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Educational Environments and Children's Physical Activity and Sedentary Behaviors

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EDUCATIONAL ENVIRONMENTS AND CHILDREN'S PHYSICAL ACTIVITY AND SEDENTARY BEHAVIORS

by

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ABSTRACT

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Children and adolescents spend the majority of their day engaged in sedentary behaviors (SB), while also not meeting physical activity (PA) recommendations. The failure to develop and maintain health enhancing behaviors from a young age may impact an individual throughout their life. With children and adolescents spending a large proportion of their waking hours in a school setting, the educational environment presents an opportunity in which children and adolescents' PA and SB can be positively influenced. Therefore, the purpose of this dissertation was to explore how children and adolescent's school time PA and SB are associated with the educational setting, and how these behaviors change over the course of the school year and in response to non-traditional classroom settings. To address this purpose, three individual studies were completed. **Study 1: Comparison of measures of elementary student's classroom postural behaviors using direct observation and accelerometry in a school setting.** The results of our research are only as good as the measures used, therefore to begin this series of studies two commonly used objective methods to assess children's PA and SB were compared. Specifically, the inclinometer function of a hip-worn Actigraph GT3X+ accelerometer (ACC) and direct-observation (DO) were evaluated in their measurement of child and adolescent posture within a classroom environment that included stand-biased and traditional seated desks. Our results suggest that the measurement of both sitting and standing while in either a stand-biased or

traditional seated desk were significantly different between DO and ACC, with DO consistently recording a higher proportion of time spent sitting, and a lower proportion of time standing regardless of desk assignment. The difference between DO and ACC measures of sitting (-18.9%; $p=0.041$) were significantly smaller when students used a stand-biased compared to a traditional seated desk. There was no significant difference between DO and ACC measures of standing between desk types, and lower limb fidgeting was found to have no main or interaction effect between desk type and differences of postural measures. It is important to remain cognizant of the methodologies used to assess youth behaviors, and the influence these measurement techniques can have on intervention outcomes involving environmental and other behavioral modifications. **Study 2: An exploration into the variation of children's in-school physical activity across the school year.** Study two explored the variation in children and adolescents PA behaviors during active periods of the school day across the school year. Participating students completed a survey on five separate occasions throughout the school year, assessing activity levels during active transportation to and from school, at recess, and in physical education class. Our results suggest that overall, the weekly minutes that children and adolescents spent engaging in moderate- to vigorous-intensity PA (MVPA) remained relatively stable during recess (Avg: 42.2±12.2 minutes/week) and physical education class (Avg: 17.7±5.6 minutes/week) throughout the year. Statistically significant differences were found in the estimated weekly minutes of MVPA accumulated during active transportation to- and from-school, with the greatest accumulation occurring in September (To-School: 15.3±5.7 minutes/week; From-School: 32.0±10.5 minutes/week), and the lowest accumulation of MVPA to-school and from-school occurring in December (13.9±6.5 minutes/week; $p=0.01$) and March (28.5±11.9 minutes/week; $p<0.001$), respectively. During active transportation to-school, weekly

MVPA was highest in September (Fall; 15.3±5.7 minutes/week), and lowest in December (Winter; 13.9±6.5 minutes/week; p=0.01), while significant differences in active transportation from-school occurred between September (Fall; 32.0±10.5 minutes/week), December (Winter; 29.6±11.6 minutes/week; p=0.003), March (Spring; 28.5±11.9 minutes/week; p<0.001), and April (Spring; 29.2±12.0 minutes/week; p<0.001). Opportunities for PA throughout the school day may have been insufficient to aid youth in meeting recommendations, however the weekly opportunities which students are provided to engage in MVPA do not vary meaningfully throughout the year. To address this, school administrators may consider increasing the frequency and length of time which students are provided to engage in PA throughout the school day, such as during recess and physical education class, or by seeking to increase participation during periods of the school day where students are less consistently active throughout the school year, including during active transportation to- and from-school. **Study 3: Comparison of children's physical activity and sedentary behaviors between a nature-based and traditional educational setting.** The third and final study of this dissertation aimed to compare within-child differences in PA and SB of a sample of children attending a single Pre-Kindergarten (Pre-K) educational program which alternated school days between a traditional and nature-based school setting. Overall, the results from this study suggest that children spent a significantly greater proportion of school time engaging in MVPA (+2.4±3.4%; p=0.002) while in a nature-based compared to a traditional Pre-K setting. Moreover, differences in MVPA between a nature-based and traditional program setting were most pronounced during the winter (~6 min/day), particularly while engaging in unstructured free play (~5 min/day). While the winter season has been shown to be a time when youth PA levels are at their lowest, the PA levels of children while in a nature-based setting remained constant from winter to spring.

Therefore, modifying educational practices to increase opportunities for structured and unstructured activities outdoors, particularly during periods of the year when children are least active, may have the potential to positively influence children's in-school PA and SB. **Overall Conclusion.** Together, these dissertation findings contribute toward a better understanding of the potential that the school setting has to provide meaningful and consistent opportunities for youth to engage in more active behaviors throughout the school day. The methodological approach of Study 1 highlights the differences in the measurement and interpretation of youth activity behaviors encountered when the methods of assessment vary, particularly as schools may seek to modify educational environments and promote more active behaviors. Study 2 provided insight into times of the school day and periods throughout the school year in which opportunities for children and adolescents to engage in PA can be enhanced, and Study 3 reinforces the relationship between time outside and children's PA levels, providing one avenue for traditional school programs to incorporate more activity into the school day. Overall, the results of these studies provide school administrators and decision makers with important information surrounding school-related factors which are associated with children and adolescents PA and SB, and inform improvements in opportunities for the accumulation of school time PA. Ultimately, this dissertation contributes towards a body of research seeking to increase the quantity and quality of activity behaviors youth engage in, and to aid in the development of the healthy habits that children and adolescents practice throughout their lifespan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER 1: INTRODUCTION

Background

Children and adolescents spend a large proportion of their waking hours in school, and a majority of that time is spent engaging in sedentary behaviors (SB) [153]. Excessive amounts of time engaging in SB by youth has been associated with poorer physical [3, 38, 49, 68, 81, 130, 192, 202] and mental [22, 26, 80, 88, 158, 172] health outcomes, potentially impacting life in and outside of the school setting. Therefore, the school setting presents an environment where children and adolescents can develop the knowledge, skills, and behaviors which influence their adoption of long-term positive health behaviors through practices which decrease the quantity of time spent engaging in SB [31].

In addition to SB, physical activity (PA) is vital for the healthy physical, mental, and emotional development of youth. Children and adolescents who engage in at least 60-minutes of PA daily at the moderate- to vigorous-intensity level (MVPA) receive a number of positive physical [45, 74, 96, 137, 148, 181] and mental [109, 137, 168] health benefits. Unfortunately, few youths engage in sufficient levels of PA to receive significant health benefits [37, 87, 186]. Therefore, identifying ways to increase PA remains a public health priority. Schools present a unique setting in which PA behaviors can be influenced. While much of the school day may be spent sitting, children and adolescents are additionally presented with specific opportunities in which PA is encouraged [91], and these can occur inside and outside as well as through either structured, teacher-led activities, or through engagement in unstructured free play-based activities [14, 101]. Importantly the benefits associated with PA are distinct from the consequences resulting from excess SB [170] and therefore addressing both behaviors has the potential to significantly impact an individual's quality of life.

The schedule and activities of the school day can vary greatly depending on the grade level, teacher, administrative policies, and other factors at the individual school, and district-wide levels which influence the sedentary nature, and the opportunities for PA, during the school day [34]. While many schools have traditional seated desks in their classrooms, others offer a modified classroom environment, with learning taking place while using alternate forms of seating or desks, or possibly outside in a nature-based setting. Regardless of the setting in which a student attends school, their experiences, delivered through either structured or unstructured activities, and led or influenced by teachers, parents, peers, and siblings, play a significant role in shaping children and adolescent's activity behaviors, knowledge, and attitudes as they develop and grow [50, 60, 93, 189].

Although primarily focused on learning outcomes, schools provide an avenue to positively address the development of both the mental and physical health of a child through the inclusion of educational objectives and meaningful opportunities for PA throughout the day [97]. It has been shown however, that the traditional approach to education, consisting largely of time spent in classrooms while seated at workstations, can be a significant contributor to total daily SB and may detract from time spent engaging in physical activity PA [53]. Encompassing such a large part of a child's day, it is important to understand how the school setting which children attend on a regular basis can influence PA and SB to ensure that children and adolescents are provided experiences which encourage, instead of hinder, the development of healthy behaviors. However, the quantity and distribution of physically active behaviors students engage in during school-time warrants further investigation to better understand the potential for modifying the classroom and school environments and enhancing active behaviors across the school day. Novel approaches to modifying the school and classroom environments to support PA, while still enabling learning, may therefore serve as one step towards altering the PA and SB participation trajectory of children and adolescents.

In addition to the incorporation of practices to improve PA and SB in school, the methods by which these behaviors are measured is important when drawing comparisons or inferences from data collected, and to fully understand whether alterations to the traditional school setting result in meaningful behavioral change. There are a variety of ways in which PA and SB levels of youth can be validly and reliably assessed. However, each method available for the assessment of youth PA and SB have different strengths and weaknesses associated with their feasibility and application [178]. Therefore, the choice of method can alter the amount of PA and SB that is recorded [70, 112, 126]. Direct observation and accelerometry are two commonly used objective measures of children's PA and SB, while questionnaires and other subjective approaches can also prove useful. Although these measurement approaches assess the same behaviors (PA or SB), each has their own utility, making some circumstantially more informative than others in school settings [41]. As school settings are altered to promote PA and decrease SB, having accurate and reliable measures of changes (or a lack thereof) to PA and SB will help researchers, educators, administrators, and parents understand how to address these behaviors and enhance the well-being of youth.

Within this dissertation, three individual studies are presented. These studies aim to further our understanding of the associations between the school setting and children and adolescent's PA and SB. Broadly, this dissertation will focus on in-school PA and SB measurement strategies and the role that the school setting plays as a moderator of these behaviors. This three-study dissertation will include: (1) a methodology-focused study comparing the use of accelerometry and direct observation in the objective measurement of student's classroom postural behaviors; (2) an analysis of factors associated with the variation in students school day PA behaviors across the school year; and (3) a cross-sectional study that compares children's PA and SB while attending school in two distinct settings. In combination, these three studies will contribute towards a better understanding of the association between the school setting and the PA and SB of children and adolescents.

Statement of Purpose

The purpose of this dissertation was to explore how children and adolescent's school time PA and SB are associated with the educational setting, and how these behaviors change over the course of the school year and in response to non-traditional classroom settings.

Specific Aims & Hypotheses

Study 1: Comparison of Measures of Elementary Student's Classroom Postural Behaviors using Direct Observation and Accelerometry in a School Setting

The first study of this three-study dissertation was a secondary analysis of data, with a focus on comparing two commonly employed methods of measuring children and adolescents' activity behaviors in a school setting. Classroom postural and movement behaviors of third, fourth, and sixth grade students were recorded by direct observation and a hip-worn accelerometer while using either a traditional seated or stand-biased desk.

S1A1: The aim of this study was to compare time spent sitting and standing when assessed by two commonly used physical activity measurement methods.

S1H1: It was hypothesized that sitting and standing time measured by direct observation and accelerometry would be significantly different in a stand-biased, but not a traditional seated desk.

S1H2: Higher levels of lower-limb fidgeting while using a stand-biased desk, but not a traditional seated desk, would result in greater differences in sitting time measured by accelerometer and direct observation.

Study 2: An Exploration into the Variation of Children's In-School Physical Activity Behaviors Across the School Year

The second of this three-study dissertation was an exploratory secondary analysis of data collected utilizing a prospective observational approach. Within this analysis, factors associated with the variation in student's school day PA behaviors across the school year were investigated. Students completed the Youth Activity Profile (YAP) five times throughout the school year, responding to questions that focused on active periods of the school day such as active transportation to and from school, recess, and physical education class.

S2A1: The primary aim of this study was to explore changes in school day moderate- to vigorous-intensity PA behaviors across the school year.

S2H1: It was hypothesized that children and adolescents would report engaging in a significantly greater amount of MVPA during the school day in the fall, compared to the winter and spring seasons, and that the difference between the winter and spring seasons would not significantly differ.

<u>Study 3: Comparison of Children's Physical Activity and Sedentary Behaviors Between a Nature-Based and Traditional Educational Setting</u>

In the third and final study of this dissertation, a within-subject design was used to compare Pre-Kindergarten (Pre-K) children's in-school PA and SB between a traditional school setting and an alternate, nature-based setting.

<u>S3A1:</u> The primary aim of this study was to compare differences in children's accelerometer-determined school-day PA and SB between Pre-K programs in an outdoor, nature-based setting and a traditional, indoor educational setting.

<u>S3H1:</u> It was hypothesized that children would accumulate significantly more PA and less SB during the school day while attending a nature-based, outdoor Pre-K program, compared to a traditional, indoor Pre-K program.

<u>S3A2:</u> The secondary aim of this study was to compare children's PA and SB while attending Pre-K in an outdoor, nature-based setting and a traditional, indoor educational setting between the winter and spring.

<u>S3H3:</u> It was hypothesized that there would be no significant differences in PA and SB between the spring and winter seasons while children attended a nature-based Pre-K program.

S3H4: It was hypothesized that children attending a traditional Pre-K program would accumulate significantly more PA and less SB in the spring compared to the winter season.

S3A3: The third aim of this study was to compare differences in the PA and SB of children during periods of structured and unstructured time between outdoor, nature-based and indoor, traditional Pre-K programs.

S3H7: It was hypothesized that children attending a nature-based program would spend significantly more time engaging in PA during both structured and unstructured periods of the school day compared to a traditional classroom setting.

S3H8: It was hypothesized that children attending a traditional program would spend significantly more time engaging in SB during both structured and unstructured periods of the school day compared to a nature-based classroom setting.

Assumptions of the Studies

The following assumptions are made for each study: 1) Participants will answer all questionnaires honestly and to the best of their ability; 2) Participants will wear their accelerometer as directed by the researcher, remembering to put the device on and remove it as per study instructions; 3) Direct Observation will only be conducted during "normal" classroom periods; and 4) Monitoring of participants (i.e. through the wearing of an accelerometer or being the subject of direct observation) will not result in a change of typical behaviors.

Limitations of the Studies

Broadly, limitations of these studies relate to the specific populations being studied and the inability to generalize findings to individuals outside of these groups. Additionally, the methodologies used to collect data may have limitations. It is hoped however that the findings from these studies provide further insight into children and adolescents' PA and SB levels, and their associations with various school settings, PA opportunities, and the school year. Each study has its own strengths and limitations. A limitation of study one was the chance that participants wore the accelerometer device incorrectly on days in which they were responsible for putting the device on. To address this, participants were shown the correct placement of the accelerometer at the beginning of each measurement period, and also received written instructions outlining correct wear. Additionally, teachers were asked to monitor students' accelerometer use to assist in ensuring that devices were being worn correctly on days that researchers were not present. The use of focal-point time sampling for the conduction of direct observation (DO) was another limitation. This DO approach involved a 5-second observation period followed by a 25-second recording window, meaning that some postural or fidgeting behaviors may have occurred during the time in which observations were being recorded and therefore only captured through accelerometry. A limitation of study two was the potential for recall bias to influence student responses to the self-report instrument administered during each assessment period. To address this potential for bias, the survey used in this study has been previously shown to be valid and reliable among children and adolescents, and assessments were administered with a trained researcher on hand to guide participants through each question and assist with any confusion or questions which arose. Additionally, the Youth Activity Profile (YAP) only captures estimates of children and adolescents PA during specific periods of the day, and at the weekly level, potentially missing additional opportunities for PA which occurred outside of the periods assessed or on a more random basis throughout the school week. Finally, a limitation of study three was the inability to assess children's PA and SB outside of the school day. In this study data was collected among 4-5-year-old children, however two class periods occurred each day and the limited number of devices available for data collection required the collection of these devices at the end of each class period for cleaning and redistribution in the following class. Additionally, the pilot nature of this study resulted in a small sample size assessed over just two, four-day school weeks across the winter and spring seasons. Therefore, it is recommended that the protocol for this study be replicated among a larger sample of participants, and for a greater length of time across seasons, to assess replicability. For more specific limitations of each study within this dissertation, please refer to the respective manuscript chapter for that study.

Practical Significance of the Studies

Throughout the day children and adolescents spend a significant proportion of time engaging in SB, while also struggling to engage in sufficient amounts of PA to receive positive health benefits [37, 139]. During a typical school year, children and adolescents spend a large proportion of their weekday waking hours in a school setting, and much of this time is spent sitting [153]. Traditional educational practices favor sedentary approaches to learning with specific periods of the day set aside for youth to engage in PA [91]. Because of this, the school setting has been recognized as a point at which children and adolescents PA and SB can be meaningfully influenced [31]. When the traditional educational setting is modified, through either environmental or classroom means, to enhance PA and decrease SB, such as the incorporation of stand-biased desks into the classroom or by taking a nature-based approach to instructional time, the educational goal of supporting students' academic achievement remains intact. Additionally, the PA and SB habits which youth develop beginning at a young age are likely to track into adulthood, therefore utilizing the school setting to promote healthy activity behaviors among students increases the likelihood of developing into a more active, and healthier adult [66, 94, 180]. Two of the three studies presented within this dissertation explore ways in which teachers and administrators may be able to modify the school setting to support the physical and mental development of students. Furthermore, this dissertation will highlight considerations for researchers and evaluators when conducting assessments of children and adolescent's activity behaviors within a modified school setting.

Scientific Significance of the Studies

The school setting has been highlighted as a place where children and adolescents' activity behaviors can be positively influenced [31]. Previous research has suggested a need to better understand discrepancies between methods of measuring youth activity behaviors, particularly in the assessment of postural behaviors in a free-living setting [41, 43, 71]. Additionally, while PA levels of youth are understood to vary significantly throughout the year [6], it remains unknown whether the structured nature of the school setting protects against this variation, at least during the time that children and adolescents are in school. Finally, novel approaches to modifying the school setting for the promotion of healthy activity behaviors, such as through a nature-based approach to education have displayed preliminary success [107, 184, 197], yet questions remain as to how these modified programs compare to traditional approaches to education both related to students' activity levels, and education. The studies within this dissertation will contribute to a growing body of research exploring approaches by which the traditional educational setting can be modified to decrease the proportion of school time children and adolescents spend engaging in SB while increasing active behaviors [32, 200]. More specifically, the first study of this dissertation examined the applicability of two commonly employed methods in the measurement of children and adolescent's postural behaviors in a modified classroom setting between students using either a traditional seated desk, or a height-adjustable stand-biased desk. The use of stand-biased desks in a classroom, with an included height-adjustable stool and attached fidget bar to support sitting, compared to a seated desk and chair, has the potential to influence the ability to accurately assess sitting and standing behaviors. The second study of this dissertation will contribute to a gap in the literature surrounding the variation in children and adolescents in-school PA behaviors across the school year, when engaging in structured and regularly scheduled opportunities for PA. Finally, the third study of this dissertation is, to our knowledge, the first study assessing differences in the PA and SB levels of children in a Pre-K educational program which regularly alters school days between a traditional, and nature-based educational setting. Scientifically, these studies can move the fields of PA and public health forward by better understanding ways in which the school setting may be used as a point of intervention to positively enhance children and adolescent's daily PA levels, while ultimately encouraging the development of long-term healthy behaviors.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

Throughout the United States, children and adolescents are failing to achieve the physical activity (PA) and sedentary behavior (SB) recommendations to maintain or receive positive health benefits [37, 139]. Consistently failing to meet these recommendations place youth at a heightened risk of developing chronic physical and mental conditions [88, 130, 158], and increases the likelihood of engaging in similar behaviors through adulthood [66].

On average, children and adolescents in the United States spend approximately 6.6 hours per day across 180 days per year in an elementary, intermediate, or high school setting [52]. Throughout their school lives, from kindergarten through high school, students will spend the majority of their time at a desk engaging in classroom instruction. Additionally, active parts of the school day such as recess and physical education, have been increasingly sacrificed in support of a focus on didactic learning and standardized test preparation [84, 203]. The time children spend engaging in school-related activities plays a significant role in the quantities of PA and SB accumulated during the week. With intentional opportunities to engage in PA in school decreasing, it is important to investigate other means by which SB can be mediated while continuing to support academic goals.

The following review of the literature will focus on defining PA and SB, its prevalence and health impacts among children and adolescents, and methods by which it is both objectively and subjectively measured. Additionally, factors which influence PA and SB will be examined, including prior research on the impact of seasonality, differences between structured and unstructured time, and the incorporation of nature-based practices into an educational setting.

Physical Activity & Sedentary Behaviors of Children & Adolescents

Recommendations on the Quantity & Quality of Physical Activity & Sedentary Behaviors

PA and SB have been directly linked to health, development, and function in children and adolescents. Therefore, countries, policy makers, national and international organizations have all published guidelines on the quantity and quality of PA and SB that is recommended to positively impact the health of children and adolescents. In order to understand the influence which PA and SB have on children and adolescents' lives, it is important to review recommendations for health enhancement, the prevalence of youth meeting these recommendations, disparities among children and adolescents meeting PA and SB recommendations, and finally the potential health impacts of not meeting these recommendations.

Physical Activity

The term 'Physical Activity' is defined by the World Health Organization (WHO) as, "any bodily movement produced by skeletal muscles that requires energy expenditure", or more succinctly, "all movement" [201]. This all-encompassing definition is purposely broad as it includes both intentional forms of PA such as exercise, and unintentional forms, such as the completion of chores around a house, or engagement in unstructured free play. The recommendations towards the amount of PA children and adolescents should engage in for positive health benefits has been widely adopted around the world. For children 1-4 years of age, it is recommended that at least 180 minutes per day be spent engaging in any type of physically active behaviors, with an emphasis placed on activities at the moderate- to vigorous-intensity level [199]. Between the ages of 5-17 years, children and adolescents are recommended to engage in a minimum of 60 minutes of PA at the moderate- to vigorous-intensity level every day of the week. Additionally, children and adolescents should engage in activities which strengthen muscle and bones on at least 3 days per week, as a portion of total PA accumulation [201].

One of the key components of these PA recommendations is the intensity at which activity is performed. Research has established that maximum benefits are gained when children and adolescents engage in at least moderate-intensity PA, however this is also the most complex feature of the recommendations to characterize. One way in which PA intensity can be quantified is through a Metabolic Equivalent (MET). Originally developed for adults with the assumption that it could be applied across all age groups; one MET was considered equal to the amount of oxygen consumed while sitting at rest (3.5 mL O_2/kg/min; or 1 kcal/kg/hour). However, it has since been recognized that the metabolic activity of youth varies significantly from that of adults, and even within various stages of development [120]. For this reason, youth MET's (MET_y) were developed by dividing measured oxygen consumption (VO_2) by basal metabolic rate (rate of energy expenditure at rest), calculated through age-, sex-, and mass-specific Schofield equations. Similar to that which was developed by Ainsworth et al. [2] for adults, Butte and colleagues [27] published a 'Compendium for Physical Activities in Youth' which categorizes various activities by their metabolic demands. Because children and adolescents tend to vary in the activities which they choose to engage in as they age, categorized MET_y values have been further stratified into age-specific reference groups (6-9, 10-12, 13-15, and 16-18 years), ultimately providing an easier way to understand the metabolic energy cost of performing different activities at varying levels of intensity [142].

Sedentary Behavior

Equally as important to meeting the PA guidelines for health enhancement, children and adolescents should also be aware of the quantity of SB which they engage. In 2012, members of the Sedentary Behaviour Research Network (SBRN) published a standardized definition of SB as, "any waking behavior characterized by an energy expenditure less than or equal to 1.5 MET's while in a sitting or reclining posture". Furthermore, the SBRN sought to distinguish SB from physical inactivity, acknowledging that both behaviors contribute to poorer health outcomes in people independent of one another. Physical inactivity therefore can be conceptually thought of as individuals performing insufficient amounts of PA to meet specific activity guidelines [170]. In maintaining consistency, the WHO provides SB recommendations within its 24-hour movement guidelines for children and adolescents. It is recommended that children between 1-4 years of age not be restrained for more than one hour at a time in any seated/reclining device or while strapped to their caregivers back, or spend extended periods of time sitting. Additionally, screen time, which is often used as a proxy indicator for SB should be limited to one hour or less for children between 2-4 years of age, while not being recommended for children 1 years of age or less. Furthermore, caregiver engagement through reading and storytelling during sedentary time is highly encouraged across this age group [199]. Children and adolescents (5-17 years of age) have a broader recommendation for SB, stating that the amount of time being sedentary should be limited, particularly that spent engaging in recreational screen time [201].

While the United States does not currently promote specific recommendations for SB, reports on total time spent sedentary across all waking hours, and the engagement in proxy-indicators of SB such as leisure-time screen viewing provide insight into children's behavioral practices. The American Academy of Pediatrics recommend that children between 2-5 years limit screen time to one hour or less per day of high-quality programming, and adolescents refrain from engaging in more than two hours per day of leisure-related screen time [1]. However, while screen-time recommendations continue to be used as an indicator of SB, the evolution of media consumption and the prevalence of screens throughout life have made these guidelines progressively more difficult for children and adolescents to attain today [154].

