Comparison of device location to direct observation

The purpose of hypothesis 1 was to examine the accuracy of a hip-worn and wrist-worn Actigraph accelerometer in assessing time (min) spent in different intensity categories using direct observation as the criterion measure. Kruskal Wallis Test was used to compare differences between device location to direct observation during semi-structured activity (dance). Table 2 depicts findings from hypothesis 1. There was a significant difference between D.O. and the hip worn device for time spent in sedentary time (D.O. = 1.39 ± 2.18; hip = 12.38 ± 8.25; $p < 0.05$), light activity (D.O. = 44.77 ± 6.82; hip = 30.23 ± 5.47; $p < 0.01$), vigorous activity (D.O. = 0.50 ± 1.01; hip = 4.05 ± 3.56; $p < 0.05$), and total PA (D.O. = 51.36 ± 2.19; hip = 40.46 ± 8.25; $p < 0.01$). Conversely, the hip location was able to accurately assess moderate activity and MVPA. In addition, there was a significant difference between D.O and the wrist worn device for time spent in light activity (D.O. = 44.77 ± 6.82; wrist = 5.27 ± 4.98; $p < 0.01$), vigorous activity (D.O. = 0.50 ± 1.01; wrist = 27.65 ± 22.87; $p < 0.01$), and MVPA (D.O. = 6.59 ± 5.34; wrist = 44.14 ± 7.57; $p < 0.01$). The wrist location was able to accurately assess sedentary, moderate, and total activity.

Table 2. Estimates of PA variables by condition (mean ± sd, 95% CI)

Variable (min)	D.O.	Hip	Wrist
Sedentary	1.39±2.18, 0.00-3.14	*12.38± 8.25, 5.78-18.98	3.43± 4.12, 0.13-9.25
Light PA	44.77±6.82, 39.32-50.23	**30.23± 5.47, 25.84-34.61	**5.27± 4.98, 1.28-9.25,
Moderate PA	6.09±4.61, 2.40-9.78	6.18± 2.61, 4.10-8.27	16.49± 19.56, 0.83-32.14
Vigorous PA	0.50±1.01, 0.00-1.31	*4.05± 3.56, 1.19-6.90	**27.65± 22.87, 9.36-45.95
MVPA	6.59± 5.34, 2.32-10.86	9.79± 6.03, 4.97-14.61	**44.14± 7.57, 38.09-50.19
Total PA	51.36± 2.19, 49.61-53.12	**40.46± 8.25, 33.86-47.06	49.40± 4.12, 46.11-52.70

D.O. = direct observation, sd = standard deviation, 95% CI = 95% confidence interval, PA = physical activity, MVPA = moderate to vigorous physical activity

* $p < 0.05$ (compared to D.O.)

** $p < 0.01$ (compared to D.O.)

Comparison of device location and meeting PA dosages

The purpose of hypothesis 2 was to assess the similarity between device location (wrist) and number of days a participant met different doses (days, minutes/day) of PA using hip location as the reference measure. Due to the small sample size, Fisher Exact Test was used to analyze hypothesis 2. Additionally, due to the nonparametric nature of the data, Kruskal-Wallis Test was used to compare sedentary time and MVPA time between device location for participants that met the preselected PA dosages. There was no significant difference between device location and meeting PA dosage for 1-2 and 3-4 days. However, there was a significant difference between device location and assessing whether a participant met PA dosage for 5 - 7 days. Table 3 depicts findings from hypothesis 2.

Table 3: Comparison of monitor location and meeting PA dosage

PA Dose (MVPA)	Hip		Wrist		P-Value	Odds Ratio
	Yes	No	Yes	No		
1-2 day, 60 min/day	5	15	2	18	0.41	0.34
3-4 days, 60 min/day	3	17	3	17	1.00	1.00
5-7 days, 60 min/day	4	16	13	7	0.01	7.01

The average minutes for time spent in sedentary activity and MVPA of the participants who met the preselected PA dosages between the hip and the wrist location are presented in Table 4. On average, participants who met preselected PA dosages had higher minutes of MVPA levels for wrist location compared to hip location. Furthermore, participants had higher minutes of sedentary levels for the wrist location compared to the hip location.