Prevalence & Disparities

Physical Activity

Within the United States, the majority of children and adolescents between the ages of 6-18 years are not meeting the PA recommendations of 60 minutes per day at the moderate- to vigorous-intensity levels. Troiano and colleagues [186] analyzed a nationally representative data set of objectively measured activity behaviors in children and adolescents (n=6329 providing at least 1-day; and n=4867 providing 4+ days of valid data) from the 2003-2004 National Health and Nutrition Examination Survey (NHANES). Among children between the ages of 6-11, 42.0±1.6% (%±SE) met or exceeded PA recommendations. However, the percentage of adolescents achieving recommended levels of PA declined significantly to the point where just 8.0±1.1% of 12-15-year-olds, and 7.6±1.2% of 16-19-year-olds met or exceeded the 60 minutes per day threshold. It should be noted however that these results included children who provided a minimum of one-day of complete data, which cannot be considered representative of average behavior characteristics [186]. The 2018 United States Report Card on Physical Activity for Children and Youth [87] used data from the 2005-2006 NHANES and only reported on participants who provided at least 5 days of objectively measured PA data. In this report, 42.5%

of 6-11-year children met PA guidelines, while just 7.5% of adolescents 12-15 years and 5.1% of adolescents 16-19-years met the guidelines.

More recent qualitative assessments of children's PA, however, provide greater insight into the trends of children's PA and SB over time. The 2019-2020 National Survey of Children's Health (NSCH) found that just 20.6% of children and adolescents between 6-17 years reported engaging in at least 60 minutes of moderate- to vigorous-intensity PA on every day of the week, while the majority of respondents (42.4%) reported meeting this goal between 1-3 days per week. Further broken down by age group, 26.2% of children 6-11 years, and 15.2% of adolescents 12-17 years reported achieving at least 60 minutes of moderate- to vigorous-intensity PA every day of the week [37].

Sedentary Behavior

Drawing from 2015-2016 NHANES self-report data, approximately 1/3rd of children and adolescents between 6-19 years of age reported engaging in less than two hours of recreational screen time per day, while slightly more young children (6-11 years; 35%) report engaging in less than two hours per day of recreational screen time than older children (12-19 years; 31%). Among high school students, the 2017 Youth Risk Behavior Surveillance Survey (YRBSS) found that nearly half (43%) of respondents self-reported engaging in greater than 3 hours of screen time through computers or other electronic devices per day [87]. Further reinforcing these findings, objective measures of children and adolescents SB collected for the 2003-2004 NHANES report found that children between 6-11 years were recorded as spending an average of approximately 6.1 hours per day engaged in SB, while adolescents between 12-15 and 16-19 years were found to engage in approximately 7.5 and 8.0 hours per day in SB, respectively [139].

Determinants of Physical Activity & Sedentary Behaviors

Children and adolescents' personal and environmental situations contribute significantly to the quantities of PA and SB in which they engage. Beyond age-group, additional factors shown to influence these behaviors include sex, race and ethnicity, weight status, socioeconomic status, as well as the built environment where these behaviors occur. While the greater disparities in PA levels are found by age and sex, it is important to recognize that a combination of factors frequently play a role as determinants of children and adolescent's activity behaviors. Data collected from the 2019-2020 National Survey of Children's Health (NSCH) revealed that 23.1% of boys and 18.0% of girls between 6-17 years engaged in at least 60 minutes of PA on every day of the week. Additionally, 12.4% of girls and 10.2% of boys reported not meeting this PA threshold on any day of the week [37]. Differences in race and ethnicity also exist, with 23.8% of White, non-Hispanic youth between 6-17 years reporting engaging in at least 60 minutes of moderate- to vigorous-intensity PA on every day of the week. This is compared to 19.5% of Black, non-Hispanic, 15.7% of Hispanic, 14.2% of Asian, non-Hispanic, and 22.5% of Other, non-Hispanic youth reporting meeting the same threshold. Further, 8.2% of White, non-Hispanic youth reported not meeting this threshold on any days of the week, which was lower than Black, non-Hispanic (16.0%), Hispanic (14.7%), Asian, non-Hispanic (12.6%), and Other, non-Hispanic (10.2%) youth.

Compared to self-report surveys, accelerometer data from the 2003-2004 NHANES found similar differences between groups in the prevalence of children and adolescents meeting PA recommendations by age, sex, and weight status [198]. However, by race/ethnicity it was found that non-Hispanic Black and Mexican American youth achieved PA recommendations at a higher rate across all age groups compared to non-Hispanic White youth. While only statistically significant among the youngest age group of 6-11-year-old children, these findings from objectively measured data contradicts frequently reported activity disparities based on race and ethnicity, often collected through self- or proxy-report surveys and interviews [24, 51]. Whitt-Glover and colleagues [198] speculated that these findings were related to the discrepancy in the behaviors captured between objective and subjective measurement methods of children and adolescent's PA. While subjective measures often refer to specific structured and organized periods and events throughout the day, they do not capture the same level of free-living activity behaviors as an objective monitor worn for all waking hours. Finally, no significant differences were found between any age, racial or ethnic groups based on socioeconomic status, however among adolescents between 16-19 years, those from the lowest household income bracket consistently met the PA guidelines more frequently than their higher-income counterparts, something not seen among younger children [198].

The amount of SB performed by children and adolescents also differs based on sex, age, and race/ethnicity, however these differences are smaller than those seen with PA levels. Girls (38%) report meeting screen time recommendations of two hours or less per day more frequently than boys (28%) [87]. In analyzing 2003-2004 NHANES data, Whitt-Glover and colleagues [198] found objectively measured SB to range from 5.5 hours per day among 6-11-year-old normal weight non-Hispanic White children to 8.5 hours per day among 16-19-year-old non-Hispanic Black adolescents. Throughout this data set however, only two significant differences between racial and ethnic groups based on sex and socioeconomic status were observed. It was found that non-Hispanic Black girls between the ages of 6-11 years were significantly more sedentary than non-Hispanic White girls within the same age group, and that non-Hispanic Black children and adolescents within the middle socioeconomic status group ($25,000-$54,999) were significantly more sedentary than non-Hispanic White children and adolescents within the same household income range. Overall, however, the similarities in time spent engaging in SB across sex, race and ethnicity, socioeconomic status, and weight status suggest that children and adolescents have established consistent patterns of SB in which they engage throughout each day.

Both the built environment and the organizational structure of activities throughout the day have been shown to contribute towards children and adolescents PA and SB. Examples of environmental settings which influence PA and SB include activities taking place at school or at home, and whether they are inside or outside. Within these environmental settings, the extent to which children engage in activities following a predetermined schedule developed to achieve specific goals, or the level of structure an activity follows, further influences the quantities of PA and SB children and adolescents accumulate each day. In 2017, Brazendale and colleagues [23] highlighted the contribution that structure makes to the activity behaviors of children and adolescents. The 'Structured Days Hypothesis' postulates that the structured organization of a child's school week exerts a beneficial effect on PA, SB, and other health outcomes. This is due to the protective effect that a structured setting provides children in controlling obesogenic behaviors, including compulsory opportunities for PA, reductions in screen time and other leisure-time SB, and the regulation of caloric intake and sleep schedules. In this sense, children and adolescents are more likely to engage in PA and control levels of SB when presented with scheduled periods structured with specific behaviors in mind. In contrast however, unstructured periods, particularly across entire days or series of days, have been presented as a time of greater engagement in SB and reduced PA in the absence of scheduled activities to moderate the engagement in obesogenic behaviors. While the 'structured days hypothesis' specifically focuses on the entire day in its suggestion that children and adolescents are more active during the school week compared to during the weekend or over summer vacation, this does not discount the significant accumulation of SB which still occurs during the school day, and the smaller contributions that structured and unstructured periods within a day make towards in-school levels of PA and SB.

Throughout the school day, children and adolescents are presented with specific and often scheduled periods in which either PA or SB occurs. Knowing that children and adolescents spend a significant amount of the school day sedentary, Beck et al. [13] conducted an observational study among a cohort of fifth graders from an urban school district in the United States that specifically focused on comparing in-school and out-of-school SB patterns. Findings from this study indicated that children engaged in significantly more SB during out-of-school hours compared to in-school hours (49% vs. 35% of timeframe), and on weekend days compared to weekdays (48% vs. 43% of waking hours). Within structured settings, a review of 187 studies assessing children and adolescent's PA and SB in places such as schools, childcare programs, and afterschool and summer programs, it was found that children engaged in more moderate- to vigorous-intensity PA (MVPA) during afterschool and summer programs compared with in schools and childcare settings. More specifically, while in school, 36.7 min/hour (223.9 minutes total) was spent engaging in SB, and approximately 4.4 min/hour (27.8 minutes total) in MVPA. Similarly, in a childcare setting, 36.7 min/hour (221.8 minutes total) was spent engaging in SB, while 5.1 min/hour (32.1 minutes total) were spent in MVPA. In after-school programs, summer camps, and through sport and PA programming, children and adolescents accumulated on average 11.7 min/hour (23.5 minutes total), 6.4 min/hour, and 20.9 min/hour (18.9 minutes total) of MVPA, respectively [182]. Finally, Barbosa and colleagues [10] assessed 370 preschoolers between the ages of 4-6 years using accelerometers and found that on average preschool-aged children are spending close to 90% of their school-time sedentary. Of the remaining time in preschool, on average 6.1% was spent in light-intensity PA (LPA), 2.15% in moderate-intensity PA (MPA), and 1.4% in vigorous-intensity PA (VPA). Moreover, the study conducted by Barbossa et al. [10] highlighted the importance of location and setting in the promotion of PA among preschool children, with recreation rooms, playgrounds, and the recess period being the most significant factors in promoting PA during the school day. Overall, the findings by Beck et al. [13], Tassitano et al. [182], and Barbossa et al. [10] suggest that structured settings have the ability to promote PA, however these periods of promotion are often interspersed with time spent in SB. Additional factors influencing children and adolescents' PA and SB during the school day must therefore be considered.

In addition to the role that the organizational structure of a day plays on children and adolescents PA and SB engagement, the amount of time spent outside has been shown to have a strong positive association with PA accumulation throughout the day. Lee and colleagues [102] conducted a review focused on time outside and play among a cohort of children between 3-12 years. It was found that individual factors of sex, race/ethnicity, and age, parental factors including attitude, support, and parenting practices, proximity to outdoor spaces, and seasonality all acted as significant correlates to the likelihood of children and adolescents engaging PA outside. These findings were reinforced by those of Schaefer et al. [169], who found that children who spent the majority of their after-school time outside participated in significantly more MVPA (61.0 vs. 39.9 min/day), spent less time engaging in SB (539 vs. 610 min/day), and were 2.8 times as likely to achieve the recommended 60 minutes of MVPA per day compared to children who spent no time outside after school. Similar results were also found in a longitudinal study conducted by Nigg and colleagues [129]. Among a sample of German youth, time outside was positively related to lower levels of SB, and higher MVPA, with children spending two or more hours outside receiving the greatest benefits (SB: -17.8 min/day; MVPA: 3.9 min/day). Additionally, boys and younger children were found to engage in greater levels of MVPA outside compared to girls and older children, respectively. While outdoor time is typically limited during the school day, findings from these studies suggest that the incorporation of more time outside may act as a reinforcing factor to encourage children's engagement in PA.

While many factors contribute towards children and adolescent's engagement in PA and SB, schools continue to present a setting in which alterations to the structured environment and the incorporation of more active approaches to education, can improve children and adolescent's activity profiles. Through repeated exposure to these opportunities throughout the school year, the promotion of healthy activity behaviors increases the likelihood of their eventual adoption and maintenance in the support of positive health outcomes early in children's life.

Benefits of Physical Activity

Children and adolescents who regularly meet the PA recommendations have been shown to benefit both physically and mentally. Often considered a primary approach to achieving or maintaining good health, the regular engagement in PA supports children and adolescent's physical health by improving cardiorespiratory fitness [148], muscular strength and endurance [45], bone strength [181], and supports reductions in excess adiposity [74]. Furthermore, engagement in PA reduces the risk of developing chronic disease risk factors, including hypertension, dyslipidemias, insulin resistance, and poor glucose regulation [96, 137]. Regular engagement in PA has also been shown to support mental and cognitive health through better academic performance and executive function [168], while reducing symptoms of depression and other mental health conditions in children and adolescents [109, 137]. Finally, compared to a physically inactive child who does not regularly meet recommendations, active children experience a higher quality of life, and increased likelihood of growing into an adult who also engages in regular PA and other positive health behaviors [66, 94, 180].

Effects of Sedentary Behavior on Health

The health effects which children and adolescents experience as a result of excess SB are distinct but additive from those experienced through physical inactivity [170]. In this sense, the health impacts from both physical inactivity and SB are compounding in the burden they place on an individual's health. Coupled with increasing levels of SB with age, the means by which Western society promotes and enables a sedentary lifestyle make it crucial to focus on children's SB habits from a young age, including the total time individuals spend engaging in SB per day, and the length of each bout of SB spread throughout the day. In children and adolescents, excess SB is associated with increased adiposity [3, 81, 202], cardiometabolic health risk factors [130], and decreased cardiorespiratory [49, 192] and muscular fitness [38, 68]. SB, and specifically screen time, along with their associated physical health impacts also have a psychological and emotional influence on children and adolescents. Individuals who engage in excess screen-based SB are more likely to display behavioral issues [80], experience lower self-esteem [26, 88], and have lower levels of academic achievement [22, 158, 172].

With the many negative health effects associated with excess SB, it is important to recognize that individuals of all ages are becoming increasingly technology-driven, and therefore potentially more sedentary across the day. In fact, in 2019 a non-profit organization named

‘Common Sense Media’ sampled “tweens and teens” (8-12 years and 13-18 years, respectively) amount of daily recreational screen use and found that on average “tweens” consumed approximately 4.75 hours of media per day, while teens nearly doubled this at approximately 7.33 hours per day engaged with non-school related screens. Additionally, roughly 19% of 8-year-olds and 69% of 12-year-olds now report owning a smartphone [154]. While physical inactivity among today’s youth remains a top concern, the rapid rise in screen-based leisure and school-related time and its relationships with SB must be considered when addressing children’s health behavior habits in the promotion of long-term behavior adoption during childhood.

Measuring Physical Activity & Sedentary Behaviors of Children & Adolescents

Outside of a controlled laboratory setting, the ability to accurately and reliably measure children’s daily PA and SB is necessary to understand the influence of the environment, and its impact on the health of a child. However, accurate and reliable assessment of activity and SB is not an easy task, and it is important to ensure that assessment strategies are feasible and non-intrusive to promote maximal compliance from participants. Additionally, the sporadic nature by which children and adolescents tend to engage in PA, through short bursts rather than sustained bouts, adds complexity to accurate assessment [8]. Within the following section, two broad approaches in the assessment of children’s PA and SB will be explored: objective and subjective measurement. In PA and SB research, objective measurements, such as accelerometry and direct observation, refer to the direct assessment of one or more dimensions of PA (ex. frequency, intensity, time, or type) through the capture of various metrics including step counts, activity bouts and intensity, and activity time. Subjective measures, such as self-report and proxy-report surveys, rely on individuals or caregivers to record or recall an activities occurrence and accurately describe the context surrounding specific events taking place [178].

Objective Measures

Accelerometry

Physical Activity and Sedentary Behavior Assessment

Accelerometers are currently one of the most widely used objective measures for capturing children's PA and SB [29], with ActiGraph brand devices outpacing competitors in their use, validity, and reliability within published research [46]. Accelerometers are small, externally worn devices with the ability to capture multidirectional movements and the acceleration (intensity) in the direction in which these movements occur. In their assessment of PA, accelerometers provide a valid measure of total activity, as well as patterns and intensities in which activities occur [161].

In order to collect the most valid and reliable data, there are a number of parameters to establish prior to measurement: placement on the body, sample frequency, epoch length, wear-time, non-wear determination, and categorization of intensity of activity.

Placement on the body. The location in which these devices are worn by a participant influences the types of movements captured, with the most common wear location being the waist in order to capture full-body accelerations [188]. Other accelerometer placements include the wrist, ankle, and thigh; however, these have not been validated to the extent which research involving accelerometer wear at the waist has [21, 131].

Sample Frequency. During their initialization, accelerometers must be set at a predetermined sampling frequency based on the complexity of movements to be captured.

Higher frequency sampling will result in the capture of shorter bursts of activities and movements compared to lower frequencies. Typical sampling frequencies used in children range from 10 Hz in older accelerometer models to 30 Hz or more in newer models, which have the ability to sample up to a maximum of 100 Hz.

Epoch. In capturing directional movements at a set sampling frequency, the data which accelerometers collect yields raw accelerations which are indicative of the intensity of movement in any given direction(s). During analysis of accelerometer data, raw acceleration values can be used without modification, or can be computed into "counts". These counts can be summed across set time periods termed epochs. Epochs can range in length from 1-60 seconds. Shorter epoch lengths provide a more accurate estimation of the intensity of shorter bouts of activity, which is ideal for the analysis of children's PA behaviors [131]. During movement, the magnitude of counts in an epoch determines the intensity of acceleration, therefore indicating time spent at various intensities of PA [36].

Wear-/Non-Wear Time and Valid Days. Accelerometers can be used for a variety of research in free-living environments. When used in free-living settings, it is important that accelerometers collect sufficient data to reflect a participant's habitual levels of PA and SB for the research setting they are in. Multiple factors must be considered when deciding if a behavior has been captured, including the total number of days recorded, the amount of time recorded each day, and the proportion of days making up wear- and non-wear time.

Selecting the appropriate number of days to record participants' behavior is important to capture the day-to-day variance in PA and SB levels. Trost et al. [190] measured the total daily PA and SB of 381 children and adolescents (grades 1-12) for seven consecutive days. It was found that seven days of monitoring resulted in acceptable between-day reliability coefficients

(ICC = 0.76-87) while accounting for weekday and weekend differences in activity levels, however this varied by age group. Among children in grades 1-6, it was estimated that between 4-5 days would provide sufficient evidence of habitual behaviors (ICC = ≥0.80), while adolescents in grades 7-12 were estimated to requires 8 to 9 days of valid wear time to reach an intraclass correlation coefficient of 0.80 or higher.

Within each day, accelerometers must be worn for an appropriate amount of time to reflect the behaviors they aim to capture, referred to as a valid day. Determination of a valid day is typically done by wearing a device for a minimum number of waking hours, however when sampling a specific period of time in a day, valid wear-time can also be based on a proportion of that period in which a sufficient number of participants provide data. Among a sample of 7,705 children asked to wear an accelerometer across all waking hours for seven consecutive days, Rich and colleagues [151] found that a minimum of 10 hours per day provides the greatest reliability (r = 0.86) indicative of a valid day and encompassing most waking hours. In assessing specific periods or events within a day, Catellier et al. [30] proposes a '70/80' approach, in which a valid day can be defined by a measurement period where at least 70% of participants provide recorded data, and therefore 80% of that measurement period constitutes a minimal valid day.

In the determination of a valid day when using accelerometers for research, periods of device non-wear must also be considered. Modern accelerometers use two functions to estimate periods of non-wear, including device position (based on the inclinometer function and explained in further detail under *Postural Assessment*) and consecutive minutes of zero-counts. Wear log diaries are an additional means by which participants can be requested to record periods of device wear and non-wear throughout the day. The time at which the device is put on in the morning and taken off at night, or times throughout the day when the device is not worn, such as during water-based activities or when the participant forgets to put on the device, provide researchers with a timeline of events to aid in their data analysis. Vanhelst and colleagues [194] assessed seven algorithms to determine non-wear time among a sample of 77 adolescents between 10-17 years of age. It was found that the choice of defining non-wear time by length of continuous consecutive zeros can have a significant impact on total recorded sedentary time in youth, and the recommendation to use an algorithm for 30-minutes of consecutive zeros to identify non-wear time in youth was ideal for the accurate estimation of total time sedentary compared to total wear time.

Cut-Points. To date, the most common presentation of accelerometer-recorded PA data is through the use of cut-points (CP) to indicate PA intensity ranging from sedentary, to light-, moderate-, and vigorous-intensity. CP categorization of PA intensity relies on accelerations measured through the accelerometer's vertical axis or in tri-axial models, based on an amalgamation of the vertical (up-down), longitudinal (forward-backward) and lateral (left-right) axes, termed vector magnitudes [103]. Multiple CP values have been developed, each with different CPs for each intensity category threshold. This causes confusion for researchers because different CP thresholds will alter the way in which recorded data is interpreted. Furthermore, the categorization of SB as distinct from periods of non-wear and light-intensity PA is important to fully understand the behavioral profile of children and adolescents.

Among the ActiGraph family of accelerometer models, multiple youth CP calibration studies have been conducted seeking to establish means to accurately describe participants time spent engaging in various intensities of PA and SB. Calibration studies use a criterion measure, often direct or indirect calorimetry, as an estimate of energy expenditure relative to the counts accumulated during activities performed at various intensities.

Evenson and colleagues [56] conducted a calibration study involving 33 children between 5-8 years who were asked to wear an ActiGraph accelerometer (model 7164) on the right hip and perform a series of activities while also wearing a portable metabolic unit. Activities ranged in intensity, and included time resting while seated, coloring books, walking at a slow and brisk pace on a treadmill, running on a treadmill, and a variety of other activity behaviors in a controlled setting. Collecting accelerometer data at a sampling frequency of 10 Hz over 15-second epochs, summed activity counts were compared to 15-second intervals of indirect calorimetry to determine the relationship between accumulated counts and energy expenditure. For this study, total counts occurring over 15-second epochs were summed into 60-second epochs, or counts per minute (cpm), and PA intensity levels were determined to be ≤100 cpm for SB, 101-2295 cpm for Light-Intensity PA (LPA), 2296-4011 cpm for Moderate-Intensity PA (MPA), and ≥4012 cpm for vigorous-intensity PA (VPA).

Among a sample of 50 preschoolers between 3-5 years, Butte et al. [28] conducted a similar calibration study using an ActiGraph accelerometer (model GT3X+) worn on the right hip, and compared activity counts during a set of structured activities to a room respiration calorimeter. While wearing an accelerometer, participants were placed in a room which measured oxygen consumption and carbon dioxide production through respiration, without requiring the participant to wear additional equipment such as with the use of portable metabolic devices. Among children, this approach can prove less burdensome than indirect calorimetry to the participant, therefore eliciting behaviors that may be less influenced by unfamiliar and potentially cumbersome equipment. Age-appropriate activities including coloring, watching television, playing with toys, performing aerobic activities, and napping were measured. Additionally, children were provided opportunities to engage in periods of free play while being measured. A second arm of the study among 105 children between 3-5 years involved the collection of wear data across seven consecutive days in free-living conditions compared to a criterion measure of energy expenditure using doubly labeled water. Resulting CPs from these two assessment periods were summarized using both counts per minute (cpm) based on the single vertical axis measurement, and as vector magnitudes. For preschool children, Butte et al. [28] classified activity level CPs based on a single vertical axis as <240 cpm (SB), 240-2119 cpm (LPA), 2120-4449 cpm (MPA), and ≥4450 cpm (VPA). Using vector magnitudes, intensity levels were classified as <820 cpm (SB), 820-3907 cpm (LPA), 3908-6111 cpm (MPA), and ≥6112 cpm (VPA). When using vector magnitudes, cpm is higher due to the accumulation of counts across three axes of measurement as opposed to the single vertical axis used in uniaxial accelerometers.

CP values have been presented in formats which are both age-specific and applicable across all age groups. New calibration studies continue to be published as consensus remains to be reached about the appropriate application of CP, or other analytical approaches to assessing children and adolescent's activity intensity behaviors. While studies comparing the accuracy of CP's used in research are limited, efforts have been made towards standardization. In defining SB, Trost and colleagues [187] compared five published CP among a sample of 206 youth between 5-15 years. While wearing a portable metabolic unit, participants engaged in a number of structured activities. Results revealed that a commonly used CP of 100 cpm to indicate SB yielded a strong level of accuracy in both identifying periods of SB (sensitivity = 100%), and not falsely identifying periods of non-SB as SB (specificity = 79.0-79.4%). Some researchers have indicated that a higher CP may be necessary to distinguish between SB and LPA, however Trost and colleagues [187] have cautioned that a CP value that is too high is more likely to mis-classify LPA as SB and therefore negatively influence total PA levels recorded. A summary of accelerometer CPs developed using ActiGraph devices, their wear location, sampling frequency, selected epoch, and criterion measure used for calibration can be found in Appendix A.

Postural Assessment

While the primary use of accelerometers continues to be for the assessment of PA and SB, the ActiGraph GT3X+ tri-axial monitors contain an inclinometer, which allows the assessment of postural behaviors (standing, sitting, and laying down). Using the directional force of gravity relative to device positioning, the inclinometer calculates postural position based on two angles, the offset angle from the direction of gravity (y-axis) and a non-wear-specific angle which differentiates the device not being worn from laying down (z-axis). The calculation of these angles however is highly dependent on correct wear location at the waist, and the "appropriate" assumption of posture falling within the ranges of angular estimation. The ranges by which the ActiGraph inclinometer calculate posture include y $<17^{o}$ for standing, y $>17^{o}$ and y $<65^{o}$ for sitting, and y $>65^{o}$ for laying down (unless Θ_z is $<22^{o}$, indicating non-wear). Additionally, when activity counts exceed six per second (>100 cpm), devices assume a standing posture due to the presence of recorded movement [125]. Through the analytical software ActiLife (ActiGraph LLC., Pensacola, FL), it is possible to modify the preset optimal angle thresholds to fit the specific needs or findings of a research topic.