Table 4: Participants who met PA dosage

PA Dose	Hip (min)		Wrist (min)	
	Sedentary	MVPA	Sedentary	MVPA
1-2 day, 60 min/day	586.20 ± 22.81	78.60 ± 6.24	682.65 ± 18.96*	203.58 ± 13.67**
3-4 days, 60 min/day	538.33 ± 43.76	75.64 ± 9.26	646.31 ± 77.94*	207.14 ± 46.97**
5-7 days, 60 min/day	503.29 ± 14.57	81.72 ± 12.38	637.29 ± 39.74**	217.74 ± 21.84**

* $p < 0.05$

** $p < 0.01$

CHAPTER V

DISCUSSION

Introduction

PA and ST can be assessed using an array of methods, but accelerometers have emerged as the de facto preferred method of assessing free-living PA and ST due to their objectivity, minimal participant burden, and rich data that can be collected for periods of up to 4-6 weeks and beyond (84). They have traditionally been worn on the hip for comfort and ability to measure whole body movements. Further, when worn on the hip accelerometers have shown good to strong accuracy for measuring ambulatory activities (e.g., walking, running) in laboratory-based settings (21, 40, 57). Prior studies in children have shown there is lower compliance in field-based settings for hip worn monitors compared to wrist worn monitors (17). This has led to a recent trend of placing monitors on the wrist for higher wear time compliance.

Additionally, measurement techniques are often validated for use in heavily controlled, laboratory-based settings (13, 86). The laboratory based approach is important for providing a proof-of-concept that a technique can accurately measure what it is supposed to measure. However, prior studies have shown results from laboratory based validation studies are not necessarily applicable in a free living setting (24, 27, 29, 39, 72, 83). Therefore, it is vital to validate algorithms in a free-living setting to improve the accelerometers' accuracy in an ecologically valid setting.

Comparison of device location to direct observation

The primary aim of this study was to examine the similarity between device location and D.O. in assessing activity intensities and total PA during semi-structured activity (dance). The

null hypothesis for this aim was rejected, indicating that both device locations (hip and wrist) could not accurately assess all PA intensity categories (i.e., sedentary, light, moderate, vigorous, and MVPA). Using D.O. as the criterion measure, the wrist location was not able to accurately assess light PA, vigorous PA, or MVPA. Additionally, the hip location was not able to accurately assess sedentary activity, light PA, vigorous PA, or total PA. This study used the Evenson algorithm to assess activity intensity from the hip worn device. The Evenson algorithm used Receiver Operating Characteristic (ROC) curve analysis and count cut-point method to derive its intensity thresholds. The inability of the Evenson hip algorithm to accurately assess sedentary activity could be due to the threshold used to categorize sedentary time and/or the use of activity count cut-point method. The Evenson algorithm uses the count cut-point of <100 counts/min to classify sedentary time (45) which has been used as the ST threshold in prior studies and showed good accuracy (73). However, there is also evidence that refutes the use of the <100 counts/min threshold and/or using the count cut-point method to discern sedentary time (19, 52, 82). In support of this, standing quietly elicits <100 counts/min, which would be incorrectly classified as ST using the activity count cut-point threshold of <100 counts/min (48).

Based on this available information, it was not surprising, that in the current study the hip device using the Evenson algorithm was inaccurate in identifying sedentary time. It is possible that the inaccuracy in measuring ST is what led to the inaccuracy in measuring light PA and total PA. It should be noted that the initial Evenson validation study showed strong intensity classification for sedentary time and moderate to strong classification for moderate and vigorous intensities. However, the Evenson validation study occurred in a laboratory setting under strict protocols, while the current study was in an uninhibited free-living environment.

In regards to the wrist worn device, this study used the age appropriate (8 – 15 yrs old) Crouter wrist count cut-point algorithm (7), in assessing activity intensity and total PA during semi structured activity (dance). Crouter *et al.* used activity count cut-point and single linear regression model to predict energy expenditure and provide interpretive intensity cut-points. The algorithm was developed using a laboratory based protocol and was validated using unstructured activities to simulate a free-living environment. The current study observed a significant overestimation of vigorous activity, MVPA, and underestimation of light activity. Furthermore, in the current study, the wrist location was able to accurately assess sedentary, moderate activity, and total PA. In the Crouter et al. wrist algorithm study, the researchers specifically developed an inactivity threshold to distinguish sedentary time from light PA during the testing of their wrist algorithm (7). Thereby improving the algorithm's ability to accurately categorize sedentary time. Due to specifically developing an inactivity threshold to distinguish between sedentary time and light PA, it is not surprising in the current study the Crouter wrist algorithm was able to accurately measure sedentary time and consequently total PA. Further, it is possible the inaccuracy of the wrist algorithm in measuring light PA, vigorous PA, and MVPA is due to the setting in which the algorithm was validated (simulated free-living environment) and where it was applied in the current study (uninhibited free-living environment).