Limited research has been conducted assessing the validity of the ActiGraph GT3X+ inclinometer function in the measurement of posture among children and adolescents. Among a cohort of adolescents in a controlled laboratory setting, the inclinometer function of the GT3X+ was found to correctly classify standing 20% of the time, laying down 15% of the time, sitting 94% of the time, and when the device was not worn 45% of the time [71]. A second study assessing the ability of the inclinometer to assess time spent in SB using structured and free-living activities found that the GT3X+ was able to correctly classify laying down 45% of the time, sitting 54.6% of the time, and walking/running >96% of the time [43]. Although differing, these findings, particularly among a limited sample of adolescents, suggest that the most promising utility of the ActiGraph GT3X+ accelerometer inclinometer function may be in the assessment of seated postures, such as those that occur in structured settings like schools.

Direct Observation

Direct observation (DO) is a well-established approach in behavioral research [85] and continues to be widely used across scientific fields to date. When conducting direct observation, a trained researcher will typically observe the behaviors of a specific individual from a distance and without intrusion or distraction. Observers will document the behaviors that a participant engages in as they fit within the a priori-determined scope of research. Multiple methodologies exist for direct observation, broadly categorized as naturalistic or systematic in their approach [76]. Naturalistic observations refer to those made in a specific setting (ex. classroom, at recess, in the home), with no pre-determined behaviors being sought out. Instead, observers keep a record of witnessed behaviors which are deemed important, and the context surrounding their occurrence. Systematic approaches to DO involve seeking out specific behaviors through rigid methods which do not vary between observers and those being observed over time [76].

DO is often used in research to assess children's free-living activity behaviors and has previously been identified as a criterion measure for categorizing children's PA [175]. Observational systems have been developed for both site-/population-specific (ex. in a classroom, during physical education class or recess) and multi-site settings (ex. for use at school, at home, and in indoor/outdoor settings). To date, multiple DO techniques have displayed inter-rater reliability and validity against a standard criterion measure. Puhl and colleagues [146] developed the 'Children's Activity Rating Scale (CARS)', which involved the use of a 1-minute time sampling approach to categorize PA intensity on a 5-level scale. While undergoing a battery of activity behaviors in a controlled laboratory setting, a sample of 25 children between 5-6 years were observed while having heart rate (HR) and oxygen uptake (VO_2) recorded. Results from this study found significant differences in measured HR and VO_2 between activities performed at the 5-levels of the rating scale. Additionally, inter-rater reliability using CARS was found to be acceptable at 84.1%. Similarly, the 'System for Observing Fitness Instruction Time (SOFIT)' validity and reliability has been evaluated in multiple studies. McKenzie et al. [118] utilized SOFIT to assess 88 physical education classes for children between grades 3-5. SOFIT involves the use of a 10-second momentary sampling technique and a 5-category PA scale representing different intensity levels of movement during the observation period. Inter-rater reliability was between 88.3-91.8% and validity was established based on correlations between observed behaviors and class-time allocated to fitness instruction. SOFIT displayed acceptable negative correlations to class-time spent standing ($r = -0.645$), weak to moderate correlations to class-time spent walking and very active ($r = 0.488$ and 0.360), respectively, and an acceptable correlation to class-time spent in MVPA ($r = 0.685$). These findings were reinforced by Rowe and colleagues [159], who validated the SOFIT instrument amongst a large cohort of physical education class periods (n = 173) involving children in grades 1-8. For this study, the criterion measure was HR and it was found that SOFIT categories indicating activity intensity levels between 2-5 witnessed a distinct increase in HR, while the lowest levels reflecting SB while laying down or sitting, did not provide differences in recorded HR. A summary table of validated DO measures can be found in Appendix B. Much like with accelerometer CP, researchers encourage the adaptation or modification of previously published and validated instruments in future research, as opposed to developing a new system that may not be comparable to previous work [117].

An advantage of DO as a measure of PA and SB is that it allows for an observer to collect context-specific information surrounding an individual's behaviors, such as the type of PA being performed, and the social and environmental factors surrounding the observed behaviors [140]. Alternatively, the conduction of DO can be burdensome to researchers and may influence children's behaviors. For researchers, DO can require a large time commitment for both training and execution of the observations in real time, often involving multiple research team members conducting multiple observations over a period of time. DO has shown to be feasible across multiple settings outside of the typical school, including in pre-school and in the home setting [25, 115]. The burden on participants is also a concern, including the potential distraction of children from engaging in normal activity behaviors. Beyond anecdotal evidence, limited studies have reported on child-observer interactions, however in a study conducted by Puhl and colleagues [146] it was found that among a sample of children between the ages of 5-6 years, participant interaction with observers occurred just 16.6% of the time. Across research involving different age groups of children, it has been suggested that younger children might perceive observers and other research assistants present at the time of data collection to be playmates or babysitters, and therefore want to engage with them to a greater extent than older children [89, 117]. This requires an observer to be aware of and minimize the influence they may exert on participants being observed.

For the conduction of DO, observers typically select from pre-determined context-specific behaviors likely to occur during a set period of observation time. In this way, observers have the means to record activity type, intensity, environmental cues, social cues, location, and prompts contributing to behavior actions [140]. In combination with other measurement approaches, such as accelerometry or inclinometry, DO also has the potential to be modified to capture the anticipated context of the behaviors being recorded. This might include modifying an observational system to incorporate posture-related behaviors, or behaviors anticipated to occur within a structured setting such as a classroom, associated with, but unrelated to PA, such as attentiveness or fidgeting.

Subjective Measures

Self-Report

Traditionally collected in a survey, interview, diary, or log format, self-report measures request that respondents recall or report specific activities or behaviors in which they have engaged. The primary strength of self-report measures is their ease of distribution to a relatively large participant pool at a lower cost than objective measures. At the same time however, self-report measures are also limited by question item interpretability, participant recall, and social desirability bias [106]. Additionally, self-report measures are often only able to capture item-specific activities and behaviors, while failing to measure total daily PA and SB outside of the domains of assessment.

Children tend to engage in brief, sporadic bursts of PA mixed with periods of inactivity and SB. Because of this, recalling specific PA behaviors in sufficient detail can prove difficult in this age group [114], and similar to adults, children frequently overestimate time spent engaging in PA when using self-report measures [82]. Compared to children, adolescents have been shown to perform slightly better in using self-report measures on PA and SB, suggesting that children's PA behaviors are better measured through caregiver proxy-reporting or objective measurements [9, 167].

Due to the difficulties for children and adolescents when using self-report measures for recalling physical activities and SB, few have received widespread support from experts. Seven considerations in the development and application of self-report measures for children and adolescents have been recommended: 1) What domains of PA are being assessed?; 2) Does the instrument assess the frequency, intensity, duration and type of activity?; 3) Does the instrument assess the temporal dimension of PA?; 4) Over what period are participants being asked to recall their activity?; 5) Is the instrument suitable for the age group it is aimed at?; 6) Is the instrument appropriate in respect of ease of completion and participant burden, given that large samples will be required to be tested for population prevalence and surveillance?; and 7) Is the instrument suitably valid and reliable? [47]. Keeping these considerations in mind, Biddle and colleagues [19] recommend three self-report measures for population-level surveillance of children and adolescents' PA: 1) Physical Activity Questionnaire for Children/Adolescents (PAQ-C/PAQ-A), 2) Youth Risk Behavior Surveillance Survey (YRBSS), and 3) the Teen Health Survey. The use of self-report surveys for the accurate assessment of youth PA and SB continues to be of importance to researchers studying the health of this population. Advancements on the recommendations made by Biddle and colleagues [19] are ongoing, however one such assessment tool which has been developed more recently as a means to estimate children and adolescents PA and SB levels throughout the school week is the 'Youth Activity Profile' [164].

Youth Activity Profile

The Youth Activity Profile (YAP) assessment tool was developed from the PAQ-C/A and is a low-cost, simple, 15-item questionnaire which requests participants to perform a 7-day recall of: 1) activity at school, 2) activity out-of-school, 3) activity on the weekends, as well as 4) sedentary behaviors occurring throughout the week. The YAP has undergone extensive calibration [57, 163-166, 196], has been validated among children in grades 4-12 [57, 83, 164, 165], and takes approximately 7-10 minutes to answer all 15-items in the questionnaire.

Each item in the YAP questionnaire refers to specific types of activities or behaviors which typically occur during the specified periods of the day or week. For in-school physical activity (PA), questions ask about active transport to- and from-school, physical education (PE) class, activity during the lunch period, and recess. Active transportation to- and from-school are included as part of the in-school period because these opportunities for PA immediately before and after school would not otherwise take place if not for school being held on that day. For PA out-of-school, activities covered include the before school period (not including transportation to school, or activity at school), activities immediately after school (following the transportation to home period), activities occurring in the evening, as well as those occurring on each weekend day. The final outcome measured is sedentary habits, which include questions related to time spent during the week, outside of school, engaging in screen related behaviors (TV, video games, computer, and cell phone use).

The evolution of the YAP began in 2014, when Saint-Maurice and colleagues [163] conducted a calibration analysis between children's objectively measured PA behaviors and the Physical Activity Questionnaire (PAQ). The PAQ is a short-form self-report instrument from which the YAP was ultimately developed, with a primary limitation of the PAQ being a lack of sedentary behavior (SB) assessment. Calibration of the PAQ involved an initial 7-day monitoring period in which participants were asked to wear an Actigraph GT1M accelerometer at the waist, followed by completion of the PAQ-C(hild) or A(dolescent), which requests responders to recall their PA behaviors over the previous 7-days. In total, 148 participants from 4th-12th grade met accelerometer wear time compliance prior to completing the PAQ. The PAQ was scored, and multiple linear regression modeling was applied to 70% of the available sample, while the remaining 30% were used for cross validation of the developed regression equations. Overall, regression equations inclusive of age, sex, and PAQ scores was found to explain 40% of the variance in the percentage of time that participants spent in moderate- to vigorous-intensity PA (MVPA), as measured by the waist-worn accelerometer. When these regression equations were applied to the remaining 30% of the study sample, it was found that the regression model was moderately correlated ($r = 0.63$) with the accelerometer measured PA of the subsample of respondents, while the mean difference in estimated and recorded PA values was not significant (diff = 25.3±18.1min; $p = 0.17$). While these results displayed a promising approach to increasing the utility of self-report instruments in PA research, a limitation of the PAQ was that it did not assess SB, which makes up a significant portion of daily activity behaviors, ultimately leading to the development of the Youth Activity Profile (YAP).

Following the development of the YAP, a calibration and validation study employing a similar methodological approach to that used by Saint-Maurice and colleagues in their 2014 publication was conducted. Saint-Maurice and Welk [164] measured the PA and SB of 291 children in grades 4-12 using an accelerometer worn on the arm for seven consecutive days (SenseWear Armband, BodyMedia Inc., Pittsburgh, PA), across two separate weeks that were separated by 5-7 days. At the end of each week of accelerometer measurement, participants completed the YAP. Using the first measurement period for calibration, quantile regression equations were developed with item-specific YAP scores, along with age, and sex, as independent variables, and the daily proportion of time spent in MVPA or SB as the dependent variable. The second week of accelerometer and YAP assessments were then used to cross-validate the final regression equations and predict the proportion of daily time spent in MVPA and SB. For time spent in MVPA, it was found that the YAP attained a low to moderate correlation ($r = 0.19$-0.58) with the arm-worn accelerometer at the individual-level, while at the group-level YAP predicted estimates of MVPA were within 15%, 20%, and 30% of accelerometer measured MVPA for in-school, out-of-school, and weekend periods, respectively. For time spent engaging in weekday out-of-school SB a stronger correlation between YAP estimated and accelerometer recorded values was found ($r = 0.75$), while group level estimates of SB were found to fall within 10% of objectively measured SB.

Saint-Maurice and colleagues [165] performed a follow-up validation study in which adolescents in grades 7-12 again completed the YAP following a seven-day monitoring period in which an accelerometer was worn at the dominant wrist (Actigraph GT3X+). Researchers once again followed the same calibration/validation approach, however calibration for each period of the week measured (in-school, out-of-school, weekend, and sedentary behaviors) was conducted using independent samples of students. To assess validity, the final equations developed through multiple regression modeling were again applied to independent samples within each period of the week measured. Overall, it was found that the predicted values derived from YAP responses input into the developed regression equations, were once more within 10-20% of those measured by an accelerometer worn at the wrist.

In addition to the work conducted by Saint-Maurice and colleagues, calibration and validation studies have also been conducted abroad. In England, Fairclough and colleagues [57] performed their own calibration and validation of the YAP specifically focused on English youth. Following a similar methodology as previously described, 402 participants between the ages of 9-16 years wore a SenseWear Armband accelerometer for 8 consecutive days, before completing the YAP on the 8^{th} day. Researchers then divided the sample, using one sub-sample of participants to develop calibration algorithms through multiple regression modeling, before applying these developed equations to a second sub-sample of participating children. Results showed that predicted YAP values fell within 15-20% of objectively measured MVPA and SB across all periods of assessment, similar to previous validation studies by Saint-Maurice and colleagues [164, 165]. A second international validation study was conducted in the Czech Republic by Jakubec and colleagues [83], in which 567 youth between the ages of 12-16 years wore an accelerometer on the non-dominant wrist for seven consecutive days before completing the YAP. In this study, the regression equations developed by Saint-Maurice and colleagues [165] were applied to the YAP data, as a means to assess whether a survey developed in the United States, and the resulting algorithms, apply to a sample of Czech youth. The correlation between accelerometer recorded MVPA and SB and YAP estimated values ranged between 0.23-0.58. Finally, it was found that among the sample of Czech youth, the YAP better estimated the PA behaviors of respondents on weekdays compared to weekends, among older compared to younger responders, and among girls compared to boys.

Since its initial calibration and validation, the YAP continues to be refined, most recently through the development of activity-specific (i.e. recess, PE, transportation to/from school, etc.) regression equations [196], as opposed to combining activities within periods of the day (i.e. in-school, out-of-school, weekend, etc.). In this most recent study, elementary (n=374), middle (n=224), and high-school (n=119) aged students from 33 schools across two states wore a SenseWear Armband accelerometer for 7-consecutive days before completing the YAP online. Additionally, for calibration purposes, data was collected across different seasons and geographical regions throughout the school year. Utilizing the updated item-specific regression equations, it was found that relative to previous calibration studies, the mean absolute percentage error (MAPE) between YAP estimated and accelerometer measured activity behaviors were lower overall at 23.2% (updated; 25.6% original), 21.0% (27.8%), 17.1% (27.1%), and 8.4% (7.5%) for in-school PA, out-of-school PA, weekend PA, and weekday out-of-school SB, respectively.

Overall, the YAP presents a valid, low-cost, simple questionnaire, providing the opportunity to assess youth PA and SB while placing a minimal burden on participating students and teachers. For access to a complete copy of the Youth Activity Profile and instructions on scoring the survey, please refer to Appendix C and Appendix D, respectively.

Nature-Based Education & its role in Children’s Physical Activity & Sedentary Behaviors

There is a growing body of literature which suggests that today’s children are spending significantly less time outdoors than previous generations [12, 195]. PA occurring outside, particularly in a natural setting, has been shown to promote children’s mental health and wellbeing, resilience, and reduce the risk of developing chronic conditions such as type 2 diabetes mellitus and obesity [110, 123, 144, 145]. Not only are indoor spaces more often associated with SB, but evidence is emerging that children's active play is also becoming more structured and increasingly occurring indoors [12, 77-79]. Beyond this, certain behaviors may be perceived as indoor-specific, such as watching TV, doing art, and reading, which draw children inside and tend to be sedentary by nature [100]. Overall, multiple factors including a prioritization on academic achievement [174], an increase in extracurricular activity involvement [98], concerns for child safety [63], and the evolution of media consumption among youth [177] have all contributed to a shift in children's leisure-time activity behaviors trending towards time spent indoors and being more sedentary.

With an increasing number of leisure-time activities taking place indoors, coupled with a traditional school system in which children spend upwards of 6 hours per school day in classroom focused SB [52], children are currently spending the majority of their waking hours indoors engaging in SB. Nature-based education presents an alternative approach to education in which nature and the outdoor environment are at the center of learning. Furthermore, this alternative approach to education addresses many of the emerging barriers children experience towards time spent outside, including a continued focus on academic achievement, a semi-structured safe space for children to engage in PA outdoors under the supervision of a teacher(s), and the ability to control children's consumption of media throughout the school day [105, 134, 141]. Limited evidence exists however as to the effectiveness of nature-based education on substantially moderating children's in-school PA and SB levels while maintaining educational expectations.

Time outside may itself be described as a positive health behavior, due to its consistent association with increased levels of PA and decreased time spent engaging in SB among children at both the acute and habitual levels [67]. Furthermore, nature-based activities have been shown to provide a more "whole-child" approach to the encouragement of physically active behaviors, by encouraging both active and less-active children to indirectly engage in physically active behaviors. In a study conducted by Herrington and Brussoni [73], it was found that natural play spaces provide diverse opportunities to engage in PA, appealing to a larger proportion of children. Traditional playground spaces and other structured environments designed specifically for PA (ex. gymnasium) have been shown to alienate less-active children who are not inherently motivated to participate in structured, physically active behaviors. Approaches to education which employ nature-based learning may provide multiple avenues for all children to be active in school, across all intensities of behavior [69]. While free play remains one of the largest contributors to PA during the school day, children attending nature-based educational programs may, as a class, also incorporate more walking and exploring of the natural environments into their learning time. This approach not only reduces time spent engaging in SB, but also has the potential to increase the amount of total cumulative time spent engaging in PA throughout the day for all students.

Looking specifically at the relationship between access to nature in educational settings and children's PA and SB, positive associations have been found. In a comparison study conducted by Lovell [107] children between the ages of 9-11 (n=26) spent time at both a typical school and a forest school, with typical school days being further split into active and inactive days based on whether children received scheduled opportunities for PA on those days. Overall, it was found that while attending the forest school participants engaged in 2.2 and 2.7 times more PA than during an active or inactive typical school day, respectively. At the forest school, this amounted to an average of 89.4 minutes of moderate- to vigorous-intensity PA per school day compared to just 29.1 minutes during an active typical school day, and 20.5 minutes on inactive typical school days. Furthermore, participating children engaged in significantly more bouts of PA lasting 5-minutes or longer at a forest school compared to a typical school, with more than 66% of participants engaging in at least one bout of moderate- to vigorous-intensity PA lasting 20-minutes or longer on one or more days in a forest school setting.

A similar study was conducted in England among a sample of 7-9-year-old children (n=59) who spent time engaging in weekly forest school sessions, and typical school days with or without physical education classes [184]. Among this sample, children were found to engage in significantly more light-intensity PA on forest school days compared to typical days without physical education (197.1 minutes/day vs. 173.7 minutes/day; p=0.005), however it was also found that the incorporation of a physical education class on a typical school day resulted in similar amounts of light-intensity PA accumulation as that of a forest school (198.9 minutes/day vs. 197.1 minutes/day). In this study, no significant differences in the accumulation of SB or moderate- to vigorous-intensity PA were found between forest school days, typical school days with or without physical education, or weekend days. It should be noted however, that the previous two studies were both conducted within the United Kingdom (UK), where forest schools have been popularized since the 1990's [42], compared to within the United States where nature-based education started becoming more widespread around the early to mid-2000's [20].

Implementing natural spaces into education on a smaller scale has also been shown to be an effective means by which children's activity levels might increase during the school day. Wells and colleagues [197] conducted a classroom garden intervention among a group of low-income schools in New York. Following the integration of a garden space into daily learning activities, it was found that children self-reported spending less time engaging in SB during the school day compared to before the garden became accessible. Additionally, accelerometer recorded PA revealed a greater increase in the percentage of school-time spent engaging in moderate-intensity and moderate- to vigorous-intensity PA when opportunities for students to use the garden setting were provided. Finally, direct observation of children's behaviors between garden-based lessons and indoor, classroom-based lessons revealed a greater amount of time spent moving, and less time sitting while in a garden setting. As the relationship between higher quantities of PA and improved academic outcomes continues to be challenged in the United States educational system through reductions in planned opportunities for PA throughout the school day, nature-based education promotes a means by which education and PA can occur hand-in-hand.

In a time where children are spending more time indoors throughout their days than ever before, both during structured periods such as the school day and unstructured leisure-periods, nature-based education presents a promising means by which children can be provided with access to, and the mental and physical benefits from, time outside. More research is necessary however, to continue building a body of literature promoting means by which children, particularly in the United States, can both receive exposure to outdoor time in natural spaces, and continue supporting the learning and academic goals set by school leaders.

Conclusion

In summary, children and adolescents are struggling to meet the PA and sedentary guidelines for health enhancement. While efforts must be made across the entire day to improve these behaviors, the school setting presents a meaningful location in which modifications to the traditional classroom and school environments throughout the school year, may influence children and adolescents to reduce total daily SB and simultaneously increase PA levels. Evidence has pointed towards the benefits of breaking up prolonged periods of sitting, however it is imperative that the measurement of these behaviors is accurate. Furthermore, understanding factors associated with the variation of children and adolescents PA behaviors during the school day can provide insight into specific periods in which PA promotion can be enhanced in schools. Finally, with the emergence of nature-based schools in the United States, further research is necessary to improve our understanding of the relationship between PA and education in this unique setting. The long-term goal of this dissertation is to establish a line of enquiry that contributes to the growing body of literature surrounding the impact that the educational environment has on children's PA and SB.

CHAPTER 3: COMPARISON OF MEASURES OF ELEMENTARY STUDENT'S CLASSROOM POSTURAL BEHAVIORS USING DIRECT OBSERVATION AND ACCELEROMETRY IN A SCHOOL SETTING

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Abstract

Purpose: The purpose of this secondary analysis was to compare hip-worn accelerometer-inclinometer (ACC) and direct observation (DO) measurements of posture among a sample of elementary students assigned to use either a traditional seated or stand-biased desk in the classroom. **Methods:** Sixty-eight 3rd, 4th, and 6th grade students wore an Actigraph GT3X+ accelerometer-inclinometer on the hip and simultaneously underwent DO while using either a traditional seated or stand-biased desk in the classroom. On three separate occasions per measurement period, participants postural behaviors (standing, sitting, lower limb fidgeting) were observed for 5-seconds once every 30-seconds for a total of 5-minutes. ACC inclinometer measurements of standing and sitting were aligned with each 5-minute DO period. Time participants spent engaging in postural behaviors were converted to proportions (%) of total time observed across each measurement period. Statistical analyses were performed using a significance value of $p<0.05$. Significant differences between DO and ACC measurements of posture were assessed for using Wilcoxon Signed Ranks tests. Additionally, mixed effects modeling was performed to estimate the effect of desk type and lower limb fidgeting on differences between DO and ACC measurements of posture. **Results:** While using a stand-biased desk, there was a significant ($p<0.001$) difference in the proportion of time participants spent sitting (DO – ACC; 18.7%) and standing (-19.7%) between DO and ACC. In a traditional seated desk, significant differences ($p<0.001$) in the proportion of time participants spent sitting (30.2%) and standing (-25.6%) between DO and ACC were also found. Results of a mixed effects model found that the difference between DO and ACC measures of sitting was significantly smaller (-18.9%; $p=0.041$) when students were in a stand-biased compared to a traditional seated desk, and lower limb fidgeting was found to have no main effect ($p=1.000$) or

interaction effect with desk type (p=0.644) on the difference between measures of sitting. There were no significant main or interaction effects between desk type and lower limb fidgeting on the difference between DO and ACC measures of standing. **Conclusion:** Our results suggest that the difference between DO and ACC measurements of postural behaviors were significantly smaller when participants were assigned to a stand-biased compared to a traditional seated desk. While postural measurements made by ACC remained relatively stable between desk types, DO estimates of sitting increased, while estimates of standing decreased, when students were observed using a traditional compared to a stand-biased desk in the classroom. The tools we use to measure changes in PA or SB can influence the results of the intervention. Therefore, there remains a need to further examine differences between methods of measuring youth activity behaviors in a school setting, particularly when environmental modifications are introduced which alter the traditional understanding of a school and classroom setting.

Introduction

Children and adolescents are currently spending the majority of their waking hours each day engaging in sedentary behaviors (SB), with those between 6-11, 12-15, and 16-19 years of age spending an average of 6.1, 7.5, and 8.0 hours per day in SB, respectively [139]. During the school week where children and adolescents are spending on average approximately 6-hours per day in a school setting, it has been estimated that more than 75% of this time is typically spent sitting [153]. These high levels of sedentary behavior have a negative impact on health. Excess SB among children and adolescents has been associated with a number of physical consequences, including increased adiposity [3, 81, 202], cardiometabolic health risk factors [130], and decreased cardiorespiratory [49, 192] and muscular fitness [38, 68]. Excess SB has also been associated with children and adolescents' mental health, including an increased prevalence of behavioral issues [80], lower self-esteem [26, 88], and lower levels of academic achievement [22, 158, 172]. Moreover, the negative impacts of SB among children and adolescents have been found to be independent of the quantity of physical activity (PA) these individuals engage in, and the associated health benefits provided [170].

While much of the school day is spent engaging in SB, this time largely aligns with periods in which learning takes place in the classroom. With performance on learning-based assessments being a primary outcome by which students, teachers, and administrators are measured and funding is allocated, the suggestion of less time being spent in the classroom to provide greater opportunities for physical activity (PA) may not be feasible. Instead, research has increasingly looked towards innovating the classroom experience to break up extended periods of SB without sacrificing time spent learning. One such approach being explored is through the incorporation of stand-biased desks into the classroom. Stand-biased desks are height-adjustable workstations that, when set at an appropriate height for a student, allows them to stand, or sit on an accompanying stool, to complete work in the classroom. Additionally, a "fidget bar" is attached to the legs of the desk to provide students a place to rest their feet while using the elevated stool, or to rest an individual foot while standing. In contrast to a traditional seated desk, the stool which accompanies stand-biased desks is elevated so that users feet cannot touch the ground when in use, and does not possess a back rest to lean against. Through the incorporation of stand-biased desks into the classroom, students are provided with the opportunity to break up long periods of sitting in the classroom without teachers needing to sacrifice time for learning. To date, studies involving the use of standing desks in the classroom have reported positive findings in sitting and standing behaviors [5, 39, 40, 75, 90, 179], energy expenditure [15, 17, 18], postural improvements during use [16], and improved cognitive function [48, 122], however the methods by which these outcomes have been assessed have varied considerably.

Accelerometers (ACC) and Direct Observation (DO) are two valid approaches to the objective measurement of children and adolescents' PA and SB [71, 108]. In addition to measuring whole-body accelerations, the Actigraph GT3X+ accelerometer also possesses an inclinometer function capable of adding further context to stationary behaviors by categorizing them as either standing, sitting, or laying down based on the angle of the device relative to the directional force of gravity [125]. While waist-worn triaxial accelerometers are capable of assessing posture, they rely on optimal angle thresholds for each postural position to provide accurate information. This may be a challenge among children in a classroom setting because a correct seated posture may not always take place. Without additional context of the behaviors in which an individual engages, error may occur in the recording of posture when using an ActiGraph activity monitor. Limited research to date has explored the accuracy of the Actigraph ACC in the measurement of postural behaviors among youth, and results have been promising, particularly in the assessment of sitting [43, 71]. DO meanwhile is often considered a gold standard measure of individuals activity and movement behaviors [175], however DO can be resource intensive and is subject to the interpretation of posture in a free-living environment [41]. The adoption of practices intended to reduce SB in the classroom, such as the implementation of stand-biased desks, rely on the accurate measurement of the targeted behavior to explain effectiveness. Moreover, while the inclusion of a "fidget bar" with stand-biased desks may further reduce classroom SB from a seated position, in conjunction with other ergonomic differences from a traditional seated desk, the additional allowance of lower-limb movement while in a seated or standing position has the potential to further complicate measurements of SB.

It remains unclear how ACC and DO measurements compare when assessing children's and adolescents' postural behaviors in a classroom setting using either seated or stand-biased desks. Therefore, the primary aim of this secondary analysis was to compare ACC- and DO-measured posture of elementary students while using either a seated or stand-biased desk in the classroom.

Specific Aims & Hypotheses

<u>S1A1:</u> The aim of this study was to compare time spent sitting and standing when assessed by two commonly used physical activity measurement methods.

> <u>S1H1:</u> It was hypothesized that sitting and standing time measured by direct observation and accelerometry would be significantly different in a stand-biased, but not a traditional seated desk.
>
> <u>S1H2:</u> Higher levels of lower-limb fidgeting while using a stand-biased desk, but not a traditional seated desk, would result in greater differences in sitting time measured by accelerometer and direct observation.

Methods

This study was methodologically focused and involved the secondary analysis of data collected during an elementary school classroom intervention designed to determine the impact of stand-biased desks on children's physical activity (PA) and sedentary behaviors (SB) across the school year [179]. The initial part of this section will review the intervention study design, then the remainder of the section will focus on the research question that is part of this dissertation.

Intervention Study Design. The intervention was a within-classroom crossover design using teacher-allocated seating within each participating classroom. In all participating classrooms, approximately half of all traditional seated desks were replaced with AlphaBetter® Adjustable-Height Stand-Up Desks and Height-Adjustable Stools (SAFCO, New Hope, MN). Baseline data collection occurred in September while all students were using a sitting desk, with follow-up measurements occurring after the first 9-week intervention period in December (Post I), and again in April (Post II). Students who were assigned to a stand-biased desk during the first intervention period were switched to a traditional seated desk (and vice versa) during the second intervention period. Teachers were asked to encourage students assigned to the stand-biased desks in their classrooms to stand, however no other modifications to the classroom environment or teacher curriculum were made.

All study information and procedures were approved by the University of Wisconsin-Milwaukee Institutional Review Board (IRB #17.019).

Overview. The proposed study involved the analysis of the accelerometer and direct observation data collected during the intervention described above [179]. This was a methodological study comparing the differences between these two measures. For the purposes of this study, data collected at three measurement periods (Baseline, Post I, Post II) was included. During the measurement periods, students were instructed to wear an ActiGraph accelerometer (GT3X+ or wGT3X-BT; ActiGraph LLC., Pensacola, FL) on an elastic belt around the waist at the midline of the right thigh while in the classroom during the school day. Simultaneously three trained researchers conducted direct observations of students. Data from direct observation and waist-worn accelerometry were time-synchronized and utilized to compare the agreement between observed and device-recorded posture, while participants were in their classroom.

Participants. Students from combined 3rd and 4th grade, and standalone 4th and 6th grade classes who could stand for an extended period of time (>30 minutes) without pain were recruited from a single elementary school located in a Midwest city. Participant recruitment occurred prior to the beginning of the school year, during a school enrollment day. Interested families attended a presentation that provided an overview of the proposed project and what would be requested of children and their families. Families interested in enrolling into the study completed a parental consent, and children completed a verbal assent to participate in the research.

Accelerometer Assessment of Posture. Accelerometers are considered an accurate, reliable, and practical tool in the assessment of children's PA and SB through measurements of directional acceleration [41, 136, 150, 160], however evidence of their ability to accurately assess children's posture is limited.

ActiGraph GT3X+ or wGT3X-BT accelerometers (ActiGraph LLC., Pensacola, FL) were used in this study. The technology used to record data between these two models does not differ, however, the wGT3X-BT has both wireless and Bluetooth capabilities, while the GT3X+ does not. To assess posture (standing, sitting, laying down), the inclinometer function of the ActiGraph GT3X series was utilized while devices were worn on the waist.

The ActiGraph inclinometer function is calculated through a triaxial output (x, y, z) which uses the directionality of gravity relative to device positioning to determine posture. Two equations have been developed by ActiGraph to obtain the two angles necessary to determine posture. The equations are as follows:

Equation 1

$$\theta_y = \cos^{-1}\left(\frac{y}{\sqrt{x^2 + y^2 + z^2}}\right)$$

Equation 2

$$\theta_z = \cos^{-1}\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right)$$

Figure 1. Two equations used by the inclinometer function of the Actigraph GT3X+ accelerometer in the assessment of posture when the device is worn at the hip.

Within these equations, Θ indicates the offset angle on the axis delineated by the subscript letter (y or z) as it varies from its neutral position. In an upright standing posture with the accelerometer correctly placed on the hip, all gravitational force will travel along the y-axis. Similarly, when the device is not being worn and placed on a surface upright, all gravitational force is anticipated to travel along the z-axis. As a participant begins to alter their posture while wearing the device however, the offset angle on the y-axis (Θ_y) will increase. Approximate offset angles associated with specific postures, referred to as optimal angle thresholds, include y <17° for standing, y >17° and y <65° for sitting, and y >65° for laying down (unless Θ_z is <22°, indicating non-wear). When activity counts exceed six per second (>360 cpm), devices assume a standing posture is being maintained due to the level of activity being recorded [125].

Direct Observation. Direct observation (DO) is often used in research to assess children's free-living activity behaviors and has previously been identified as a criterion measure for categorizing children's PA [175]. DO can occur through the sampling of children's behaviors in real-time, or through the use of video recordings of children's free-living activities, which are then coded and analyzed at a later time. In a classroom setting however, DO can prove burdensome to researchers, teachers, children, and parents due to the time commitment, intrusiveness, and the need to maintain the privacy of participants. For this study, real-time direct observation was conducted by three trained researchers within participating classrooms to support consistency in ratings and reduce the risk of bias from a single rater. Using the Observer XT (Noldus Information Technology Inc., Wageningen, Netherlands) computer-based direct observation program, children's classroom behaviors including posture (sit/stand/lying and walking at a normal/fast pace) and fidgeting behaviors (hands/feet/both/none) were recorded using a focal-point time-sampling approach. Researchers would observe a single study participant for 5-seconds and record the behaviors they engaged in over the largest proportion of that 5-second observation during the 25-seconds following. Observations (5-second observation and 25-second recording) were repeated every 30-seconds across a 5-minute period. This time-sampling approach resulted in ten observations completed during each 5-minute observation period. Each study participant was observed on three separate occasions during each measurement period, on different days and at different times during the same academic subject instruction, for a total of thirty 5-second observation points. This protocol for DO was repeated while participants were assigned to both a stand-biased and traditional seated desk. Prior to the start of data collection, researchers were trained in the protocol for DO using video recordings of elementary-aged children using either a stand-biased or traditional seated desk and engaging in a number of postural and behavioral changes. Interrater reliability was assessed and calculated following the procedures outlined by Mahar and colleagues [111] and found to be acceptable at >0.90. Across all observations, researchers wore headphones and received a noise indicating the start of each 5-second sample, and neither teachers nor participants were aware of who was being observed at any time.

Data Analysis. Raw accelerometer output collected at a sampling rate of 100Hz in 1-second epochs were downloaded and inclinometer and accelerometer data were assessed. Only participants who wore an accelerometer during their direct observation periods were included in this analysis. Accelerometer output was aligned with each 5-minute direct observation period, where accelerometers provided a cumulative 300-seconds (5-minutes) of inclinometer and activity data. For inclinometer data, the posture detected across the 5-minute observation period was summed into time detected as standing, sitting, and laying down. Additionally, time spent engaging in SB or PA during the same period was also summed to account for the inclinometer's recognition of movement (>6 counts per second) as an indicator of a standing posture.

Posture and fidgeting from direct observation were summed in 5-second increments per observational period for a maximum potential of 50-seconds spent engaging in any single observed behavior per 5-minute observation period. For a visual representation of the recording overlap between accelerometer and direct observation data collection, please refer to Appendix E.

Inclinometer and direct observation data were converted to representative proportions (%) of comparable measurement periods between the two assessment methods. First, the proportion of total accelerometer-recorded time spent sitting, standing, laying down or moving (out of 300-seconds) was calculated. Following this, the proportion of accelerometer-recorded behaviors was then calculated based on the 5-second periods aligning with the direct observations (out of 50-seconds). Finally, direct observation data of time spent sitting, standing, moving, and engaging in lower-limb fidgeting (out of 50-seconds) was calculated. The proportion of accelerometer and direct observation measured time spent sitting or standing, as well as direct observation measured time engaged in lower-limb fidgeting while sitting or standing (while using a stand-biased desk only) was used for statistical analysis.

Statistical Analysis. All statistical analyses were performed using IBM SPSS Statistics 28 (IBM, Armonk, NY) and an alpha-significance level of $p<0.05$ was applied. Demographic variables measured at baseline are presented as either mean values (mean ± standard deviation) or % across the total sample. To address hypotheses one through four, all participants were included, regardless of desk assignment. Median differences (DO – ACC) between proportions (%) of direct observation and accelerometer measured sitting and standing were compared using non-parametric Wilcoxon Signed Ranks tests. To address hypothesis five through seven, mixed effects models estimating the effect of desk assignment and lower limb fidgeting on measurements of sitting and standing were performed.

Results

Participant Characteristics. Participants (n=68) included in this analysis underwent direct observation while wearing an accelerometer and using either a stand-biased or traditional seated desk in the classroom. On average, participating students were 9.9±1.4 years of age (mean ± SD), had an average BMI-for-age percentile of 48.8±28.6%, and were predominantly boys (55.9%), and white (76.5%). A complete breakdown of participant characteristics can be found in Table 1.

Table 1. Participant Characteristics (N=68)

	Mean or N	SD or %
Age (year)	9.9	1.4
Height (cm)	141.6	10.6
Weight (kg)	34.7	8.4
BMI (kg/m^2)	17.2	2.9
BMI-for-age (%)	48.8	28.6
Sex		
Boy	38	55.9
Girl	30	44.1
Race/Ethnicity		
White	52	76.5
Asian	8	11.8
Hispanic/Latino	6	8.8
Black/African American	2	2.9
Grade		
3rd	20	^{2}9.4
4th	26	^{3}8.2
6th	22	32.4

Classroom Sitting and Standing. There was a significant difference between the proportion (%) of DO and ACC measured sitting time (Table 2) while students were using stand-biased (DO: 70.0%; ACC: 52.8%; p<0.001) and traditional seated desks (DO: 90.0%; ACC: 46.7%; p<0.001). Significant differences were also found between the proportion of DO and ACC measured standing while students were using either a stand-biased (DO: 23.3%; ACC: 46.7%; p<0.001) or traditional seated desk (DO: 6.7%; ACC: 48.3%; p<0.001). There was no significant difference in the median proportion of observed lower limb fidgeting between students assigned to a stand-biased desk (16.7%) and traditional seated desk (16.7%; p=0.246).

Table 2. Median Proportions (%) and Inter-Quartile Range of Classroom Time Sitting and Standing

	Sitting							Standing						
	DO		ACC		DIFF			DO		ACC		DIFF		
	%	IQR	%	IQR	%	IQR	P	%	IQR	%	IQR	%	IQR	P
SBD (n=56)	70.0	33.3	52.8	32.8	18.7	38.8	<0.001	23.3	30.0	46.7	34.7	-19.7	35.10	<0.001
Trad. (n=47)	90.0	23.3	46.7	44.4	30.2	46.1	<0.001	6.7	23.3	48.3	41.0	-25.6	37.78	<0.001

Median Proportions (%) and Inter-Quartile Range of Lower Limb Fidgeting

Stand-Biased Desk		Traditional Seated Desk		
%	IQR	%	IQR	P
16.7	20.0	16.7	26.7	0.246

Note: SBD = Stand-Biased Desk; Trad. = Traditional Seated Desk. DIFF = (DO-ACC). Median values are presented to address outliers between measurements of posture (i.e. a participant who stood/sat 100% of the time). Significant differences (p<0.05) between Direct Observation (DO) and Accelerometer (ACC) measured sitting and standing, and lower limb fidgeting by desk type, determined using Wilcoxon Signed Ranks Test.

Effect of Desk Assignment and Lower Limb Fidgeting on Differences between DO and ACC measured Sitting and Standing. Results from a mixed-effects model (Table 3) using traditional seated desks as a reference found a significant main effect of desk type on the difference between DO and ACC measurements of sitting (estimate (%) ± SE; -18.9 ± 9.1%; p=0.041), with smaller differences between the two methods of measurement observed while students were using a stand-biased compared to a traditional seated desk. No significant main effect of lower limb fidgeting (p=1.000) or interaction effect between desk type and lower limb fidgeting (p=0.644) on the difference between measurements of DO and ACC sitting were found. For measurements of standing (Table 4), there were no significant main effects between desk type (p=0.115) or lower limb fidgeting (p=0.995), and no interaction effects between desk type and lower limb fidgeting (p=0.475) on the difference between DO and ACC assessments in the proportion of time participants spent standing.

Table 3. Mixed Effects Modeling estimating effect of Desk Assignment and Lower Limb Fidgeting on measurements of sitting

Parameter	Estimate	SE	df	t	P	LCI	UCI
Intercept	32.739	6.609	100	4.954	<0.001	19.628	45.851
Desk Type (Ref: Traditional Desk)	-18.91	9.141	100	-2.069	0.041	-37.045	-0.775
Lower-Limb Fidgeting	0.008	14.171	100	0.001	1.000	-28.107	28.123
Desk x Lower-Limb Fidgeting	0.169	0.365	100	0.463	0.644	-0.555	0.892

Table 4. Mixed Effects Modeling estimating effect of Desk Assignment and Lower Limb Fidgeting on measurements of standing

Parameter	Estimate	SE	df	t	P	LCI	UCI
Intercept	-30.785	5.775	100	-5.331	<0.001	-42.242	-19.327
Desk Type (Ref: Traditional Desk)	12.709	7.988	100	1.591	0.115	-3.138	28.557
Lower-Limb Fidgeting	0.077	12.384	100	0.006	0.995	-24.492	24.645
Desk x Lower-Limb Fidgeting	-0.228	0.319	100	-0.717	0.475	-0.861	0.404

Discussion

The purpose of this secondary analysis was to compare two commonly employed methods of measuring children and adolescents' physical activity (PA) and sedentary behaviors (SB) in the assessment of classroom posture while using either a seated or stand-biased desk. Participating students included in this analysis wore an accelerometer (ACC) on the waist while simultaneously undergoing direct observation (DO) using a focal-point time-sampling approach to assess postural behaviors in the classroom while assigned to either a seated or stand-biased desk. Overall, the findings from this analysis indicate that desk assignment can have a significant impact on the difference between DO and ACC measurements of student's posture in the classroom. Specifically, it was found that DO estimates of sitting were consistently higher than those simultaneously measured by the inclinometer function of the ACC, and this difference between measurement methods was smaller among students assigned to a stand-biased desk and height-adjustable stool, compared to a traditional seated desk.

Stand-biased desks are a novel approach to decreasing child and adolescent SB during the school day by altering the classroom environment to provide students with the option for standing in place of sitting while at their workstations. The term stand-biased however, refers to the fact that while these desks encourage students to stand, they are accompanied by a height-adjustable stool which provides the option to sit at the same desk as needed. Stand-biased desks therefore, by design, possess distinct differences from traditional seated desks which have the potential to alter the ways that postural behaviors are typically engaged in by students, and in turn assessed by researchers. In the present analysis, the proportion of time that participants were observed to be standing while in a stand-biased desk was approximately 3.5x higher than when in a traditional seated desk (SBD: 23.3%; Trad.: 6.7%). While it may be anticipated that individuals assigned to a stand-biased desk would stand more, interestingly the proportion of accelerometer-measured time spent standing between desk types was relatively stable at approximately 50% (SBD: 46.7%; Trad.: 48.3%). Similarly for sitting, participants were observed sitting for a greater proportion of time when using a traditional compared to a stand-biased desk (SBD: 70.0%; Trad.: 90.0%), however accelerometer measured sitting time maintained an estimation of approximately 50% once more (SBD: 52.8%; Trad.: 46.7%). In line with these findings, the difference between measurements of sitting and standing across desk types found that when students were assigned to a stand-biased desk, differences between the two methods of measurement were consistently smaller (Sitting – SBD: 18.7%; Trad.: 30.2%; Standing – SBD: -19.7%; Trad: -25.6%) compared to students assigned to a traditional desk. Furthermore, during the time that students were assigned to stand-biased compared to traditional seated desks, the primary driver of these decreases in differences between DO and ACC measurements appears to be primarily from changes in time observed sitting and standing by

DO, while estimations by ACC inclinometer remained relatively stable at approximately 50% across postural behaviors. Without additional context of the observation period, the contrast between measurement techniques employed in the assessment of children's classroom posture highlights the need to further address inequalities in estimations of activity behaviors and its significance to the generalization of findings. To our knowledge, the application of the Actigraph GT3X+ inclinometer function in the assessment of youth postural behaviors has been limited and with significant variation, with the correct classification of sitting behaviors occurring between approximately 50% [43] and 90% [71] of the time during semi-structured activities in a controlled setting. While the present study employed a focal-point time-sampling approach to DO in real time, using 5-second intervals representing 30-seconds of behaviors and summed across 5-minutes, the differences between the methods of assessment (DO vs. ACC) while in a seated desk reflect comparable outcomes (DO: 90.0%; ACC: 46.7%; Diff: 30.2%) to those presented by Crouter and colleagues [43]. In a classroom setting, the structured nature of activities being performed (i.e. teacher instruction and work being completed at assigned workstations) enhances the justification of using a time-sampling approach to estimate postural behaviors [121], however the subsequent differences recognized between DO and ACC measured postural behaviors when desk type, or other classroom environmental factors vary, warrant further discussion and investigation.

Lower limb fidgeting, such as what was allowed through the inclusion of a "fidget bar" near the base of the stand-biased desks used in the present study, was hypothesized to have a potential impact on estimates of sitting and standing as measured by accelerometry. Due to the responsive nature of the inclinometer function of the waist-worn accelerometers, and the assessment of posture based on the detection of optimal angle thresholds [125], it was unknown whether lower limb fidgeting would occur more frequently, or lead to a change in postural behaviors when participants used a stool and accompanying “fidget bar” while at a stand-biased desk. Limited studies have incorporated lower limb fidgeting into the analysis of postural measurement among youth, however it appears that the primary concern is for lower limb fidgeting to be misclassified as a walking/stepping behavior [4]. In the present study, participants engaged in nearly identical amounts of lower limb fidgeting (~16.7%) at both types of desks, potentially suggesting that participants lower limb fidgeting behaviors were not influenced by the presence of a “fidget bar” while using a stand-biased desk. Additionally, the use of Actigraph GT3X+ accelerometers to assess posture would require physical movement in the form of directional bodily accelerations to misclassify lower limb fidgeting as stepping, potentially explaining the lack of association between fidgeting and measurements of sitting and standing found within this analysis. Further research into the manner in which lower limb fidgeting is detected by a waist-worn accelerometer in a controlled setting is warranted to further understand how this small behavior may influence other stationary measurements such as workstation posture.

One of the major strengths of this analysis was the use of computers and accelerometers synced to the same central time source and 1-second epochs allowed for the second-by-second analysis of differences between measurement devices across observation periods. A limitation of the present analysis was assuring that participants consistently wore accelerometer devices correctly at the waist throughout assessment periods. To address this limitation, demonstrations on the correct placement of devices and assistance with appropriate wear were provided by trained members of the research team, and teachers were encouraged to correct misuse if noticed. Within the analysis, ACC data was also filtered extensively to only include participants who wore devices and were simultaneously observed across all three measurement periods, and that DO data was collected by three members of the research team who achieved an inter-rater reliability >0.90 suggesting substantial to near perfect agreement in observational data collection. A final limitation of this study was the use of a focal-point time sampling approach to DO, which applies the behaviors observed during a 5-second observation sample to an entire thirty-second observation window. While this approach can be useful in a structured setting such as a classroom where behaviors may be perceived as more static, there remains the potential that some postural or fidgeting behaviors may have not been recorded by DO, but still recorded through ACC if they occurred outside of the 5-second recording windows.

Conclusion

Few studies to date have examined differences in estimations of postural behaviors resulting from modifications to the classroom environment through the implementation of stand-biased desks. It was found that the difference between direct observation (DO) and accelerometer (ACC) measurements of postural behaviors varied significantly by desk assignment, with consistently smaller differences between measurement methodologies found when participants were using a stand-biased desk. Additionally, the means by which differences between measurement techniques primarily varied appeared to be as a result of decreases in the proportion of time participants were estimated to be sitting by DO, while estimations of postural behaviors by ACC remained relatively constant across time periods and desk types. As schools continue to seek out ways to reduce sedentary time through alterations to the learning environment, the results of this analysis support the need to further examine differences in the measurement of youth activity behaviors, and the methods of measurement used, when environmental modifications are incorporated which alter our traditional understanding of the school and classroom settings.

CHAPTER 4: AN EXPLORATION INTO THE VARIATION OF CHILDREN'S IN-SCHOOL PHYSICAL ACTIVITY BEHAVIORS ACROSS THE SCHOOL YEAR

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Abstract

Purpose: The purpose of this study was to examine the variation of children's in-school physical activity (PA) behaviors across the fall, winter, and spring of a single school year, as well as factors associated with the performance of these behaviors during the school day. **Methods:** Ninety-seven 3rd, 4th, and 6th grade students from a single elementary school completed the Youth Activity Profile (YAP) five times throughout the school year. Participant YAP responses were converted to estimations of the weekly time spent engaging in moderate- to vigorous-intensity PA (MVPA) during active transportation to- and from-school, recess, and in physical education class. Using a significance level of $p<0.05$, non-parametric Friedman's tests were conducted for each active period of the school day to assess for variation in MVPA across the school year. Post-hoc analyses using Bonferroni's correction were conducted for active periods found to be significantly different throughout the year. **Results:** Significant differences were found in the weekly minutes of MVPA participants accumulated during active transportation to- ($p=0.045$) and from-school ($p<0.001$) across the school year. Post-hoc analyses revealed that during active transportation to-school, weekly minutes of MVPA accumulated were significantly different between September (15.3±5.7 minutes/week) and December (13.9±6.5 minutes/week; $p=0.01$). Additionally, during active transportation from-school, the weekly minutes spent engaging in MVPA was significantly different between September (32.0±10.5 minutes/week) and December (29.6±11.6 minutes/week; $p=0.003$), March (28.5±11.9 minutes/week; $p<0.001$), and April (29.2±12.0 minutes/week; $p<0.001$), respectively. No significant differences were found in the weekly minutes of MVPA participants accumulated during recess (Avg: 42.2±12.2 minutes/week), physical education class (Avg: 17.7±5.6 minutes/week), or overall (Avg: 85.9±28.8 minutes/week) across the school year. **Conclusion:** Students may not be engaging in

sufficient levels of PA in school to achieve recommendations, however the opportunities for PA that students receive do not meaningfully vary. Two approaches recommended for exploration towards increasing the quantity of PA students accumulate in school include: 1) increasing the frequency or length of time in which children can be physically active such as through more frequent recess or physical education classes, or 2) encouraging increased student participation during the most varied active periods of the school day; active transportation to- and from-school, particularly during the coldest months of the year.