Ultimately, measurement techniques need to be validated in a context similar to the setting in which they will be used. In a true free-living setting, people rarely engage in steady-state activities or normally perform activities for defined amounts of time, thus leading to substantial variability within activity types. In simulated free-living, researchers can exert control over the types of activities and the minimum amount of time participants need to perform the activities which is a stark contrast to a true uninhibited free-living environment (48). Due to the

variability of activities in a free-living setting, algorithms that use the activity count cut-point method should focus on models that move beyond single linear regression to predict energy expenditure and provide interpretive intensity cut-points. Prior studies have shown multiple linear and non-linear regression models to be more accurate in assessing activity intensity (6, 28). As evidenced by Bassett *et al*.,(1) no simple linear regression model can accurately predict energy expenditure for all activities across all intensities. Current literature suggests that by better estimating energy expenditure in one intensity category (i.e., moderate to vigorous intensity activities), the single linear regression model sacrifices accuracy in its ability to estimate energy expenditure in other intensity categories (i.e., sedentary to light intensity range) (42).

The observed findings between hip and wrist worn monitors in the current study are similar to what other studies have reported. For example, Routen *et al.*(58) examined the concurrent validity of measures of total activity and time spent in different activity intensities between hip and wrist worn monitors in 24 children (11.2 ± 0.5 yrs). Similar to the current study, the researchers observed more time spent categorized as sedentary for the hip worn device, and more time categorized as MVPA and total PA for the wrist worn device (58). In both the Routen *et al.* and the current study, the cut points used for both anatomical locations were derived under different calibration protocols (i.e., developed under different study settings). Therefore, it is possible that the results from the Routen study and the current study are effected by what researchers refer to as the "cut-point conundrum" (79). The "cut-point conundrum" postulates that differences in activity intensity categorization between devices is due to different calibration protocols for intensity derived cut-points and not due to the monitor device or wear location (79).

Additionally, Fairclough *et al.* (17) compared hip and wrist worn monitors in a sample of 9-10 year olds (n = 129) and similar to the current study, they observed higher MVPA from the wrist location compared to the hip location. The researchers speculated that the differences observed in MVPA estimation could be due in part to wrist accelerations being disproportionately greater than those of the hip for certain types of movements (i.e. computer gaming, homework) in activities performed by children. If correct, this would explain why the current study observed higher MVPA for the wrist location compared to the hip location. The dance styles performed in this study included a high volume of arm movement and therefore could have affected the MVPA values reported by the wrist compared to the hip.

Comparison of device location and meeting PA dosages

The second hypothesis of this study was to compare device location and the similarity in assessing the number of days spent meeting predetermined PA dosages (60 min of MVPA/day for 1 - 2, 3 - 4, 5 - 7 days). The null hypothesis for this aim was rejected, indicating there was no similarities between device locations for all of the preselected PA dosages. This study observed similarities between wrist and hip location for assessing participants meeting PA dosage for 1-2 and 3-4 days. However, there was a significant difference between device location and assessment of meeting PA dosage for 5-7 days. For the preselected PA dosage of 5-7 days, the wrist location categorized significantly more participants as meeting preselected PA dosage than the hip location. This could be due to the wrist location categorizing more time spent in vigorous activity than the hip location. The difference in vigorous activity classification between device location, was an observation noted in prior studies assessing wrist and hip worn monitors (17, 60). No prior studies have attempted to compare device wear location in categorizing participants

as meeting preselected PA dosage. However, other studies have compared device location and the estimation of time spent in MVPA; which was ultimately what was done in the current study (hypothesis 2). Therefore, the discussion of the second aim of the current study will focus on time spent in MVPA over several days.