Introduction

It is recommended that children and adolescents between the ages of 5-17 years engage in a minimum of 60-minutes of moderate- to vigorous-intensity physical activity (MVPA) every day, while also limiting sedentary behaviors (SB), particularly long periods of sitting [201]. School-aged children however, struggle to meet these recommendations, with approximately 1/5th of children in the United States engaging in 60-minutes or more of MVPA every day of the week [37]. Among those children and adolescents meeting physical activity (PA) recommendations, more boys (23.1%) than girls (18.0%), and more children (6-11yr; 26.2%) than adolescents (12-17yr; 15.2%) report engaging in at least 60 minutes of MVPA every day of the week [37]. To address issues surrounding child and adolescent physical inactivity, efforts are underway to improve youth PA levels across the day.

Schools are a prime setting where PA participation can be influenced due to 1) the amount of time that children spend in school, 2) the structured and supervised nature of the school day, and 3) the school day is arguably the most consistently attended setting for all children in the United States. On average, children and adolescents spend a significant amount of their waking hours in school, approximately 6.6 hours per day over 180 days of the year [52]. This adds up to children and adolescents spending approximately 50% of all waking hours in a school setting during the school week. While much of a child's day is spent in school, not all time in school can be active. Furthermore, the time which children spend active during the school day varies based on teachers, grade level, state- and school-level policies related to PA (e.g., requirements for recess and physical education), weather, and access to safe places to be active [91]. In an attempt to increase the PA levels of children and adolescents, researchers have recommended that schools implement policies which promote high quality opportunities for PA during the school day [11] and that K-12 educators facilitate opportunities to accumulate a minimum of 30-minutes of PA every day [92].

The school day is a highly structured time, and this structure has been positively associated with PA among children and adolescents [23]. During the school day, there are times where PA is considered more compulsory, such as during physical education class, as well as times where children have the option to be physically active, such as during recess and during transportation to and from school. Studies have suggested that children will engage in more physically active behaviors when they are in a structured setting that requires physical activity, compared with an unstructured setting where PA becomes optional [23]. While the structured nature of the school day may positively impact children's PA, the extent to which opportunities for PA throughout the school day contribute to children and adolescents meeting physical activity recommendations remains unclear. Other factors which influence school-day PA throughout the school year also warrant further exploration.

While the total amount of time spent in a structured school setting provides opportunities for children and adolescents to regularly engage in PA, there are weather-related challenges that may influence PA levels throughout the school year. During the school day, some opportunities for PA such as recess and active transport to and from school occur primarily in outdoor spaces and can therefore be influenced by weather. Variations in weather conditions including precipitation, wind speed, visibility, temperature, and length of day have all been found to play a significant role in the quantity of PA children accumulate throughout the day [72]. Children living in a temperate climate within the northern hemisphere engaged in the highest levels of MVPA during the spring (April: 65 min/day) where the temperatures are mild, and the days are getting longer compared with the winter (February: 48min/day) where the temperatures are colder and the days shorter [6]. Weather has also been shown to impact transportation to and from school, with students being less likely to engage in active transport during the winter compared to the fall and spring [99]. Meanwhile, findings surrounding PA during the recess period have yielded mixed results, with either no difference in PA between seasons [155, 156], or higher levels of PA in the spring compared to the fall [162]. Traditionally, physical education classes have a designated indoor space, and are required for most, if not all students, making this time less susceptible to variations in children's activity levels across seasons [104]. While seasonal variation in total daily PA of children and adolescents has been established, no study has documented the impact of season on school day PA across the school year.

The structured nature of the school setting has the potential to have a powerful influence on the PA behaviors of children and adolescents. However, there remains a lack of research specifically focusing on the impact which seasonal changes might have on children and adolescents school day activity behaviors, and whether the structure of the school day aids in the maintenance of PA levels throughout the school year. Through a better understanding of the opportunities for PA provided during the school day teachers and administrators can gain valuable insight into specific periods of the school day or year which can be targeted to enhance the contribution of the school day towards aiding youth in meeting the recommended levels of PA for health. Therefore, the purpose of this study was to examine the variation of children's in-school PA behaviors across the fall, winter, and spring seasons of a single school year.

Specific Aims & Hypotheses

S2A1: The primary aim of this study was to explore changes in school day moderate- to vigorous-intensity PA behaviors across the school year.

S2H1: It was hypothesized that children and adolescents would report engaging in a significantly greater amount of MVPA during the school day in the fall, compared to the winter and spring seasons, and that the difference between the winter and spring seasons would not significantly differ.

Methods

Study Design and Overview. This was an exploratory secondary analysis which examined the variation and associations of children's in-school PA behaviors. The data included in this analysis was collected utilizing a prospective observational approach during the 2016-17 school year. Data was collected at five time points, spanning the fall through spring periods, to account for seasonal and school-related changes in PA behaviors of elementary students. The Youth Activity Profile (YAP) [164], a self-report survey utilizing 7-day recall to estimate the proportion of time in-school in which students engage in moderate- to vigorous-intensity PA (MVPA), was used to measure in-school PA. Survey distributions took place in the morning at the beginning of the school week, once in September, November, December, March, and April (Fall through

Spring), respectively. Further information on the study design and setting can be found in Swartz et al. [179].

All procedures used in this study were approved by the Institutional Review Board at the University of Wisconsin-Milwaukee (IRB #17.019) to comply with human subject research requirements.

Participants. Participants included children enrolled in participating 3rd, 4th, and 6th grade classrooms from a single public elementary school located within a large metropolitan area in the state of Wisconsin. Eligibility criteria for this secondary analysis included: 1) fluency in the English language, 2) enrollment for the 2016-17 school year at the participating elementary school, and 3) no physical constraints preventing a participant from being able to stand or move without limitation. In the original study, stand-biased desks were utilized in the classroom by approximately half of all participating students. However, because this secondary analysis does not include the classroom period, all participating students were included in this analysis regardless of desk assignment.

Youth Activity Profile. The YAP is a valid and reliable self-report questionnaire utilizing 7-day recall to examine periods of the school week in which youth typically engage in PA and SB [57, 83, 164-166, 171, 196]. The YAP was distributed in the classroom to students at the start of the first day of the school week. One or more research team members distributed physical copies and guided participating students through the survey, answering questions from students about the survey, and providing clarifications. For the remainder of the school year, participants from grades 3 and 4 continued to receive verbal instructions and guidance through the survey, while students in grade 6 were encouraged to complete the survey independently while a member of the research team remained present to resolve any issues that arose.

Data Analysis. For this study, the YAP was used to specifically look at the school-based item-specific responses including transportation to school, physical education (PE) class, recess, lunch, and transportation home from school. Each item response in the YAP first underwent a raw scoring process which resulted in a predicted percentage of time that a respondent spends in MVPA during each item-specific period. Following the raw scoring of each item, participants predicted (%) activity levels were further converted to estimated weekly minutes of MVPA distributed across the in-school period.

To perform the raw scoring of the YAP, each item was first scored on a 0-4 scale, with the exception of a respondent reporting not participating in a specific activity listed on the questionnaire (ex. no PE, recess, or time for PA during lunch), in which case an estimate of MVPA for that respondent during that period of the day was not made. Welk and colleagues [196] developed and refined item-specific in-school regression equations (N=4) which utilize each item's YAP response score (0-4), the respondents grade level (GRADE; 0 = elementary school [≤5th grade], 1 = middle school [6th–8th grades], and 2 = high school [≥9th grade]), and sex (SEX; 0 = male, 1 = female) to estimate the proportion of time spent in MVPA during item-specific periods of the school day. In total, there are 4 regression equations available for the in-school period; the lunch period has been excluded due to inconsistencies in MVPA across students during this time [196]. The regression equations used in the present analysis are presented in Table 5.

Table 5. Equations for Estimating Weekly Proportions of Time in Moderate- to Vigorous-Intensity Physical Activity (%MVPA)

Active Transportation to School	=	3.33 + (2.50 x YAP) – (1.67 x GRADE) + (0.00 x SEX)
Physical Education Class	=	23.95 + (1.87 x YAP) + (9.84 x GRADE) – (15.7 x SEX)
Recess	=	45.28 + (5.90 x YAP) + (0.00 x GRADE) – (28.2 x SEX)
Lunch	=	N/A
Active Transportation Home	=	12.50 + (5.54 x YAP) – (0.67 x GRADE) – (5.17 x SEX)

Note: YAP = 0-4 [item score]; GRADE = 0 [elementary ≤5th grade], 1 [middle 6th-8th grade], 2 [high school ≥9th grade]; SEX = 0 [male], 1 [female].

Using each participant's school schedule, predicted percentages of time spent in MVPA were converted to predicted weekly minutes of activity for each period indicated above. Using information from a student's school schedule, the predicted percentage of time spent in MVPA was multiplied by the number of days the activity period occurred (ex. recess 1x per day, 5 days/week = 5; PE 2 days/week = 2), and by the total minutes per day making up each period of activity (ex. recess = 10:00am – 10:15am = 15 minutes; PE = 11:00 am – 11:30am = 30 minutes). Furthermore, the 30 minutes immediately before and after the school day were considered the time periods in which active transportation to and from school occurred, respectively.

Statistical Analysis. All statistical analyses were conducted using IBM SPSS Statistics 28 (IBM, Armonk, NY), and a significance value set at $p<0.05$. Estimates of activity derived from survey response items were assessed for meeting statistical assumptions for analysis. Participant characteristics were summarized using frequencies, percentages, and mean ± standard deviation. Both the estimated proportion of time, as well as minutes of MVPA were aggregated at the school level across the total school week and all item-specific outcomes were additionally summed into a single value representing the in-school period (i.e. Transport to school + Recess + PE + Transport from school = In-School MVPA). To address the primary hypothesis, non-parametric Friedman's tests were conducted independently for each active period of the school day, focusing on the variation in YAP estimated MVPA between the five assessment periods, respectively. Post-Hoc analyses using Bonferroni's correction were further conducted for any periods of the school day found to vary significantly over time.

Results

Participant and Environmental Characteristics. On average, participating students (n=97) were (mean ± SD) 10.1±1.5 years of age, of a healthy body mass index (BMI; 17.9±3.2 kg/m^2) and BMI age- and sex-matched percentile (52.8±29.7%). Participants were predominantly male (57.7%) and white (80.4%), with 22.7%, 36.1%, and 41.2% of the sample enrolled in 3^{rd}, 4^{th}, and 6^{th} grade, respectively. Further information regarding participant characteristics can be found in Table 6.

Table 6. Participant Characteristics (N=97)

	Mean or N	SD or %
Age (year)	10.1	1.5
Height (cm)	146.1	29.4
Weight (kg)	37	9.9
BMI (kg/m^2)	17.9	3.2
BMI (%-tile)	52.8	29.7
Sex		
Boy	56	57.7
Girl	41	42.3
Race/Ethnicity		
White	78	80.4
Asian	9	9.3
Black/African American	3	3.1
Mixed Race	7	7.2
Grade		
3rd	22	22.7
4th	35	36.1
6th	40	41.2

Weather varied seasonally across the school year (Table 7). The average weekly temperature was highest in the early fall (September: 21.2 °C) and progressively decreased until reaching its lowest in the winter (December: 2.6 °C), before increasing through the spring (April: 7.1 °C). Humidity remained relatively constant across all measurement periods (Difference: 12.2%), and wind speed varied between an average of 12.6 kph in September and 22.8 kph in April. Overall precipitation was negligible with a maximum of 0.9 cm occurring in November, and a minimum of 0.2 cm occurring in December.

Table 7. Average Weekly Weather Conditions Across Time Points

	September	November	December	March	April
Temperature (°C)	21.2	10.4	2.6	3.4	7.1
Humidity (%)	72.5	78.4	76.5	74.2	66.2
Wind Speed (kph)	12.6	17.5	15.7	17.6	22.8
Precipitation (cm)	0.6	0.9	0.2	0.5	0.6

Physical Activity Accumulation in School. Weekly in-school levels of moderate- to vigorous-intensity physical activity (MVPA) were self-reported by participants at five different points throughout the school year (Table 8). On average, participants engaged in (mean ± SD) 14.3±5.5 minutes/week of MVPA during active transportation to school, 42.2±12.2 minutes/week of MVPA during recess, 17.7±5.6 minutes/week of MVPA during PE class, and 30.0±10.3 minutes/week of MVPA during active transportation home across all assessment periods. While recess provided the highest accumulation of MVPA weekly across measurement periods, only students in grades 3 and 4 (n=49) were provided with recess throughout the year, with this opportunity for PA being eliminated for students in 6th grade. Overall, the average time participants engaged in MVPA in-school on a weekly basis accounted for approximately 57% (85.9±28.8 minutes/week) of the in-school weekly recommendation of 150 minutes (30 minutes/day) for children and adolescents 6-19 years of age.

Table 8. Comparison of Changes in Estimated Weekly Minutes of MVPA Across School Year

Active Period In School	September		November		December		March		April		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Active Transport to School (N=85)	15.27	5.72	14.21	6.01	13.86	6.51	14.21	6.18	14.13	6.54	**0.045***
Recess (N=49)	41.24	13.31	41.60	12.33	42.51	12.52	42.60	12.98	42.87	12.61	0.204
Physical Education (N=85)	17.61	5.39	17.83	5.85	17.71	5.76	17.67	5.86	17.62	5.62	0.364
Active Transport Home (N=84)	32.00	10.48	30.50	10.94	29.55	11.61	28.52	11.93	29.15	11.99	**<0.001***
Overall (N=84)	88.25	28.15	86.16	28.82	85.29	30.22	84.58	30.55	85.24	30.64	0.611

*Note: Significant differences (***p<0.05**) between repeated measures were assessed using Friedman's Test. Only participants in grades 3 and 4 had recess in this school.*

Seasonal Variation in School Day Physical Activity. Throughout the school year, weather was the only factor which changed over time for participants, with no changes in the time-of-day students engaged in opportunities for PA, the number of opportunities participants had to engage in PA, teachers, school policies, or safety. Significant differences were found in weekly minutes of MVPA during active transportation to- ($p=0.045$) and from-school ($p<0.001$) across the school year (Table 8). Post-hoc analyses using Bonferroni's Correction (Figure 2) revealed that specifically, weekly minutes spent engaging in MVPA during active transportation to-school was significantly different between September (15.3±5.7 minutes/week) and December (13.9±6.5 minutes/week; $p=0.01$). Meanwhile, weekly minutes spent engaging in MVPA during active transportation home were significantly different between September (32.0±10.5 minutes/week) and December (29.6±11.6 minutes/week; $p=0.003$), March (28.5±11.9 minutes/week; $p<0.001$), and April (29.2±12.0 minutes/week; $p<0.001$), respectively.

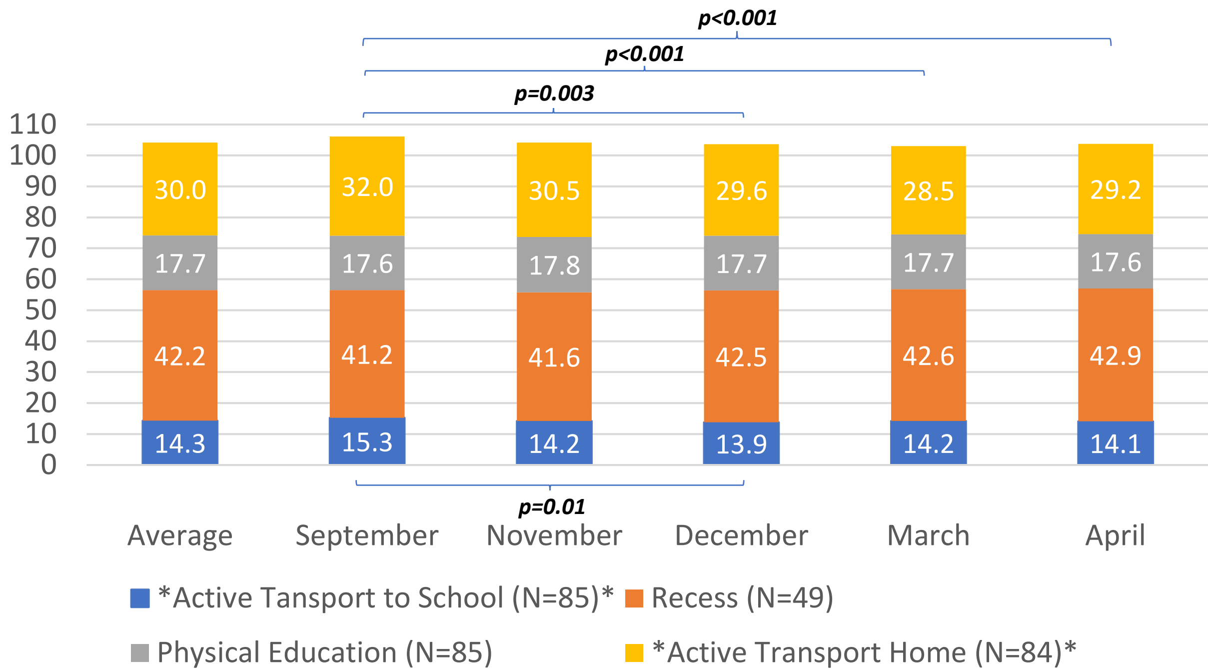

Figure 2. Distribution of Students Self-Reported Weekly In-School Minutes of MVPA Across the School Year.

Discussion

The purpose of this study was to examine the variation of children and adolescent in-school physical activity (PA) behaviors across the school year, and the factors potentially associated with these behaviors within a structured school setting. Participant weekly levels of moderate- to vigorous-intensity PA (MVPA) during active transportation to- and from-school, recess, and in physical education (PE) class, were assessed at five different time points throughout the year, once in September, November, December, March, and April, respectively. The results of this study suggest that the PA behaviors during the in-school period, in particular the time children and adolescents spend engaging in active transportation to- and from-school, were statistically different throughout the school year. However, these statistical differences in MVPA only totaled to approximately 1.5 minutes/week, accounting for less than 1% of the recommended weekly PA for this age group, and therefore limiting the practical meaningfulness of these differences.

During the school year, a significant portion of children and adolescents waking hours are spent in a school setting, therefore opportunities for PA throughout the in-school period have the potential to significantly impact total daily PA levels. It has previously been suggested that schools provide children and adolescents with opportunities to accumulate at least half of the daily 60-minute PA recommendation for health, totaling 150 minutes/week [92]. In the present study however, it was estimated that participants were accumulating an average of 85.9±28.8 minutes/week of MVPA in school across the school year, or just 57.3% of the 150-minute in-school recommendation during the week. Moreover, in the present study students in 6th grade were not provided with any opportunities for recess during the school day, which was the largest contributor towards total weekly in-school MVPA among 3rd and 4th grade students providing an average of 42.2±12.2 minutes/week of MVPA. Additionally, PE class which was the third largest average contributor to participants weekly in-school MVPA (17.7±5.6 minutes/week) occurred on just two days per week, for a 30-minute class on each day. Because the PA behaviors individuals learn from a young age have such a profound effect on habitual levels of PA across the lifespan [183], the failure to provide students with sufficient opportunities in-school to engage in PA during the school week can have a detrimental impact in the development of healthy life habits and behaviors.

Across measurement periods, the weather factor with the greatest variation was temperature, with an average high of 21.2 °C occurring in September, and a low of 2.6 °C in December, a difference of 18.6 °C coinciding with the most- and least-active in-school assessment periods. Despite negligible precipitation and relatively stable humidity levels and wind speed across the school year, participant weekly levels of MVPA varied the greatest between the warmest and coolest periods of assessment, declining steadily from September through March, before rebounding slightly in April. While specifically looking at the structured period of the school day, these findings align with those previously reported by Atkin and colleagues [6], who found that total daily MVPA was lowest among children during the winter months. However, in contrast to previous findings suggesting children's total daily MVPA was highest in the Spring [6], in the present study the month of September recorded the highest levels of MVPA in-school, with the Spring months of March and April recording the lowest levels of weekly MVPA in school. While it is unclear in the aforementioned study which seasonal variables, if any, contributed to the variation of participants PA levels over time, similar to the present study the authors proposed that limited daylight hours and adverse weather conditions were two potential drivers of change [6], although these values were not recorded.

Active transportation, whether to- or from-school, has been recognized as a time in which children and adolescents PA behaviors can be meaningfully influenced [65]. However, individuals who choose to engage in active transportation to and from school are often restricted by both proximity [58] and weather [99]. In the present study, weather-related factors appeared to be most impactful on active transportation, with the only significant variation in children and adolescents weekly in-school MVPA occurring in active transportation to-school between the months of September (15.3±5.7 minutes/week) and December (13.9±6.5 minutes/week), and to-home between the months of September (32.0±10.5 minutes/week) and December (29.6±11.6 minutes/week), March (28.5±11.9 minutes/week), and April (29.2±12.0 minutes/week), respectively. While active transport to school contributed the least to children and adolescent's total weekly levels of MVPA in-school, active transport home from school was the second largest contributor behind recess. Moreover, much like recess, active transport is an activity which, weather permitting, can take place on all five days of the school week and therefore has the ability to consistently contribute towards children and adolescents PA attainment throughout the school year.

This study had a number of strengths and limitations. To our knowledge, this is the first study to specifically analyze the associations between seasonality and youth activity behaviors during the in-school period across a single school year. Additionally, over 86% of participants completed all five assessments throughout the school year. The instrument used (Youth Activity Profile; YAP) in the assessment of participants weekly levels of MVPA has been extensively validated and was administered by trained researchers in each participating classroom. At the same time however, the ability of the YAP to only provide estimates of MVPA at the weekly level limited the ability to assess factors associated with participants PA at the daily level. Finally, while the YAP captures the primary periods in which children and adolescents encounter opportunities to engage in PA throughout the day, participants may have encountered additional opportunities to engage in PA not captured by the YAP, such as during time spent in the classroom or over the lunch period. However, the YAP was still able to capture variations in participants PA levels across the activities and periods measured by employing the same approach to collecting information across the school year.

Conclusion

While the in-school period, comprising of active transportation to- and from-school, recess, and physical education (PE) class, is a highly structured period of children and adolescents’ day, ¾th’s of the opportunities for physical activity (PA) encountered occur primarily in an outdoor setting and therefore are subject to factors associated with weather and seasonality. Additionally, the active period which contributed the second lowest amount towards students' weekly school day PA levels was PE class, which was offered twice weekly for 30 minutes per class. In contrast, recess was offered for 15 minutes each day of the week, resulting in this period of activity being the largest contributor to students' weekly PA levels in school. For school administrators to successfully increase the quantity of PA which children and adolescents accumulate throughout the school day, two primary options exist. First, schools can increase the frequency or length of time in which children can be physically active, such as through the provision of PE on more days of the week or by lengthening the time that students have recess. Secondly, an increased focus can be placed on increasing student participation during the most varied active periods of the school day. Specifically, active transportation to– and from-school are periods with the potential to increase daily PA behaviors of children and adolescents, particularly during the colder seasons when weekly PA levels are at their lowest. For most school systems, the weekly schedule is rigid and therefore the second proposed option may present a more appealing approach without a need to sacrifice time spent learning or fulfilling other educational demands. Future research should therefore explore the overall promotion of active transportation among students, particularly during colder periods of the year, as two influential factors which can be addressed to promote greater PA levels among children and adolescents throughout the school year.

CHAPTER 5: COMPARISON OF CHILDREN'S PHYSICAL ACTIVITY AND SEDENTARY BEHAVIORS BETWEEN A NATURE-BASED AND TRADITIONAL EDUCATIONAL SETTING

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Abstract

Purpose: To compare within-child differences in physical activity (PA) and sedentary behaviors (SB) among a sample of children attending a single Pre-Kindergarten (Pre-K) educational program with alternating days between a traditional and nature-based setting. **Methods:** Twenty-six children wore an accelerometer at the hip while in school for eight total days across two four-day school weeks, with week one occurring in the winter, and week two in the spring. Children alternated school days between a traditional, and a nature-based Pre-K setting so that two days per week were spent in each location. Butte cut points were applied to accelerometer data to determine the average proportion of time that children engaged in SB, light-intensity PA (LPA), moderate- to vigorous-intensity PA (MVPA), and total PA per day between class settings. Paired-samples t-tests, independent samples t-tests, and Wilcoxon signed ranks tests were used with a significance value of $p<0.05$ to determine whether differences existed in SB and PA levels between school settings, across seasons, and between structured and unstructured periods of the school day. **Results:** Overall, children in a nature-based school setting spent a significantly greater proportion of time engaging in MVPA compared to a traditional school setting (+2.4±3.4%; $p=0.002$). This difference in MVPA held true during both structured (+1.3±2.8%; $p=0.034$) and unstructured (+8.0±9.9%; $p<0.001$) periods of the school day between a nature-based and traditional school setting, and SB was also found to be significantly different between both structured (-2.5±6.1%; $p=0.046$) and unstructured (-3.1±7.1%; $p=0.032$) periods.