When looking at estimated time spent in MVPA over several wear days, the findings from the current study are similar to what others have reported. For example, Fairclough *et al*. (17) compared physical activity output from wrist and hip accelerometers in a sample (n = 129) of 9-10 year olds for seven consecutive days. Similar to the current study, Fairclough et al. reported higher time spent in MVPA at the wrist compared to the hip in children over several wear days. The authors postulated that the difference in MVPA time between device locations was two-fold. First, during vigorous ambulatory activities, higher accelerations at the wrist relative to the hip are observed because of greater shoulder muscle activity compared with walking and slow running, when arm swing and resultant wrist accelerations are more passive. Second, wrist accelerations could be disproportionately greater than those of the hip for certain types of movements that occur regularly during children's free-living activity.

Physical activity recommendations are a quantification of time that should be accumulated daily in MVPA. Thus, differences in the amount of time estimated at different activity intensities, specifically MVPA, between different anatomical locations could have significant public health implications. Most notably NHANES has begun assessing PA from the wrist location. This study gives some insight that it may not be applicable to compare NHANES data from the wrist location to prior NHANES data recorded from the hip. Additionally, future PA interventions, that aim to increase daily MVPA, using a wrist device, should not attempt to compare activity outcomes from prior studies that used the hip location.

Strengths and Limitations

Strengths of this study include the use of direct observation in the form of video monitoring as the criterion measure. With video monitoring, it is possible to review the activities multiple times to ensure the coding of activity intensities is accurate. Reviewing observed activities multiple times is not possible with traditional D.O, resulting in a higher probability of intensity misclassification or not observing an activity at all. In field based research, direct observation is regarded as the gold standard for assessing PA. This study is also novel in that it is the first study to examine the efficacy of the Crouter wrist cut points in a field based setting. This is of significance because it is important to determine the accuracy of the Crouter wrist algorithm against a gold standard in the setting where it will be primarily used by health researchers. Lastly, the current study had a homogenous sample of girls living in a low SES urban environment, representing a subset of the population where little PA information is currently available.

This study was limited by a number of factors. A small, homogenous (low SES girls) sample size performing one type of activity (dance). Additionally, there was no criterion measure in assessing the accuracy of the Crouter wrist cut point in determining if participants met PA recommendations, only a reference measure was used. A reference measure is a secondary measure which has been previously validated against a criterion measure. In the current study, the hip device was the reference measure, meaning the results of aim two in the current study is not indicative of the validity for wrist worn monitors in assessing habitual PA over several wear days. Additionally, the video monitoring D.O. is a limitation, because the intensity ratings are subjective to the individual rater's perception. Although, this procedure has been validated in

adults, video monitoring with the Noldus Observer XT software has not yet been validated in children. Further, the Troiano wear-time algorithm was used for wear-time validation for the wrist monitor, but this algorithm was developed for the hip location. At the time of this study, no wear-time algorithm had yet been developed for the wrist location.

Conclusions and Future Directions

The primary aim of this study was to examine the accuracy of a hip-worn and wrist-worn Actigraph accelerometer in assessing time spent in different intensity categories in pre-adolescent girls, using direct observation as the criterion measure during semi-structured dance classes. This study observed that neither device location was able to accurately measure all activity categories. The secondary aim of this study was to assess the similarity between device location and number of days participants met different doses (days, minutes/day) of PA using hip location as the reference measure. This study observed that the hip and wrist device locations were not similar in measuring different doses of PA.

Traditional accelerometer algorithms rely on the activity count cut-point method and use single linear regression with limited parameters to model the relationship between accelerometer output, energy expenditure, and intensity cut points. As demonstrated in this study and prior studies, this approach has continuously produced mixed to poor results in field-based settings because linear regression is often inadequate in capturing the complex relationship between acceleration patterns and movement that occurs in free-living settings. In addition, multiple linear and non-linear regression models dependent on the count cut-point method are inaccurate as well. Lyden *et al* (40) demonstrated activities with similar energy expenditures, such as raking and descending stairs, can produce very different activity counts/min (raking= 203 activity

counts/min vs descending stairs= 3,245 activity counts/min) and would therefore produce different energy expenditures and be categorized as different intensities. Thus researchers have begun to explore more sophisticated data processing techniques, such as machine learning techniques.

Machine learning is the general term for an array of mathematical techniques that can be used to recognize patterns in acceleration data and use those patterns to accurately predict activity type and energy expenditure. Trost *et al.* (77) demonstrated that machine learning techniques can accurately predict activity type in children from both the wrist and hip location. Additionally, Staudemayer *et al.* (69) demonstrated the validity of a machine learning technique (artificial neural network) in predicting energy expenditure in adults. Machine learning algorithms are more flexible than traditional regression methods and extracts more of the rich data available from the acceleration signal, resulting in an improved performance across the PA intensity spectrum by identifying activity type through pattern recognition.