During the winter, children spent a significantly greater proportion of time engaging in MVPA (+5.2±4.2%; $p<0.001$), and less time engaging in SB (-6.9±7.2%; $p<0.001$) while in a nature-based compared to a traditional school setting. Once more these differences in MVPA held true during both structured (+3.1±3.4%; $p<0.001$) and unstructured (+12.3±9.6%; $p<0.001$) periods of the day in the winter, while significantly less time was spent engaging in SB during structured periods of the school day (-9.0±7.1%; $p<0.001$) when children were in a nature-based compared to a traditional classroom setting. During the spring, children spent a significantly greater proportion of time engaging in SB (+2.6±5.9%; $p=0.033$) while in a nature-based compared to a traditional school setting, with a significantly greater proportion of time being spent in SB during structured periods (+4.0±7.5%; $p=0.015$) and less time in SB during unstructured periods (-5.5±8.0%; $p=0.003$). **Conclusion:** Results from this study suggest that modifying educational practices to include outdoor education has the potential to increase the quantity of in-school PA children accumulate while simultaneously reducing SB.

Introduction

From an early age, physical activity (PA) promotes the development of physical, mental, and emotional health as well as the development of various movement skills [143]. Parents and caregivers of preschool-aged children play a crucial role in their development as both promoters and modelers of PA behaviors [143]. Ultimately, providing young children with sufficient opportunities to engage in high levels of PA while moderating engagement in sedentary behaviors (SB) may increase the likelihood of developing and maintaining healthy activity behaviors throughout childhood and into adulthood [86].

While a large percentage of children are enrolled in preschool and pre-kindergarten (Pre-K) programs in the United States, the traditional educational setting for these programs often struggle to provide sufficient opportunities for PA [140, 149], resulting in children spending the majority of their school time engaging in SB [136, 149]. There are many potential reasons for the high levels of SB during preschool, including a short timeframe in which to fit many curricular demands, sleep and quiet times, as well as the amount of time children spend inside versus outside during school [10, 33, 35].

The distribution of time spent indoors and outdoors throughout the day has consistently been shown to be a primary determinant of children's participation in PA and SB [113]. Among youth, outdoor time is positively associated with PA [169], therefore an educational program which offers more opportunities for time outside should result in greater levels of PA among children during the school day. While traditional preschool programs spend the majority of time indoors, nature-based programs typically spend time playing and learning in a natural outdoor setting.

Nature-based education presents an alternative approach to education in which nature and the outdoor environment are at the center of learning and play. These settings address many of the perceived barriers to spending time outside [63, 98, 174, 177], through the provision of a structured and supervised educational setting primarily set outdoors. Furthermore, compared to traditional playground spaces and other structured environments which have been shown to alienate less-active children from participating in PA, natural play spaces and nature-based learning can provide more diverse opportunities for PA throughout the school day, therefore supporting the PA of more children [73]. In a time where children are spending more of each day indoors [12, 195], nature-based education presents a promising means by which children can benefit from access to time outside.

In a traditional educational program, increased time outside would most likely result from already physically active periods, such as lengthening recess or moving other free time outdoors. Nature-based educational programs on the other hand, incorporate time outside, and PA, into both structured (i.e. instructor-led learning and play) and unstructured (i.e. free play) periods of the school day. Previous research has suggested that structured aspects of a school day, such as class time where PA is encouraged or required, and the ability to oversee unstructured periods of free play, can enhance children's activity levels compared to less structured periods [23]. Along with the positive association between time outside and children's PA and SB [95], the incorporation of more structured periods of a school day into these outdoor settings has the potential to meaningfully alter children's in-school activity levels, warranting further exploration.

To date, positive associations between children and adolescents PA levels and time spent in a nature-based, outdoor educational setting have been published [107, 184, 197], however to our knowledge no studies have directly compared differences in PA and SB among children participating in a traditional versus nature-based educational setting. Therefore, the purpose of this study was to compare within-child differences in PA and SB between a traditional and nature-based educational Pre-K program setting.

Specific Aims and Hypotheses

S3A1: The primary aim of this study was to compare differences in children's accelerometer-determined school-day PA and SB between Pre-K programs in an outdoor, nature-based setting and a traditional, indoor educational setting.

> S3H1: It was hypothesized that children would accumulate significantly more PA and less SB during the school day while attending a nature-based, outdoor Pre-K program, compared to a traditional, indoor Pre-K program.

S3A2: The secondary aim of this study was to compare children's PA and SB while attending Pre-K in an outdoor, nature-based setting and a traditional, indoor educational setting between the winter and spring.

S3H3: It was hypothesized that there would be no significant differences in PA and SB between the spring and winter seasons while children attended a nature-based Pre-K program.

S3H4: It was hypothesized that children attending a traditional Pre-K program would accumulate significantly more PA and less SB in the spring compared to the winter season.

S3A3: The third aim of this study was to compare differences in the PA and SB of children during periods of structured and unstructured time between outdoor, nature-based and indoor, traditional Pre-K programs.

S3H7: It was hypothesized that children attending a nature-based program would spend significantly more time engaging in PA during both structured and unstructured periods of the school day compared to a traditional classroom setting.

S3H8: It was hypothesized that children attending a traditional program would spend significantly more time engaging in SB during both structured and unstructured periods of the school day compared to a nature-based classroom setting.

Methods

Study Design.

This was a naturalistic observational study comparing the physical activity (PA) and sedentary behavior (SB) levels of Pre-Kindergarten (Pre-K) children from a single educational program that includes both a traditional classroom setting and a nature-based classroom setting. Data collection was completed across two separate, 4-day school weeks (Monday through Thursday), with the first school week taking place in January 2019, and the second in May 2019. Monday and Wednesday all students attended class in a traditional, indoor classroom setting. Tuesday and Thursday all students attended class in a nature-based, outdoor classroom setting. School days included an “AM” and “PM” Pre-K session, with each lasting approximately 2-hours and 45-minutes. Students attended the same morning or afternoon session every school day. While the classroom environment differed between school days, students attended class with the same teachers, teacher aides and fellow students. This study and all documents used were approved by the Institutional Review Board at the University of Wisconsin-Milwaukee (IRB# 19.124) to align with human subject research requirements.

Participants.

Participants were recruited from a single Pre-K school program located in a rural, Midwest community in the United States. Eligibility criteria to participate in this study included current enrollment in the selected Pre-K program, the ability to actively participate in program activities, and no lower-limb ambulatory limitations that would impact the accuracy of the activity monitors used. The proposed study was a pilot study, intended to examine the feasibility of conducting research with this population and in this research setting, therefore an a priori power analysis was not conducted and a maximum number of eligible participants from the participating Pre-K program were recruited.

Procedures and Naturalistic Conditions.

Program administrators and teachers were approached at the beginning of the school year and collectively engaged in the planning of the study protocol. Teachers acted as the primary liaison of study information between caregivers and researchers. Primary caregivers were first informed of the study by e-mail with an accompanying study information sheet clearly outlining the purpose of the study and participant expectations. This was followed by the distribution of a recorded video in which the primary researcher conducting the study introduced them self, provided an overview of the study, and introduced viewers to an accelerometer measurement device which would be used to record participant activity behaviors. Primary caregivers were then provided with an introductory packet containing a study information sheet (Appendix F), the caregiver informed consent document (Appendix G), a health history and demographics questionnaire (Appendix H), and a copy of the child assent (Appendix I). Primary caregivers were requested to complete the informed consent and health history and demographics documents and return them to the classroom teacher in a provided sealed envelope. Following the distribution of the introductory packet, a trained researcher entered the classroom and completed the assent process with students which involved the completion of an assent document and an opportunity to try wearing an accelerometer on a belt fastened around the waist. Students further provided verbal assent to participate in the research study on each day that data was collected by agreeing to wear an accelerometer. If a participant did not verbally assent to wear a measurement device on any day of data collection, or if they decided during the day that they no longer wanted to wear a device, then the participant would be exempt from data collection for that day.

On each day that data was collected, a trained researcher assisted participating children in correctly putting on an accelerometer. Students wore the accelerometer on the waist over the midline of the right thigh, according to manufacturer’s instructions. Devices were worn from the moment a child arrived for the school day until the end of their class period. Direct observation of class-wide behaviors was also conducted by a trained researcher to add context of the locations and types of activities participants engaged in throughout the school day (Appendix J). Accelerometer and direct observation data was recorded simultaneously throughout each 2-hour 45-minute class period.

Traditional School Setting. The traditional classroom setting which children attended on Monday and Wednesday was located in a daycare center attached to a church building. Within the classroom (~850 square feet) there were multiple spaces for learning and activity engagement. The main learning space consisted of a carpeted floor with a whiteboard and other learning materials on the walls. A mobile whiteboard was also available for use. In this learning space, students stood or sat on the floor and engaged in multiple short (~15 minutes each) learning activities per day. The remaining space in this classroom included tables with chairs where students sat for snack time, and also where arts and crafts were completed. Multiple active "stations" consisting of a sensory stimulation table, a small indoor playhouse, and a reading nook with books and stuffed animals made up the rest of the classroom. Students also had access to an outdoor playground.

The outdoor playground accessible to the traditional education setting was approximately 3,000 square feet and deemed "natural" by the teachers and administrators of this school. This playground consisted of a fenced in space primarily containing play structures made from natural materials (Appendix K). There was a sand pit, a large dirt hill, several logs intersecting one another for balance-type activities, a small lean-to which provided additional shade, and a water table. Students had access to a play shed, where all play materials were stored including but not limited to buckets, shovels, cooking materials (pots/pans/utensils), and a few plastic wagons and wheelbarrows. A few areas for sitting, including logs, a wooden drum used as a table, and a few plastic benches (doubling as additional storage) made up the rest of the space.

The length of time that children spent engaging in various activities throughout the school day varied daily, however in the traditional setting children typically began their days with an outdoor recess period, before completing the remainder of class activities inside of their classroom.

Nature-Based School Setting. The nature-based classroom setting which children attended on Tuesday and Thursday was situated at a nearby nature center. The nature-based classroom setting included an indoor classroom that could be used in the winter, an outdoor classroom, a large, outdoor play space, and nearly 400 acres of land with 10 miles of hiking trails that connected to other natural play spaces in forest, prairie, and wetland ecosystems.

The indoor classroom was approximately 650 square feet and consisted of a large floor space for students to sit and engage in indoor activities, and a few tables against one wall. The "outdoor" classroom (~1,000 square feet) was located in a rustic building with a wooden floor and a wood-burning stove for heating. This rustic space was primarily used for bag storage and in the event of significant weather, otherwise a concrete platform with benches located directly outside of the rustic building acted as the classroom space.

The primary outdoor play space, located adjacent to the classrooms, consisted of a large field (~0.4 acres/16,000 square feet), a climbing structure surrounded by water (similar to a narrow moat), a sheltered tree house, a secondary climbing structure made of harvested wood from the property, and a small boulder field (Appendix L). The primary climbing structure had a rope ladder on one side that crossed over the moat, and a staircase on the other side for easier access to the top. The sheltered tree house consisted of stairs leading to a platform with a roof and windows which could be shuttered. The secondary climbing structure consisted of multi-level platforms that required climbing to ascend to the top.

In addition to the primary outdoor play space, this program also had access to hiking trails which could be used for learning activities and also lead to auxiliary play spaces. One auxiliary play space was approximately 600 feet from the outdoor classroom and was located within a large maple forest with minimal underbrush where students were allowed to wander around within sight of their teachers, build structures from fallen logs, and this area also doubled as a space for tree climbing using ropes and harnesses. An additional auxiliary play space (~1,200 feet from the outdoor classroom) consisted of a large boulder field on the side of a small hill which provided children the option to climb on rocks and engage in other free play activities. During school days in the nature-based setting, time indoors was intended to be at a minimum and the majority of class activities took place outside. School days in the nature-based setting began with a free play session in the primary play space followed by a varied schedule of semi- and fully-structured learning- and play-based activities taking place either in the classroom or surrounding space within the nature center.

One overarching goal of this Pre-K program, across the traditional and nature-based settings, was to provide children with access to the outdoors for at least 75% of total school time, with the majority of that occurring in the nature-based setting. At both school locations, students were encouraged to wear waterproof boots and suits every day with the anticipation of getting dirty. During class periods across program settings, students would receive opportunities to engage in both structured and unstructured activities. In this study, structured activities were defined as activities which were planned, had a specific goal or purpose, and were intentionally led/supervised by a teacher or teacher’s aide. Unstructured activities, often also referred to as unstructured free play, were periods throughout the school day in which children were allowed to engage in their own decision-making with minimal direction provided by teachers.

Measurements.

Student and Environmental Characteristics.

Prior to the start of the study, primary caregivers completed a brief health history and demographics questionnaire. Primary caregivers answered questions regarding their child's perceived overall health, birth date (Month/Year), sex, race/ethnicity, and an estimation of the child's height and weight. Hourly weather reports from the National Oceanic and Atmospheric Administration (NOAA) were collected to supplement direct observation and activity monitoring data at both the nature-based and traditional school locations.

Activity Monitoring. Participants wore one ActiGraph GT3X accelerometer (ActiGraph LLC., Pensacola, FL) on a belt fastened around the waist from the moment they arrived for the school day until the end of their class period. Researchers assisted with the accurate positioning of the accelerometers at the start of each class period, and with the collection of accelerometers at the end of each class period. Accelerometers have been deemed an accurate, reliable, objective, and practical assessment tool of children's PA and SB [41, 136, 150, 160]. When worn on the body, accelerometers measure the speed and direction in which a person moves in a tri-axial environment. During initialization, these devices can be set to capture movements at a frequency between 30-100 Hz/second; with a higher frequency capable of capturing more complex movements. A set sampling frequency over time yields raw counts, which can be summed into periods of time defined as epochs and lasting between 1-60 seconds. Shorter epochs are capable of capturing more finite bouts of activities and are ideal for recording activities of differing intensities occurring in succession of one another. For this study, activity monitors were set to collect data at a rate of 100 Hz/second summed into 15-second epochs, in order to capture the often-sporadic movement patterns of children [64, 132]. The speed, or magnitude of recorded acceleration during an epoch can be translated into an estimation of PA intensity through the use of activity counts [36].

Direct Observation of Physical Activity Behaviors. Direct observation is widely used, and in the context of PA research is often used to assess children's free-living activity behaviors [175]. Multiple methodologies exist for the conduction of direct observation among children [76]. For this study, direct observation was conducted by a trained researcher using a group-wide naturalistic observational approach.

Accelerometers were the primary method of PA and SB measurement, while direct observation provided additional context surrounding activities performed throughout the school day. Accelerometer and Direct Observation of PA and SB were time matched. To ensure harmonious data collection, the researcher used a watch that had been synced with the computer used to initialize all accelerometers as a timepiece for direct observation.

Data Analysis.

Downloaded data was filtered and saved using a start and end wear time specific to each participant, class period, and day, resulting in 8 individual files (4 days per school week and two data collection periods – winter and spring) per participant. Participating children were included in the analysis if they wore an accelerometer for seven or more days across all data collection periods. Butte and colleagues [28] have developed regression formulas that translate counts into estimates of activity intensity through the use of cut-points (counts per minute; cpm). Activity counts of preschool-aged children (3-5yr) are categorized into time spent in SB (SB, ≤240cpm), light- (LPA, 241-2120cpm) and moderate- to vigorous-intensity (MVPA; ≥2120cpm) PA, based on the summation of four consecutive 15-second epochs into a 60-second epoch [28]. Resulting intensity levels recorded per minute were then summed across children's total wear time to indicate total time spent in SB, LPA, and MVPA. Because of significant differences in accelerometer wear time between educational program settings under certain conditions assessed (i.e. by season, in un-/structured activities, etc.), children's activity behaviors are presented as a proportion (%) of wear time rather than minutes that behaviors were engaged in. Direct observation data was manually input into a summary spreadsheet of each recorded class periods schedule. During observations, the researcher documented the time at which different phases of the school day started and stopped, the structured quality of each phase (structured/unstructured), the location where each phase of the school day took place (ex. classroom, playground, trails, etc.), and additional notes which aided in adding context to the accelerometer-recorded activity.

Statistical Analysis.

All statistical analyses were conducted in IBM SPSS Statistics 28 (IBM, Armonk, NY). An Alpha level of $p<0.05$ was used to determine significance. Demographic and time-based data collected through direct observation was summarized as mean or percentage (%) ± standard deviation (SD) and compared using Independent Mann-Whitney U Tests and Chi-Square Tests of association. To address the three specific aims of this study, within-child differences in PA and SB between school environments were assessed using paired-samples t-tests, independent samples t-tests, or Wilcoxon signed-ranks tests for data that was normally or not-normally distributed, respectively.

Results

Student and Environmental Characteristics.

A total of 27 children (18 boys) enrolled in this study, however one student was withdrawn from the study after not verbally assenting to wear a device throughout the data collection period. Therefore, 26 students were included in the analyses. Across 8 total classes measured, participants provided accelerometer data for an average of 7.7 class periods. Children were 4.9±0.5 years of age (mean ± SD) and had a mean Body Mass Index percentile of 58.1±34.4%. The majority of participants were white (92%), not Hispanic/Latino (85%), and were reported by their caregiver as being in 'excellent' or 'very good' overall health (89%). Further information on participant demographics and characteristics can be found in Table 9.

Table 9. Participant Characteristics							
	Total (N=26)		Boys (n=18)		Girls (n=8)		
	Mean or N	SD or %	Mean or N	SD or %	Mean or N	SD or %	P
Age (year)	4.9	0.5	4.8	0.5	5.1	0.4	0.178[a]
Height (cm)	107.7	6.1	108.2	5.0	106.7	8.8	0.852[a]
Weight (kg)	18.7	2.4	19.1	2.8	17.9	1.4	0.494[a]
BMI (%-tile)	58.1	34.4	62.7	30.8	47.6	42.2	0.492[a]
BMI Classification							
Underweight	3	11.5	1	5.6	2	25.0	0.238[b]
Healthy Weight	13	50.0	10	55.6	3	37.5	
Overweight	3	11.5	3	16.7	0	0.0	
Obese	4	15.4	2	11.1	2	25.0	
Missing	3	11.5	2	11.1	1	12.5	
Overall Health							
Excellent	17	65.4	12	66.7	5	62.5	0.339[b]
Very Good	6	23.1	5	27.8	1	12.5	
Good	1	3.8	0	0.0	1	12.5	
Fair	1	3.8	1	5.6	0	0.0	
Missing	1	3.8	0	0.0	1	12.5	
Race							
White	24	92.3	17	94.4	7	87.5	0.524[b]
Other	1	3.8	1	5.6	0	0.0	
Missing	1	3.8	0	0.0	1	12.5	
Hispanic/Latino							
Yes	3	11.5	1	5.6	2	25.0	0.112[b]
No	22	84.6	17	94.4	5	62.5	
Missing	1	3.8	0	0.0	1	12.5	

Note: P-values indicating differences between Boys and Girls were obtained using Independent-Samples Mann-Whitney U[a] and Pearson Chi-Square[b] Tests

Weather was typical for this region during both data collection periods (Table 10). During the winter period, the average temperature while children were outside in either a nature-based or traditional setting ranged from -0.5 °C to -2.3 °C, relative humidity ranged from 75.3% to 77.8%, there was negligible precipitation, and average wind speed was between 11.5 kph to 15.5 kph. During the spring period, the average temperature while children were outside in either a nature-based or traditional setting ranged from 15.7 °C to 18.3 °C, relative humidity was between 54.1% to 54.7%, and wind speed averaged between 10.9 kph to 11.6 kph. An average of 0.21mm of precipitation occurred while children were in a nature-based setting, and none occurred while in a traditional setting.

Table 10. Characteristics of the School Day

	Winter		Spring	
	Nature-Based	**Traditional**	**Nature-Based**	**Traditional**
Weather During Time Outside				
Temperature (°C)	-0.5	-2.3	18.3	15.7
Humidity (%)	77.8	75.3	54.7	54.1
Precipitation (mm)	0.0	0.0	0.2	0.0
Wind Speed (km/h)	11.5	15.5	11.6	10.9
Class Period Organization				
Time Outside (h:m:s)	0:50:39	0:42:18	1:59:11	1:00:37
Structured Time (h:m:s)	1:38:42	1:49:08	1:46:23	1:40:13
Teaching Time (h:m:s)	0:24:48	0:42:58	0:30:12	0:41:07
Play Time (h:m:s)	0:34:51	0:34:12	0:40:48	0:49:17

Note: Each class period lasted approximately 2:45:00, however the beginning of each day of data collection involved equipping participants with devices, therefore class period length varied daily.

Combining the winter and spring assessment periods, children in a nature-based setting spent more time outdoors (Diff: +33.5±6.9min), less time engaging in structured, teaching-specific activities (i.e. learning letters and numbers, "lecture"-based activities; Diff: -14.5±0.6min), but more time in structured, instructor-led activities (i.e. nature walks, "hands-on" activities; Diff: +12.4±1.0min) throughout the school day, compared to a traditional classroom setting.

Physical Activity & Sedentary Behavior Differences between a Nature-Based and Traditional Classroom Setting.

Overall (winter and spring combined), there were no significant differences in average accelerometer wear time (WT) between the nature-based (140.5±3.6min) and traditional (142.0±6.9min; p=0.322) classroom settings. Children in a nature-based setting spent a significantly greater proportion of time engaging in MVPA compared to a traditional classroom setting (Diff: +2.4±3.4%; p=0.002), and there were no significant differences in time spent in SB or LPA (Table 11).

Winter. In the winter, there was a significant difference in accelerometer WT between a nature-based (135.3±0.3min) and traditional (142.4±1.4min; p<0.001) classroom setting. Compared to the traditional classroom setting, children in the nature-based setting spent a significantly smaller proportion of time engaging in SB (Diff: -6.9±7.2%; p<0.001), and a significantly greater proportion of time engaging in MVPA (Diff: +5.2±4.2%; p<0.001) and total (LPA+MVPA) PA (Diff: +6.9±7.2%; p<0.001).

Spring. During the spring, there was no significant difference in accelerometer WT between the nature-based (145.6±7.0min) and traditional (141.6±13.6min; p=0.190) classroom settings. Compared to the traditional classroom setting, children in the nature-based setting spent a significantly greater proportion of time engaging in SB (Diff: +2.6±5.9%; p=0.033), and significantly smaller proportion of time engaging in LPA (Diff: -2.3±5.3%; p=0.041) and total PA (Diff: -2.6±5.9%; p=0.033), but no difference in time engaging in MVPA (p=0.677).

Table 11. Comparison of Participants In-School Physical Activity and Sedentary Behaviors Between Winter and Spring in a Nature-Based or Traditional Educational Setting (N=26).

	All Participants					**Nature-Based**					**Traditional**				
	Nature-Based		***Traditional***			***Boys (n=18)***		***Girls (n=8)***			***Boys (n=18)***		***Girls (n=8)***		
	Mean	**SD**	**Mean**	**SD**	**P_1[a]**	**Mean**	**SD**	**Mean**	**SD**	**P_2[b]**	**Mean**	**SD**	**Mean**	**SD**	**P_2[b]**
Winter															
SB (%)	42.4	6.4	49.3	6.7	**<0.001**	40.6	5.9	46.4	5.7	**0.028**	48.2	7.0	51.6	5.7	0.242
LPA (%)	41.3	4.3	39.6	5.1	0.091	42.0	4.6	39.8	3.5	0.236	39.7	5.0	39.5	5.6	0.950
MVPA (%)	16.3	4.4	11.1	9.9	**<0.001**	17.4	4.5	13.8	3.1	0.051	12.1	5.1	8.9	2.2	0.097
Total PA (%)	57.6	6.4	50.8	6.7	**<0.001**	59.4	5.9	53.6	5.6	**0.028**	51.8	7.0	48.4	5.7	0.242
Wear Time (min)	135.3	0.3	142.4	1.4	**<0.001**	135.3	0.3	135.3	0.3	0.866	142.3	1.5	142.6	1.4	0.616
Spring															
SB (%)	41.9	8.1	38.4	6.7	**0.033**	39.5	8.0	44.3	7.5	0.161	37.4	6.3	40.5	7.5	0.276
LPA (%)	42.8	4.7	45.0	4.8	**0.041**	43.7	4.2	40.8	5.2	0.138	46.0	4.3	42.8	5.4	0.118
MVPA (%)	16.2	5.8	16.6	5.4	0.677	16.8	6.5	14.9	4.0	0.374	16.6	5.3	16.7	6.0	0.975
Total PA (%)	59.0	8.1	61.7	6.7	**0.033**	60.5	8.0	55.7	7.5	0.161	62.6	6.3	59.5	7.5	0.276
Wear Time (min)	145.6	7.0	141.6	13.6	0.190	145.1	7.5	146.7	6.0	0.605	143.9	9.9	136.4	19.4	0.329
Total															
SB (%)	41.7	6.3	43.8	6.2	0.057	40.1	5.8	45.4	6.3	**0.023**	42.8	6.1	46.1	6.2	0.220
LPA (%)	42.1	3.4	42.3	4.5	0.720	42.9	2.9	40.2	4.0	0.076	42.9	4.3	41.2	5.0	0.389
MVPA (%)	16.3	4.6	13.9	4.3	**0.002**	17.1	4.8	14.4	3.4	0.161	14.4	4.6	12.8	3.5	0.390
Total PA (%)	58.3	6.3	56.2	6.2	0.057	60.0	5.8	54.6	6.3	**0.045**	57.2	6.1	53.9	6.2	0.220
Wear Time (min)	140.5	3.6	142.0	6.9	0.322	140.2	3.8	141.0	3.1	0.619	143.1	5.0	139.5	9.9	0.359

Note: Statistical significance was analyzed between classroom settings (P_1) and for boys and girls within classroom settings (P_2). Statistical significance was determined using Paired Samples T-Tests[a] and Independent Samples T-Tests[b].

Structured & Unstructured Periods of the School Day.

Combining both measurement periods, there were no significant differences in the amount of time that children engaged in structured activities between a nature-based (101.6±3.7min) and traditional (100.2±7.1; p=0.711) classroom setting. Within those structured activities, children in the nature-based setting spent a significantly smaller proportion of time engaging in SB (Diff: -2.5±6.1%; p=0.046), and a significantly greater proportion of time engaging in MVPA (Diff: +1.3±2.8%; p=0.034) and total PA (Diff: +2.5±6.1%; p=0.049) compared with the traditional setting. Across both measurement periods children engaged in significantly less unstructured time in the nature-based (38.9±2.0min) compared to the traditional (41.8±1.7min; p<0.001) classroom setting. During unstructured time, children in the nature-based setting spent a significantly smaller proportion of time engaging in SB (Diff: -3.1±7.1%; p=0.032) and LPA (Diff: -4.9±7.9%; p=0.010) but spent a significantly greater proportion of time engaging in MVPA (Diff: +8.0±9.9%; p<0.001) and total PA (Diff: +3.1±7.1%; p=0.033), compared with the traditional classroom setting. The PA and SB levels of children during structured and unstructured periods of the school day for the nature-based and traditional program settings can be found in Table 12.

During the winter period, children spent significantly less time engaging in structured activities in the nature-based program compared to the traditional classroom setting (98.4±5.6 vs.107.8±3.8min; p<0.001). Further, the proportion of time spent engaging in PA and SB differed between programs settings. Specifically, children in the nature-based setting spent a significantly smaller proportion of structured time engaging in SB (Diff: -9.0±7.1%; p<0.001), and a significantly greater proportion of time engaging in LPA (Diff: +5.9±4.9%; p<0.001) and MVPA (Diff: +3.1±3.4%; p<0.001) compared with the traditional classroom setting.

Table 12. Participants In-School Physical Activity and Sedentary Behaviors During Structured and Unstructured Periods of the School Day Across Winter and Spring in a Nature-Based or Traditional Educational Setting

	Total									
	Structured					Unstructured				
	Nature-Based		*Traditional*			*Nature-Based*		*Traditional*		
	Mean	**SD**	**Mean**	**SD**	**P_1**	**Mean**	**SD**	**Mean**	**SD**	**P_2**
Winter										
SB (%)	47.4	6.4	56.4	7.1	**<0.001**	26.4	9.9	27.1	11.6	0.849
LPA (%)	41.2	5.2	35.2	5.3	**<0.001**	42.0	6.5	53.5	8.3	**<0.001**
MVPA (%)	11.4	3.0	8.4	3.4	**<0.001**	31.7	11.8	19.4	11.6	**<0.001**
Total PA (%)	52.6	6.4	43.6	7.1	**<0.001**	73.6	9.9	72.9	11.6	0.849
Time (min)	98.4	5.6	107.8	3.8	**<0.001**	36.9	5.9	34.6	2.8	0.130
Spring										
SB (%)	49.5	8.4	45.5	7.6	**0.015**	19.0	8.8	24.5	7.8	**0.003**
LPA (%)	38.6	6.2	42.1	5.0	**0.011**	52.5	8.1	50.8	7.9	0.354
MVPA (%)	11.9	4.0	12.4	4.6	0.629	28.5	14.7	24.7	9.7	0.218
Total PA (%)	50.5	8.4	54.5	7.6	**0.015**	81.0	8.8	75.5	7.8	**0.003**
Time (min)	104.7	9.6	92.6	13.6	**0.005**	40.8	3.0	49.0	1.9	**<0.001**
Total										
SB (%)	48.5	5.9	50.9	6.5	**0.046**	22.7	8.1	25.8	8.2	**0.032**
LPA (%)	39.9	4.4	38.7	4.6	0.228	47.3	5.6	52.2	6.3	**0.010**
MVPA (%)	11.5	2.8	10.4	3.5	**0.034**	30.1	10.5	22.1	8.4	**<0.001**
Total PA (%)	51.6	5.9	49.1	6.5	**0.049**	77.3	8.1	74.2	8.2	**0.033**
Time (min)	101.6	3.7	100.2	7.1	0.711	38.9	2.0	41.8	1.7	**<0.001**

Note: P-values obtained using Wilcoxon Signed-Ranks Test. P_1 indicates comparisons between *Structured* times, while P_2 indicates comparisons between Unstructured times.

There was no significant difference in the amount of time that children engaged in unstructured activities between classroom settings during the winter (p=0.13). However, in the nature-based setting, children spent a significantly lower proportion of unstructured time engaging in LPA (Diff: -11.6±8.4%; p<0.001) and a significantly greater proportion of time engaging in MVPA (Diff: +12.3±9.6%; p<0.001) compared with the traditional classroom setting.

During the spring, there was a significant difference in the amount of time that children spent engaging in structured activities between a nature-based and traditional classroom setting (104.7±9.6min vs. 92.6±13.6min; $p=0.005$). Further, the proportion of time spent engaging in PA and SB differed between program settings. Specifically, children in the nature-based setting spent a significantly greater proportion of structured time engaging in SB (Diff: +4.0±7.5%; $p=0.015$), and a significantly smaller proportion of time engaging in LPA (Diff: -3.5±6.0%; $p=0.011$) and total PA (Diff: -4.0±7.5%; $p=0.015$) compared with the traditional program.

There was also a significant difference in the amount of time children spent engaging in unstructured activities between a nature-based and traditional classroom setting (40.8±3.0 vs. 49.0±1.9min; $p<0.001$) in the spring. During this time, children in the nature-based setting engaged in a significantly smaller proportion of SB (Diff: -5.5±8.0%; $p=0.003$), and a significantly greater proportion of total PA (Diff: +5.5±8.0%; $p=0.003$) compared with the traditional setting.

Other Factors Associated With Activity Behaviors Between Program Settings.

When examining data from both measurement periods together, boys spent less time engaging in SB (40.1±5.8%) and more time engaging in PA (60.0±5.8%) in the nature-based setting compared to girls (SB: 45.4±6.3%; $p=0.023$; PA: 54.6±6.3%; $p=0.045$). There was no difference in the amount of time spent in SB or PA between boys and girls in the traditional classroom setting (Table 11).

When examining the two assessment periods individually, the gender comparison in winter mirrors the results from the overall data. In a nature-based setting during the winter assessment period, boys spent less time engaging in SB (40.6±5.9%) compared to girls

(46.4±5.7%; p=0.028), and more time engaging in PA (boys: 59.4±5.9%; girls: 53.6±5.6%; p=0.028). In the traditional classroom setting, there were no significant differences found in the proportion of time which boys and girls spent engaging in activity behaviors.

In the spring, there was no significant difference in the proportion of time that boys and girls spent engaging in SB, LPA, MVPA, or total PA in either a nature-based or traditional classroom setting.

Discussion

The purpose of this study was to compare the physical activity (PA) and sedentary behavior (SB) levels among a sample of children attending a single Pre-Kindergarten (Pre-K) program which alternated school days between a traditional and nature-based educational setting. The results of this study suggest that attending school in an outdoor, nature-based program setting was positively associated with the amount of time that children engage in PA and SB, particularly during the winter months when children's PA levels are often lower than other seasons [6]. Specifically, it was found that children engaged in approximately six additional minutes of moderate- to vigorous-intensity PA (MVPA) in a nature-based compared to a traditional Pre-K program setting during the winter season, and this appeared to be driven in large part by nearly twice as much time spent in MVPA during unstructured periods of the school day. Differences in activity behaviors were not as large during the spring season when students spent more time outside and engaging in free play in both program settings. When combining data from both seasons, the data showed that children spent a significantly greater proportion of time engaging in MVPA by an average of approximately three minutes per class period in a nature-based setting.

Nature-based pedagogy focuses on the creation of educational settings which embrace nature, promote the mental and physical development of children, and place an emphasis on play-based learning. Furthermore, in nature-based education teachers provide extensive opportunities daily for children to engage in both outdoor unstructured play and structured learning [124]. This unique environmental approach to education sets nature-based programs apart from traditional educational practices, which may gravitate more frequently towards utilizing indoor spaces for periods of structured learning and, in some cases, unstructured play. Within the present study, these differences were evident through the distribution of structured and unstructured activities between nature-based and traditional educational settings, and the proportion of these periods which children spent engaging in PA and SB. Despite slightly more time on average being allocated to unstructured activities (i.e. free play) in a traditional (41.8±1.7min) compared to a nature-based (38.9±2.0min) program setting, children in a nature-based setting spent a significantly greater proportion of this time in unstructured activities engaging in MVPA (30.1±10.5% vs. 22.1±8.4%) and total PA (77.3±8.1% vs. 74.2±8.2%). While these differences are statistically significantly different, practically, a calculated difference of approximately 2-3 minutes between program settings may not reach the threshold of meaningful difference however these results present the potential for children to benefit from increased time spent in a nature-based setting. Additionally, results from the present study are echoed by Ernst and colleagues [55], who assessed the step counts of preschool-aged children who attended either a nature-based or “non-nature” (i.e. traditional) preschool program, where it was found that unstructured play contributed significantly to children’s PA accumulation in a nature-based setting, even in the winter. When considering structured activities in the present study, which consisted of teacher-led activities (i.e. “hands-on”) and learning experiences (i.e.

“lecture”), children were significantly more active in a nature-based compared to a traditional educational setting, once more engaging in a greater proportion of MVPA (11.7±2.8% vs. 10.4±3.5%) and total PA (51.6±5.9% vs. 49.1±6.5%). Previous research has highlighted the importance of both unstructured and structured activities in children’s PA accumulation. In a study conducted by Frank and colleagues [61], preschool-aged children were exposed to three recess conditions, free play, structured movement sessions, and a control condition in which primarily sedentary activities were offered. The findings of this study suggested that children were significantly more active in both free play and structured play compared to the control condition, and that structured movement-based activities aided less-active children in accumulating greater amounts of PA than free play alone. In the present study, structured time in the nature-based setting included time engaging in teacher-led hikes to various outdoor learning and play spaces. Along these hikes learning-based activities which would otherwise take place in a classroom setting, such as writing practice and the learning of the alphabet, would be completed using natural approaches. In this program, this included writing with twigs into the ground, and using firewood to build letters with a partner. In this sense, nature-based learning, through the incorporation of play- and movement-based learning in a natural setting, provided all children with more opportunities to engage in PA, through structured and unstructured approaches, regardless of habitual activity behavior levels.

The environment in which a child learns has a significant impact on the quantities of PA and SB engaged in. It has been suggested that up to 50% of the variation in preschool-aged children’s activity behaviors may be directly attributable to the childcare environment [59]. With the emphasis on time outside, nature-based educational programs have the potential to provide opportunities for PA which programs set in more traditional childcare settings are not able to take advantage of, including opportunities for teachers to incorporate PA into learning practices. This is apparent in the current study when examining the differences in the proportion of time that children spent engaging in PA and SB between program settings, when the teacher remained the same and children were prepared for variations in weather conditions. On average, across both the winter and spring measurement periods, children spent approximately 22.8 minutes in MVPA, 81.9 minutes in total PA, and 58.6 minutes in SB while in a nature-based setting, compared to 19.7 minutes in MVPA, 79.8 minutes in total PA, and 62.2 minutes in SB in a traditional setting. While MVPA was the only activity behavior found to be statistically significantly different between program settings when measurement periods were combined, the winter season, when children are often the least active, was a period in which the nature-based setting provided children with sufficient opportunities that their levels of PA and SB remained comparable to those measured in the spring. In contrast, the winter measurement period in the traditional program setting resulted in approximately 15 less minutes spent in PA, and 15 more minutes engaging in SB compared to the spring assessment period. Irrespective of program setting however, the quantity of light-intensity PA (Traditional: 25.4 min/hr; Nature-Based: 25.2 min/hr), MVPA (Traditional: 8.3 min/hr; Nature-Based: 9.8 min/hr), total PA (Traditional: 33.7 min/hr; Nature-Based: 35.0 min/hr) and SB (Traditional: 26.3 min/hr; Nature-Based: 25.0 min/hr) in which children engaged during the present study, were both meaningfully better than findings by O'Brien and colleagues [133] who conducted a review of studies to compile the mean values of light-intensity PA (13.1 min/hr), MVPA (6.1 min/hr), total PA (19.6 min/hr) and SB (41.2 min/hr) which preschool-aged children engaged in across various childcare settings in North America. Findings from the current study may suggest that, while the program setting and environment is important to providing children with greater opportunities to engage in PA throughout the school day, the overall educational program children attended may have followed a more active approach to education than many other childcare programs, regardless of classroom setting, and warrants further investigation.

Overall, participants in the present study consistently spent a large proportion of each class period engaging in PA regardless of a nature-based or traditional classroom assignment. Despite class periods lasting just 2.5 hours, the accumulation of total PA for children involved in this study ranged from 38% (69 min, Traditional, Girls, Winter) to 50% (90min, Traditional, Boys, Spring) of the recommended 180 minutes daily [143] across school settings and measurement periods. Time outside has been suggested to have a strong positive impact on children's PA and SB [67]. In a nature-based setting time outside encompassed a significant proportion of a total class period, equating to approximately 1/3rd of class time during the winter, and nearly ¾th's of class time during the spring. In this program, time outside was not just associated with unstructured free play, but also included periods of structured activities which were both learning- and movement-focused. It has previously been shown that even small changes to incorporate natural spaces into a school day can effectively improve children's activity behaviors [197]. By viewing the incorporation of nature-based educational experiences on a continuum, both the traditional classroom space, which included a natural playground and open classroom concept, and the nature-based program setting, located at a nature-center surrounded by natural play spaces and hiking trails, can be considered as likely to contribute greater opportunities for children to be physically active than in a traditional preschool setting with limited access to outdoor spaces. In the present study, although a greater proportion of unstructured time was spent engaging in PA, both unstructured and structured periods of class time provided meaningful opportunities for children to accumulate PA. This can be seen by the approximately $2/3^{rd}$ of total class-time PA accumulation occurring during structured periods of the day, relative to the approximately $1/3^{rd}$ accumulated during unstructured periods across both classroom settings. The relationship between time outside and children's engagement in both unstructured free-play and structured periods of learning and teacher-led activities in childcare settings presents a promising approach to enhance PA levels and begin building healthy activity behaviors from a young age, warranting further investigation.

This study was not without limitations. First and foremost, the pilot nature of this study included a small sample size of participants from a single preschool program which alternated days between two classroom settings across two four-day school weeks. Therefore, although positive outcomes were found among children attending preschool in a nature-based setting, further research is necessary on a larger scale to replicate results. Additionally, data collection did not take place during the beginning of the school year in the fall, potentially limiting the seasonal interpretation of results. In a preschool program however, the beginning of the school year is a period in which teachers, children, and their families are acclimating to a new setting and schedule, and it was therefore decided among researchers and school leaders to begin data collection at a later time when children had fully adapted and committed to the program. Finally, a number of approaches unique to young children were taken to remain transparent with participants in this study and provide children with a voice for their participation. Children enrolled in this study provided daily verbal assent to wear an accelerometer, received assistance in their appropriate placement, and a researcher remained present throughout data collection periods to reduce burden placed on teachers.

Conclusion

To our knowledge, this was one of the first studies conducting a within-child comparison of preschool-aged children's activity behaviors between a nature-based and traditional classroom setting. During early education, children are already beginning to form the activity habits they will carry and continue to develop into adulthood. Therefore, any intervention promoting higher levels of PA at this age should be explored. Results from this study suggest that modifying educational practices to include outdoor education has the potential to increase the quantity of in-school PA children accumulate while simultaneously reducing SB. Future research should focus on expanding the transfer of the educational practices followed within this nature-based program (time outside engaging in structured learning- and movement-based activities) to a traditional educational setting, to explore the magnitude by which children's in-school activity behaviors can be positively influenced.

CHAPTER 6: SUMMARY AND CONCLUSION

In the United States, children and adolescents continue to struggle with meeting physical activity (PA) recommendations, while engaging in excessive amounts of sedentary behaviors (SB) throughout the day [37, 139]. Moreover, the prevalence of youth failing to engage in sufficient levels of PA, and those who accumulate high levels of SB, both increase significantly from childhood into adolescence [87, 139]. When considering opportunities to address youth activity behaviors, the school setting presents as a location in which meaningful changes can be implemented with the potential to impact a large proportion of children and adolescents beginning from a young age. Across the United States, more than 98% (>56 million) of all children and adolescents attend either a public or private school [127, 128], consisting of approximately 180 instructional days with each lasting an average of six hours, and in which roughly 75% of that time is spent engaging in SB [153, 182]. In addition to the large quantities of SB which children and adolescents accumulate during the school day, and despite the overwhelming consensus of the responsibility schools have in supporting the physical and mental/cognitive health of students, traditional opportunities for PA in school have decreased over time and not been effectively replaced [91]. Therefore, the purpose of this dissertation was to explore how children and adolescent's school time PA and SB are associated with the educational setting, and how these behaviors change over the course of the school year. To address this purpose, three individual studies were completed.

STUDY 1: COMPARISON OF MEASURES OF ELEMENTARY STUDENT'S CLASSROOM POSTURAL BEHAVIORS USING DIRECT OBSERVATION AND ACCELEROMETRY IN A SCHOOL SETTING

The first study of this dissertation involved the secondary analysis of two commonly used methods of measuring PA and SB in the assessment of children and adolescent's postural behaviors in the classroom while using either a traditional seated or stand-biased desk. Participating students wore an accelerometer, with a built-in inclinometer, on the waist and were simultaneously observed using a focal-point time-sampling approach while using either a traditional seated or stand-biased desk in the classroom. Results from this analysis suggest that desk assignment, but not lower limb fidgeting, had a significant impact on the difference between accelerometer and direct observation measurements of the proportion of time that participants spent sitting. Specifically, it was found that the approach used for direct observation in the present study consistently estimated a higher proportion of observed time spent sitting, and a lower proportion of time standing than accelerometer measures of each postural position. Furthermore, when students were assigned to a stand-biased desk the difference in estimates of the proportion of time spent sitting were significantly smaller than when using a traditional seated desk in the classroom. While the present analysis compares accelerometer data with direct observations recorded using a time-sampling approach, these findings display similar differences as those found within the limited research examining the ability of the Actigraph GT3X+ inclinometer to accurately determine postural positions of youth [43, 71]. Additionally, it was considered that lower limb fidgeting may potentially result in a misclassification of inclinometer-measured posture as either walking or stepping [4], while our analysis suggests that not only was there a minimal effect of lower limb fidgeting on the differences between measurements of posture, but also that students engaged in similar amounts of lower limb fidgeting across desk types. Research is only as good as the measures used, therefore the contribution of this study to the literature highlights the discrepancies between two commonly employed methods of measurement in the estimation of postural behaviors, particularly when modifications to the classroom environment take place. As schools continue to seek out ways to reduce the quantity of SB students accumulate through alterations to the learning environment, the method of measurement used to assess these behaviors warrants further consideration.

STUDY 2: AN EXPLORATION INTO THE VARIATION OF CHILDREN'S IN-SCHOOL PHYSICAL ACTIVITY BEHAVIORS ACROSS THE SCHOOL YEAR

This second study was an exploratory secondary analysis of data examining factors which are associated with the variation in elementary student's school day PA behaviors across the school year. Participating students completed the Youth Activity Profile (YAP), a validated instrument [57, 83, 164-166, 171, 196] used to estimate quantities of moderate- to vigorous-intensity PA (MVPA) during the school day, on five separate occasions throughout the year. Previous work has highlighted the potential of active transportation as a means to improve youth activity levels [65], however a number of environmental factors, including weather, influence the decision to engage in this activity and other's which may occur outside [6, 58, 99]. The results of this analysis suggested that elementary students weekly MVPA varied significantly across the school year, particularly between the early fall, winter, and spring periods. Specifically, the estimated weekly accumulation of time in MVPA while engaging in active transportation to school was significantly different between the months of September and December, while the accumulation of MVPA during active transportation home from school significantly differed between the months of September and December, March, and April, respectively. Although these differences in quantities of MVPA were statistically significant, the difference between the most and least active periods of active transportation to school was just 1.4 minutes/week, while significant differences in active transportation home from school ranged between 2.5 to 3.5 minutes/week between the most and least active periods of assessment. Therefore, these primary findings may not be the most meaningfully different, however they do lend insight into the manner by which variation in school day PA may be primarily driven by opportunities which occur outdoors thus being more susceptible to changes in weather. In examining the remaining active periods of the school day, the contribution towards weekly MVPA provided by recess and physical education class did not vary significantly throughout the school year, with recess being the largest contributor towards participants weekly MVPA for those who received it. These results are similar to those previously published which have found relatively consistent levels of PA during physical education class [104] and recess [155, 156, 162] over time. Overall, the findings from this analysis contribute to the literature by specifically looking at the variation in children and adolescents PA surrounding the in-school period, an otherwise structured period of the day with established opportunities in which PA are meant to take place. Understanding how these periods of PA change across the school year, and which vary the greatest during that time, can lend insight into potential areas for intervention moving forward.

STUDY 3: COMPARISON OF CHILDREN'S PHYSICAL ACTIVITY AND SEDENTARY BEHAVIORS BETWEEN A NATURE-BASED AND TRADITIONAL EDUCATIONAL SETTING

The third and final study of this dissertation involved the within-subjects assessment of the PA and SB of children from a single Pre-Kindergarten (Pre-K) program which alternated school days between a traditional school setting, and a nature-based setting. Participating children wore an accelerometer on the waist during school hours for one, four-day school week, at two different times during the school year, once in the winter, and again in the spring. On Monday and Wednesday of each week Pre-K classes were held in a traditional school setting, while on Tuesday and Thursday Pre-K classes were held in a primarily outdoor setting at a nature center. Throughout the study, children had the same teacher and teacher aides, with only the program setting changing. Our results suggest that overall, across both measurement periods children spent a significantly greater proportion engaging in MVPA while in a nature-based compared to a traditional school setting. Moreover, during the winter season in which PA levels are typically lowest among children, the proportion of time spent in MVPA was nearly identical to that which occurred during the spring. The maintenance of PA levels between seasons in a nature-based setting were in contrast to what was witnessed in a traditional setting, where a large increase in the proportion of time spent in MVPA, coupled with a large decrease in SB occurred from the winter to the spring period. Further breaking down each day into periods of structured and unstructured time, the winter season once again witnessed a significantly greater proportion of class time being spent engaging in MVPA while in a nature-based, compared to a traditional classroom setting during both structured and unstructured activities. With the added context provided by observations made throughout class periods, the findings of this study make sense when it is considered that normally sedentary learning-based activities which took place in a traditional school setting (ex. writing practice at a workstation) were more active in a nature-based setting (ex. stopping during a hiking activity to practice writing in the dirt or collecting logs from a woodpile to build letters). In a time where youth are spending increasing amounts of time indoors [12, 195], these findings compliment and expand upon a growing body of literature supporting the benefits to children's PA levels when attending educational programs which incorporate components of nature into the curriculum [107, 184, 197]. Additionally, this study was one of the first to conduct a within-child comparison of PA and SB while alternating school days between a traditional and nature-based school setting across the winter and spring seasons. Better understanding the ways in which modifying educational practices to incorporate outdoor education can enhance in-school PA while simultaneously decreasing SB, can lend insight to truly traditional educational settings seeking to positively influence the development of students' healthy activity behaviors.

Collectively, the three studies within this dissertation provide support to the notion that the school setting has the potential to provide meaningful and consistent opportunities for children and adolescents to engage in more active behaviors throughout the school day, however these may be negatively influenced by factors such as weather/seasonality, and traditional practices limiting the quantity of activity engaged in while in school. While the first study was methodologically focused, the results of our research are ultimately only as good as the measures used for assessment. Therefore, this study contributes to a better understanding of how these measurement techniques can be applied while reinforcing the difficulties encountered when attempting to assess youth activity behaviors collected through different means and within altered educational environments. Studies two and three look more broadly at the distribution of child and adolescent PA and SB in school over time, and reinforce the means by which the school setting can support the engagement in physically active behaviors across the school day. While study two suggested that the most variable active periods of the school day occur during times spent outside, the consistency by which the school day provides these opportunities for PA provided a certain amount of stability to the weekly accumulation of PA, even if these amounts were estimated to fall well below the recommendation of 30-minutes per day in school. Study three then expanded on the concepts of seasonality and altering the school environment to suggest that, when both students and teachers are prepared and able to spend time during the school day outside, regardless of season, previously documented declines in children and adolescents PA levels as a result of poorer weather conditions can be successfully moderated.