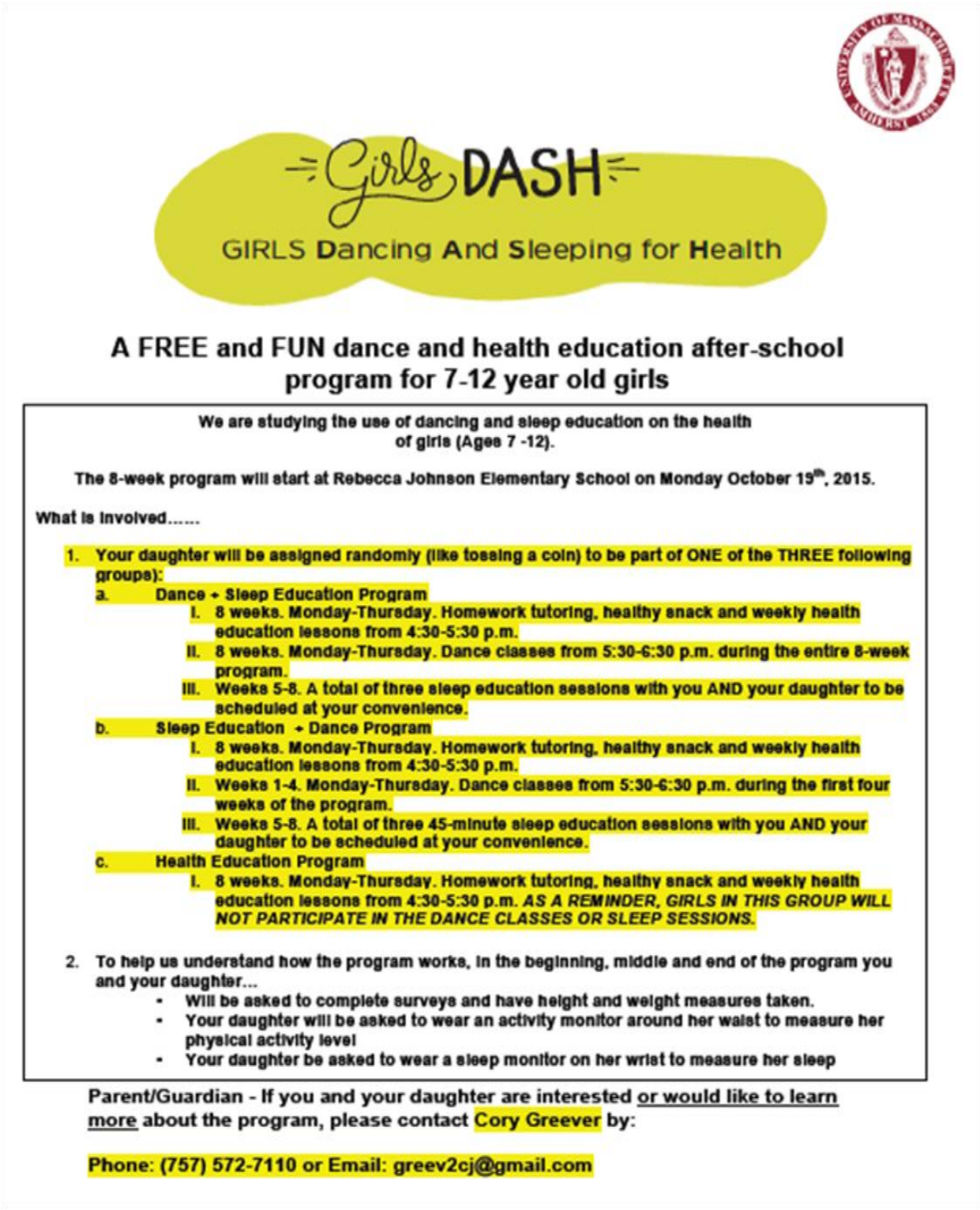
In addition, the activity count cut-point method is inadequate in capturing the complexity of ST. Currently, evidence is emerging that sedentary time is an important health determinant, independent of physical activity. Theoretically, classification of activity type by machine learning techniques would allow for better estimation of sedentary time (time spent in a reclined or seated position) and breaks in sedentary time, which are not possible using the acitivty count-cut point method..

Lastly, further testing should be done to determine the optimal anatomical location for monitor placement in children that leads to a balance between wear compliance and accuracy of data. For example, prior studies done in adults have demonstrated that upper-body activities and specific sedentary times are detected well by wrist-mounted accelerometers (48). It is important

to note that children and adults have very different movement patterns, and what maybe an optimal wear location in adults for data extraction cannot be assumed to be the same in children. Future studies should focus specifically on a pre-adolescent population in developing machine learning techniques.

APPENDIX 1

STUDY FLYER



APPENDIX 2

GIRLS DASH SCREENER

Today's Date: _____ / _____ / 20____

To be eligible for this study, we need to determine the following during the screener. All questions for eligibility have a * *before them.*

- *Age: Girl is 7 years or older, but has not had her 13th birthday.*
- *Child is able to participate in PE*
- *Child reads and speaks English*
- *Parent/Caregiver reads and speaks English*

***If NOT** eligible (at any time during screening), read:*

"I'm sorry, but based upon your answers to these questions, you and your daughter won't be eligible to participate in this study. Unfortunately we are not allowed to include girls who do not meet all of the eligibility requirements. I appreciate your taking the time to answer these questions. Thank you very much."

Opening Script

Hello, this is <<interviewer name>> calling from the UMass Girls DASH program. May I please speak with the mother of <girl's name>?

If not home: When would be a good time for me to reach him/her?

If home: Hello, my name is <<interviewer name>> and I am calling from the UMass Girls DASH program. We are a health education study for girls in grades 2, 3, 4, and 5. I am calling because you have a daughter who may be eligible for our study. We are interested to learn the impact of a dance and sleep education program. Do you have 5 minutes to talk to me?

Our 8-week study involves completing surveys and taking measurements at the beginning, at 4 weeks, and then at 8 weeks. **During these 8 weeks, girls will be randomly selected (like a flip of a coin) to participate in one of three different programs to help them stay healthy. One program includes a dance PLUS sleep education program where girls dance and then receive sleep education. One program includes a sleep education program PLUS dance program where girls receive sleep education and then dance classes. In the third program, girls participate in a health education program, where they will receive weekly health education lessons on site. The dance and sleep education classes will be held at a local community site. The health education program will consist of weekly mini-lessons that will be delivered at the intervention site.** *AS A REMINDER, GIRLS IN THIS GROUP WILL NOT PARTICIPATE IN THE DANCE CLASSES OR SLEEP SESSIONS.* **However, we will offer the dance classes twice per week, for four consecutive weeks at the conclusion of the program.** As part of the program, we ask you and your daughter to complete some questionnaires. All girls will also be offered a healthy snack and homework tutoring from 4:30-5:30 pm every day of the program. The dance classes will take place from 5:30-6:30 pm each day.

Each family participating in this program will also be paid for their time, effort, and participation for a total of $30 if all measures are completed over the 8-week study.

If you think you might be interested, I have several questions that will help us determine if your daughter is eligible to participate in Girls DASH.

Do you think you might be interested? ☐ yes ☐ no

If NO: Thank you very much for your time. If you change your mind, you can contact our program at (413) 545-6104.

If YES: Great (or some other encouragement.) Your responses to these screening questions are completely voluntary. However certain questions must be answered to determine your eligibility for the Girls DASH program. If you choose not to answer them, it will in no way affect your future associations with other programs at UMASS. Everything you tell me will be kept confidential and your answers will be seen only by our research staff. These questions take about 10-15 minutes.

PERSONAL INFORMATION

DASH ID: | | | | | | | | |

Today's Date: _____ / _____ / 20___

*1. What is <<girl's name>> birthdate? ____/____/19____

Age?_____ *(7 to 12.9 years eligible)*

2. To which of the following ethnic groups do you consider <<girl's name>> to belong to? You may choose all that apply.

☐ 1 Mexican, Mexican American or Chicano

☐ 2 Puerto Rican

☐ 3 Cuban

☐ 4 Other Hispanic or Latino

☐ 5 African

☐ 6 West Indian or Caribbean

☐ 7 Other (please specify):_____

3. In addition, to which of the following races do you consider <<girl's name>> to belong to? You may choose all that apply.

☐ 1 Black or African American

☐ 2 White

___

☐ 3 American Indian or Alaska Native

☐ 4 Asian

☐ 5 Native Hawaiian or Other Pacific Islander

☐ 6 Other (Please specify):_____

CAREGIVER PARTICIPATION / INTEREST

1. How did you hear about the program? You may choose all that apply.

☐ 1. My daughter

☐ 2. Friend or other family member

☐ 3. Child's school (e.g. flier, word of mouth)

☐ 4. Presentation at child's school

☐ 5. Church (e.g. flier, word of mouth)

☐ 6. Presentation at church

☐ 7. Child's after school program (e.g. flier, word of mouth)

☐ 8. Presentation at child's after school program

☐ 9. Other community program (e.g. flier, word of mouth)

☐ 10. Presentation at other community program

☐ 11. Newspaper ad or story

☐ 12. Mail (e.g., letter, flier, postcard, brochure)

☐ 13. Television

☐ 14. Radio

☐ 15. Health Fair

☐ 16. Internet (e.g., e-mail, listserv, web site)

☐ 17. Staff initiated phone call

☐ 18. Other (please specify):

_____

2. What interested you in participating in this program? You may choose all that apply.

- ☐ 1. Interested in diet and physical activity
- ☐ 2. Interested in health
- ☐ 3. Would be fun for me
- ☐ 4. Would be fun for her
- ☐ 5. Would help her
- ☐ 6. Wanted to learn more about the program
- ☐ 7. Wanted her to be with other kids
- ☐ 8. Wanted to be with other parents
- ☐ 9. She wanted me to come
- ☐ 10. Sounded interesting
- ☐ 11. It is an important health issue for African-Americans
- ☐ 12. Can get money or gifts
- ☐ 13. Interested in DANCE
- ☐ 14. Interested in reducing TV
- ☐ 15. Other (please specify): _____
- ☐ 16. Refusal

ELIGIBILITY CRITERIA

*** Is <<girl's name>> able to participate in Physical Education (PE) at school?**

(If PE is not offered, ask: "Would <<girl's name>> be able to participate in PE if it were offered?")

☐ yes ☐ no

*** Does <<girl's name>> have any current or past cardiovascular, musculoskeletal, or developmental conditions that would limit her ability to participate in physical activity?**

☐ yes ☐ no

*** Does <<girl's name>> have any current or past cardiovascular, musculoskeletal, or developmental conditions that would limit her ability to wear a small physical activity monitor on her waist or a small sleep monitor on her wrist?**

☐ yes ☐ no

*** Does <<girl's name>> read and speak English?**

☐ yes ☐ no

*** Does the parent read and speak English? (DO NOT READ QUESTION TO PARENT, ANSWER QUESTION BASE ON PARENT'S INTERACTION WITH DATA COLLECTOR)**

☐ yes ☐ no

SUMMARY

Considering only the screening eligibility criteria, does this girl satisfy the Girls DASH eligibility requirements?

- Age: Girl is 7 years or older, but has not had her 13th birthday.
- Child is able to participate in PE
- Child has no conditions limiting her ability to participate in physical activity or the assessments
- Child reads and speaks English
- Parent/Caregiver reads and speaks English

If eligible, read to parent/caregiver:

"Based on your answers to these questions, it looks like <<girl's name>> will be eligible to participate.

The next step in this screening process is to schedule a visit that will take place in your home. The purpose of this visit is to get you and your daughter to sign the informed consent and assent documents and to complete the baseline surveys. The visit will take about 1 hour.

We want to make this as easy as possible for you, so we can schedule this next appointment at a time that is most convenient for you and your daughter.

Do you have questions?"

INFORMED CONSENT & BASELINE ASSESMET VISIT

Did the girl and her parent/caregiver agree to schedule a visit?

☐ yes ☐ no

a. If YES, scheduled date for Baseline Visit ☐ month ☐ day 20☐ year

b. If YES, scheduled time for Baseline Visit ☐ time AM PM

c. Parent First and Last Name:

First Name	Last Name

d. Girl's Name

Girl(s) First Name	Girl(s) Last Name

e. Relationship to girl(s): _____

f. Mailing Address:

City: MA, zip:

g. Phone numbers:

Home number	( ) -
Work number	( ) -
Cell	( ) -
Email address	

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