While the findings from the studies presented within this dissertation provide insight into ways that schools can enhance children and adolescents' activity behaviors while under their care, it must also be acknowledged that most documented statistically significant differences were in reality small and therefore may not have been meaningfully different over time. However, these findings provide a starting point on which future research can further explore and intervene on specific aspects of the school day, including the breaking up of long periods of SB in the classroom, active transportation to- and from-school, and ways in which structured periods of the school day can be made more active whether in an indoor or outdoor setting. Overall, school time is a structured and consistent period where children and adolescents spend much of their formative years developing the knowledge, skills, and behaviors which will influence the rest of their lives. Therefore, it is in the hands of teachers, staff, and administrators to take advantage of this time in school and provide sufficient opportunities for all students to engage in more active behaviors which will positively aid in their growth and development during the earliest years of their lives.

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Appendix A – Summary Table of ActiGraph Accelerometer Calibration Studies and Resulting Cut-Point Determinations for Youth Physical Activity and Sedentary Behavior Research

Reference	Participants	Device + Wear Location	Sampling Frequency	Epoch	Cut-Points (cpm)	Criterion Measure
Freedson (1997)[62]	N = 80 Range = 6-17 yr Mean age = 11.3 yr 41 girls, 39 boys	CSA 7164 Right Hip	10 Hz	1-minute	*	Indirect calorimetry
Trost (1998)[191]	N = 30 Range = 10-14 yr Mean age = 11.6 yr 11 girls, 19 boys	CSA 7164 R + L Hip	10 Hz	1-minute	*	Indirect calorimetry
Puyau (2002)[147]	N = 26 Range = 6-16 yr Mean age = 10.7 yr 12 girls, 14 boys	CSA 7164 Right Hip	10 Hz	1-minute	SB: <800 LPA: ≥800, <3200 MPA: ≥3200, <8200 VPA: ≥8200	Room respiration calorimetry
Ekelund (Riddoch; 2004)[152]	N = 1292 Mean age = 9.7 yr 654 girls, 638 boys	CSA 7164 Right Hip	10 Hz	1-minute	SB: <500 LPA: ≥500, <2000 MPA: ≥2000, <3000 VPA: ≥3000	n/a
Treuth (2004)[185]	N = 74	CAS 7164	10 Hz	30-seconds	SB: ≤100	Indirect calorimetry

	Range = 13-14 yr 74 girls	R + L Hip			LPA: >100, <3000 MPA: ≥3000, <5201 VPA: ≥5201	
Sirard (2005)[176]	N = 16 Range = 3-5 yr Mean age = 4.0 yr 6 girls, 10 boys N = 269 Range = 3-5 yr Mean age = 4.0 yr 144 girls, 125 boys	ActiGraph 7164 R + L Hip	10 Hz	15-seconds	3 yr SB: <1208 LPA: 1208-2459 MPA: 2460-4923 VPA: ≥4924 4 yr SB: <1456 LPA: 1456-3247 MPA: 3248-4939 VPA: ≥4940 5yr SB: <1596 LPA: 1596-3563 MPA: 3564-5019 VPA: ≥5020	Direct Observation: Child Activity Rating Scale (CARS) – 15-s momentary sampling
Pate (2006)[138]	N = 30 Range = 3-5 yr Mean age = 4.4 yr 17 girls, 13 boys	Actigraph 7164 Right Hip	10 Hz	15-seconds	SB: ** LPA: ** MPA: 1680-3367 VPA: ≥3368	Indirect calorimetry
Mattocks (2007)[114]	N = 163 Mean age = 12.4 yr 90 girls, 73 boys	ActiGraph 7164 Right Hip	10 Hz	10-seconds	SB: ≤100 LPA: >100, <3581 MPA: ≥3581, <6130 VPA: ≥6130	Indirect calorimetry

Evenson (2008)[56]	N = 33 Range = 5-8 yr Mean age = 7.3 yr 21 girls, 12 boys	ActiGraph 7164 Right Hip	10 Hz	15-seconds	SB: ≤100 LPA: >100, <2296 MPA: ≥2296, <4012 VPA: ≥4012	Indirect calorimetry
van Cauwenberghe (2011)[193]	N = 18 Mean age = 5.8 yr	ActiGraph GT1M Right Hip	30 Hz	15-seconds	SB: <1492 LPA: 1492-2339 MPA: 2340-3523 VPA: ≥3524	Direct Observation: Child Activity Rating Scale (CARS)
Hänggi (2013)[71]	N = 49 Range = 10-15 yr Mean age = 10.8 yr 22 girls, 27 boys	Actigraph GT3X Right Hip	n/a	1-second	Vector Magnitude SB: <180 LPA: 180-3360 MVPA: >3360	Indirect calorimetry
Crouter (2013)[44]	N = 109 Range = 8-15 yr Mean age = 11 yr 52 girls, 57 boys	Actigraph GT3X Right Hip	30 Hz	1-second	*	Indirect calorimetry
Romanzini (2014)[157]	N = 79 Range = 10-15 yr 39 girls, 40 boys	Actigraph GT3X R + L Hip	n/a	15-seconds	Vertical Axis SB: <185 LPA: 185-2427 MPA: 2428-3271 VPA: ≥3272 Vector Magnitude SB: <721 LPA: 721-3027 MPA: 3028-4447	Indirect calorimetry

					VPA: ≥4448	
Butte (2014)[28]	Room calorimetry N = 50 Range = 3-5 yr Mean age = 4.5 yr Doubly Labeled Water N = 105 Range = 3-5 yr Mean age = 4.6 yr	Actigraph GT3X+ Right Hip	n/a	15-seconds	Vertical Axis SB: <240 LPA: 240-2119 MPA: 2120-4449 VPA: ≥4450 Vector Magnitude SB: <820 LPA: 820-3907 MPA: 3908-6111 VPA: ≥6112	Room respiration calorimetry Doubly Labeled Water

*For studies reviewed which presented a regression equation instead of cut-points, the equation is listed below.

- Freedson (1997): METs = 2.757 + (0.0015 x cpm) – (0.08957 x age (yr)) – (0.000038 x cpm x age (yr))
- Trost (1998): Kcal/min = -2.23 + (0.0008 x cpm) + (0.08 x body mass (kg))
- Crouter (2012): Two-regression equation models using Vertical Axis and Vector Magnitude
    - Vertical Axis if counts/10-sec >25 and coefficient of variation (CV) ≤35; MET = $1.982^{(0.00101 \text{ x counts/10-s})}$
    - Vertical Axis if counts/10-sec >25 or CV >35; MET = 2.842 + (0.00288 x counts/10-s)
    - Vector Magnitude if counts/10-sec >75 and CV ≤25; MET = $0.0137^{(0.848 \text{ x ln(vector magnitude counts/10-s))}}$
    - Vector Magnitude if counts/10-sec >75 or CV >25; MET = 1.219 – (0.145 x (ln(vector magnitude counts/10-s) – (0.0586 x ln(vector magnitude counts/10-s))^2) + (0.0229 x (ln(vector magnitude counts/10-s))^3

**Pate (2006) only defined CP for moderate- and vigorous-intensity physical activity.

Appendix B – Summary Table of Direct Observation System's Used in Youth Physical Activity and Sedentary Behavior Research

Reference	**Participants***	**Calibration Methods**	**Reliability**	**Criterion Measure**	**Validity**
Puhl (1990)[146] – Children's Activity Rating Scale (CARS)	N = 25 Range = 5-6 yr Mean age = 5.6 yr 13 girls, 12 boys	5-level scale to categorize intensity of physical activities Observation made at beginning of each minute and throughout each minute if intensity category changes	Inter-rater reliability = 84.1%	VO_2, HR	VO_2 and HR were significantly different between activities representing 5-levels on scale
Bailey (1995)[7] – Modified Fargo Activity Time sampling Survey (FATS)	N = 4 Range = 7-10 yr Mean age = 8.3 yr 2 girls, 2 boys	30 of 42 possible activity/intensity codes replicated 3-second continuous time sampling across 24-minute block in laboratory controlled "free-living" conditions.	Inter-rater reliability = 91.0%	VO_2, HR	High correlation between VO_2 and HR (r = 0.95). Activity intensity categorized by measured VO_2
Epstein (1984)[54] – Activity Patterns and Energy Expenditure (APEE)	N = 19 Range = 5-8 yr Mean age = 7.2 yr 19 girls	15-second time sampling interval 5-level activity scale based on perceived energy expenditure during free-living conditions	Inter-rater reliability = 93.3%	HR	Total correlation high between HR and activity intensity categories (r = 0.82)

O'Hara (1989)[135] – Children's Physical Activity Form (CPAF)	N = 36 Range = 8-10 yr Mean age = 8.9 yr 18 girls, 18 boys	4-category scale representing different intensity levels of movement during Physical Education class 1-minute time sampling interval checking all categories of intensity occurring in each minute	Inter-rater reliability = 97.0%	HR	Time-series model correlations between HR and observed activity intensity acceptable range (r = 0.61-0.72)
McKenzie (1991)[119] – Behaviours of Eating and Activity for Children's Health Evaluation System (BEACHES)	N = 19 Range = 4-9 yr Mean age = 6.3 yr	5-category physical activity scale 25-second observation interval followed by 35-second recording interval	Inter-rater reliability = 94.0-99.0%	HR	HR increased with each activity code increment (Range = 99-153 bpm)
Rowe (1997)[159] – System for Observing Fitness Instruction Time (SOFIT)	N = 173 Range = Grades 1-8 Mean age = 10.6 yr 81 girls, 92 boys	5-category physical activity scale representing different intensity levels of movement during Physical Education class 10-second momentary time sampling every 20-second interval	n/a	HR	Categories 2-5 witnessed increase in HR between levels, while categories 1-2 did not witness differences in HR levels.
McKenzie (1991)[118] – System for Observing	N = 88 Range = Grades 3-5	5-category physical activity scale representing different intensity levels	Inter-rater reliability = 88.3-91.8%	Lesson Context Categories	Correlations to class-time allocated to fitness

Fitness Instruction Time (SOFIT)		of movement during Physical Education class 10-second momentary time sampling every 20-second interval		- Fitness	Standing: r = -0.645 Walking: r = 0.488 Very Active: r = 0.360 MVPA: r = 0.685
Klesges (1984)[89] – Fargo Activity Time sampling Survey (FATS)	N = 14 Range = 2-4 yr 7 girls, 7 boys	8-categories of child behavior related to different intensities of activities 10-second momentary time sampling every 20-second interval	Inter-rater reliability = 91-98%	Physical Activity Recorder - LSI	Composite index correlation of the activity observed compared to the activity monitor was high (r = 0.90)
Sharma (2011)[173] – System for Observing Fitness Instruction Time for Preschoolers (SOFIT-P)	N = 27 Range = 3-6 yr Mean age = 3.8 yr 16 girls, 11 boys	5-category physical activity scale modified to represent different intensity levels of movement in a preschool setting 10-second momentary time sampling every 20-second interval	Inter-rater reliability = 78-92%	ActiGraph GT3X Accelerometer	Correlations between observations and accelerometer recorded activity were moderate SOFIT-P MPA vs. GT3X SB: -0.532 MPA: r = 0.506 MVPA: r = 0.532 SOFIT-P MVPA vs. GT3X SB: r = -0.541 MPA: r = 0.530 MVPA: r = 0.541

					SOFIT-P SB vs. GT3X SB: r = 0.541
Brown (2006)[25] – Observational System for Recording Physical Activity in Children-Preschool Version (OSRAC-P)	n/a	8-observational categories indicating context surrounding different movement behaviors among preschoolers 5-second momentary time sampling every 30-second interval	Inter-rater reliability = 85-100%	n/a	n/a
McIver (2009)[115] – Observational System for Recording Physical Activity in Children-Home (OSRAC-H)	N = 13 Mean age = 4.5 yr 6 girls, 7 boys	10-observational categories indicating context surrounding different movement behaviors in the home 5-second momentary time sampling every 30-second interval	Inter-rater reliability = 88-99%	n/a	n/a
McIver (2016)[116] – Observational System for Recording Physical Activity in Children-Elementary School (OSRAC-E)	N = 71 Grades K-5 32 girls, 39 boys	9-observational categories indicating context surrounding different movement behaviors in an elementary school setting 5-second momentary time sampling every 30-second interval	Inter-rater reliability = 96.9-99.7%	n/a	n/a

*When validation data is provided, the participant values reflect those who participated in the validation portion of the study. Participant values provided for observation systems without validation data indicate participants involved in initial pilot testing.

Appendix C – Youth Activity Profile: Survey

Before you begin, it is important to get some basic information about your school and about you.

Circle your Gender: Male Female

Circle your School Level: Elementary School Middle School High School

Circle your Grade: 3 4 5 6 7 8 9 10 11 12

ID _____________

How many days each week do you have PE?
a. 0 days (never)
b. 1 day
c. 2 days
d. 3 days
e. 4 days
f. 5 days

How many recess breaks / study hall periods do you have per day?
a. 0
b. 1
c. 2
d. 3
e. 4

How many times last week did you attend sessions or practices for sports or structured physical activities that were led by a coach, instructor or leader
a. 0
b. 1
c. 2
d. 3
e. 4
f. 5 or more

The Youth Activity Profile will ask you about the time you spend being active (both in school and out of school) and the time you spend being sedentary.

- **Physical activities** are things that involve a lot of walking, running or moving around. It includes biking and dancing as well as sports or outdoor play that involves a lot of moving around.

- **Sedentary activities** are things such as watching TV, or playing video games, computer games, or hand-held games that you do in your free time. It does NOT include the time you spend sitting while eating or while doing homework.

Most questions will ask you only to think about the last 7 days but a few questions will ask about what you typically do (on a normal week). There are no right or wrong answers so provide honest answers.

Youth Activity Profile
Activity Levels - at School

Activity Levels - at School. These questions ask about your physical activity at school. This includes physical education but you may also be active on your way to school, during breaks, or at lunch. Answer the questions based on your physical activity at school in the last 7 days.

1. Activity To School: How many days did you **walk or bike to school**? *(If you can't remember, try to estimate)*
a. 0 days (never)
b. 1 day
c. 2 days
d. 3 days
e. 4-5 days (most every day)

2. Activity during Physical Education Class: During **physical education**, how often were you running and moving as part of the planned games or activities? *(If you didn't have PE, choose "I didn't have physical education")*
a. I didn't have physical education
b. Almost none of the time
c. A little bit of the time
d. A moderate amount of time
e. A lot of the time
f. Almost all of the time

3. Activity during Breaks/Study Hall: During **recess breaks or study halls**, how often were you playing sports, walking, running, or playing active games? *(If you didn't have a break at school, choose "I didn't have breaks/study hall")*
a. I didn't have recess breaks/study hall
b. Almost none of the time
c. A little bit of the time
d. A moderate amount of time
e. A lot of the time
f. Almost all of the time

4. Activity during Lunch: During **lunch break**, how often were you moving around, walking or playing? *(If you didn't have a lunch break at school, choose "I didn't have lunch breaks")*
a. I didn't have lunch breaks
b. Almost none of the time
c. A little bit of the time
d. A moderate amount of time
e. A lot of the time
f. Almost all of the time

5. Activity from School: How many days often did you **walk or bike from school**? *(If you can't remember, try to estimate)*
a. 0 days (never)
b. 1 day
c. 2 days
d. 3 days
e. 4-5 days (most every day)

Youth Activity Profile
Activity Levels at Home

Activity Levels - Outside of School. These questions ask about your overall levels of physical activity during different periods of time (outside of school time). This would include structured exercise or sport activities as well as activity playing with friends, dancing or doing work/chores. Answer the questions based on your physical activity outside of school in the last 7 days.

6. Activity before School: How many days **before school (6:00-8:00 am)** did you do some form of physical activity for at least 10 minutes? (This includes activity at home NOT walking or biking to school)
a. 0 days
b. 1 day
c. 2 days
d. 3 days
e. 4 to 5 days

7. Activity after School: How many days **after school (between 3:00 -6:00 pm)** did you do some form of physical activity for at least 10 minutes? (This can include playing with your friends/family, team practices or classes involving physical activity but *NOT walking or biking home from school*)
a. 0 days
b. 1 day
c. 2 days
d. 3 days
e. 4 to 5 days

8. Activity on Weeknights: How many **school evenings (6:00-10:00 pm)** did you do some form of physical activity for at least 10 minutes? (This can include playing with your friends/family, team practices or classes involving physical activity but *NOT walking or biking home from school*)
a. 0 days
b. 1 day
c. 2 days
d. 3 days
e. 4 to 5 days

9. Activity on Saturday: How much physical activity did you do last **Saturday**? (*This could be for exercise, work/chores, family outings, sports, dance, or play. If you don't remember, try to estimate)*
a. No activity (0 minutes)
b. Small amount of activity (1 to 30 minutes)
c. Small to Moderate amount activity (31 to 60 minutes)
d. Moderate to Large amount of activity (1 to 2 hours)
e. Large amount of activity (more than 2 hours)

10. Activity on Sunday: How much physical activity did you do last **Sunday**? (*This could be for exercise, work/chores, family outings, sports, dance, or play. If you don't remember, try to estimate)*
a. No activity (0 minutes)
b. Small amount of activity (1 to 30 minutes)
c. Small to Moderate amount activity (31 to 60 minutes)
d. Moderate to Large amount of activity (1 to 2 hours)
e. Large amount of activity (more than 2 hours)

Youth Activity Profile
Sedentary Habits

These questions ask about time spent resting and sitting. You probably sit while eating, doing homework, or playing musical instruments. But you also may spend time sitting while watching TV, playing video games, using the computer or using your phone, or iTouch/iPad). Answer these questions about the time you spent sitting during these activities <u>in the past 7 days</u>.

11. TV Time: How much time did you spend **watching TV** outside of school time (*This includes time spent watching movies or sports but NOT time spent playing video games*).
a. I didn't watch TV at all
b. I watched less than 1 hour per day
c. I watched 1 to 2 hours per day
d. I watched 2 to 3 hours per day

e. I watched more than 3 hours per day

12. Video Game Time: How much time did you spend **playing video games** outside of school time? (*This includes games on Nintendo DS, wii, Xbox, PlayStation, iTouch, iPad, or games on your phone*)
a. I didn't really play at all
b. I played less than 1 hour per day
c. I played 1 to 2 hours per day
d. I played 2 to3 hours per day
e. I played more than 3 hours per day

13. Computer Time: How much time did you spend using **computers** outside of school time? (*This doesn't include homework time but includes time on Facebook as well as time spent surfing the internet, instant messaging, playing online video games or computer games*)
a. I didn't really use the computer at all
b. I used a computer less than 1 hour per day
c. I used a computer 1 to 2 hours per day
d. I used a computer 2 to3 hours per day
e. I used a computer more than 3 hours per day

14. Phone / Text Time: How much time did you spend using your **cell phone** after school? (*This includes time spent talking or texting*).
a. I didn't really use a cell phone
b. I used a phone less than 1 hour per day
c. I used a phone 1 to 2 hours per day
d. I used a phone 2 to 3 hours per day
e. I used a phone more than 3 hours per day

15. Overall Sedentary Habits: Which of the following best describes your **typical** sedentary habits at home? *(Try to think about a typical week and not just last week)*
a. I spent almost none of my free time sitting
b. I spent little time sitting during my free time
c. I spent a moderate amount of time sitting during my free time
d. I spent a lot of time sitting during my free time
e. I spent almost all of my free time sitting

Appendix D – Youth Activity Profile: Scoring

Participant responses to the YAP first undergo a raw scoring process to determine the predicted percentage of time that a respondent spends in MVPA or SB. Following the raw scoring, participants predicted activity levels can be further converted to estimated weekly minutes of MVPA and SB distributed across the in-school, out-of-school, and weekend periods.

To perform the raw scoring of the YAP, each item is first scored on a 0-4 scale, with the exception of a respondent not participating in a specific activity listed on the questionnaire (ex. no PE, recess, or time for PA during lunch), in which an estimate of MVPA for that period of the day will not be made. Welk and colleagues [195] have developed and refined item-specific regression equations (N=10) which utilize each item's YAP response score (YAP; 0-4), the respondents grade level (GRADE; 0 = elementary school (≤5th grade), 1 = middle school (6th–8th grades), and 2 = high school (≥9th grade), and sex (SEX; 0 = male, 1 = female) to estimate the proportion of time spent in either MVPA or SB during item-specific periods of the school week. In total, there are 10 regression equations available, one regression equation for each period of the day; the lunch period has been excluded due to inconsistencies in MVPA across participants during this time. The regression equations are as follows:

In-School (%MVPA)

- Transportation to school = 3.33 + (2.50 x YAP) – (1.67 x GRADE) + (0.00 x SEX)
- PE = 23.95 + (1.87 x YAP) + (9.84 x GRADE) – (15.7 x SEX)
- Recess = 45.28 + (5.90 x YAP) + (0.00 x GRADE) – (28.2 x SEX)
- Lunch = N/A
- Transportation to home = 12.50 + (5.54 x YAP) – (0.67 x GRADE) – (5.17 x SEX)

Out-of-school (%MVPA)

- Before school = 7.11 + (0.92 x YAP) – (1.33 x GRADE) – (4.44 x SEX)
- After school = 9.23 + (3.30 x YAP) – (2.83 x GRADE) – (4.39 x SEX)
- Evening = 7.53 + (1.91 x YAP) – (2.41 x GRADE) – (3.49 x SEX)

Weekend (%MVPA)

- Saturday = 7.35 + (2.63 x YAP) – (4.09 x GRADE) – (3.26 x SEX)
- Sunday = 7.77 + (2.53 x YAP) – (3.23 x GRADE) – (3.85 x SEX)

Out-of-school (%SB)

- Weekday out-of-school = 41.58 + (5.14 x YAP) + (12.01 x GRADE) + (10.82 x SEX)

With additional knowledge surrounding the school schedule, predicted percentages of time spent in MVPA or SB can be converted to predicted weekly minutes for each period of activity indicated above. Using information from a student's school schedule, the predicted percentage of time spent in MVPA is multiplied by the number of days the activity period occurs (ex. recess 2x per day, 5 days/week = 10; PE 2x per week = 2), and by the total minutes per day making up each period of activity (ex. weekend = 6:00am – 10:00pm = 960 minutes; PE = 11:00 am – 12:00pm = 60 minutes). Furthermore, the 30 minutes immediately before and after the school day are considered the time periods in which transportation to and from school occur, respectively. The 'before school' period will begin at 6:00am until 30 minutes prior to the start of school, while the 'after-school' period will begin 30 minutes after school ends until 6:00pm, and the 'evening' period will last from 6:00pm to 10:00pm. For SB occurring out-of-school on weekdays, the estimated period of time being measured will be from 30 minutes after school ends until 10:00pm.

Appendix E – Protocol for the comparison of one observational period using 5-second momentary time sampling intervals over 5-minutes, and simultaneous 300-second accelerometer recording

	Length of one observation period (seconds)																				
Method	0 - 5	5 - 30	30 - 35	35 - 60	60 - 65	65 - 90	90 - 95	95 - 120	120 - 125	125 - 150	150 - 155	155 - 180	180 - 185	185 - 210	210 - 215	215 - 240	240 - 245	245 - 270	270 - 275	275 - 300	*Total data recorded per observation period*
Direct Observatio	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**Obs**	Record	**50-seconds**
Accelerometer	**Continuous accelerometer data collection**																				**300-seconds**

Appendix F – Study 3: Study Information Sheet

UWM physical activity and health research lab

INFORMATIONAL SHEET:

HOW MUCH DO YOU MOVE IN AN OUTDOOR PRESCHOOL PROGRAM?

What is it?	A research project where we are trying to determine how much your child moves (how physically active they are), and what types of physical activities your child performs while attending this nature-based preschool program.
When will this study take place?	Winter and Spring 2019
Where will this study take place?	At [Insert nature center's name & address]
Why are we doing this study?	Most children spend a large portion of their day sitting or otherwise being sedentary, which can have long-term negative physical and mental health consequences. It has been suggested that children who spend more time outdoors, and specifically in natural environments with opportunities for free, unstructured play, tend to engage in more physically active behaviors, while also experiencing an increase in positive emotions. Nature-based preschool programs not only present the opportunity for children to spend more time in a natural outdoor setting, but programs which actively immerse children into their natural surroundings may also lead to healthier behaviors throughout their life. However, no one has ever measured how active children really are when they attend programs like these, to confirm that they are more active. Additionally, we do not know what types of activities make children more active or otherwise encourage more physically active behaviors.
What is required of the students?	They will be asked to wear an activity tracker (similar to a fitbit) attached to an elastic belt around the waist while attending the program. These devices will be handed out at the start of each day and returned at the end of each day before child pickup. Nothing will be required of your child outside of the program.

	We will also observe program activities each day to document the types of activities included in the program, while determining which activities lead to higher amounts of physical activity over others.
What is required of the parents?	Parents will be asked to fill out a questionnaire about their child's current health and demographic information at the start of the study.
What should I do if I am interested in enrolling my child into this study?	If you are interested in enrolling your child into this study please complete the enclosed forms titled: 1. "Parental Permission for Research Participation" 2. "Child Health & Demographics Questionnaire". Once completed, please place these documents into the enclosed envelope and send it back with your child to the [Insert Program Center Name] by the first day of the study (Insert Date). Please also review the form titled, "Minor Assent for Research Participation" with your child. A research team member will complete this document in-person on the first day of the study. We will be sending out a follow-up e-mail in the near future to answer any additional questions you might have and also ask again if you are interested in enrolling as participants into this study. Please feel free to contact me with any questions. Nathan Tokarek ntokarek@uwm.edu (414) 229-4392

Appendix G – Study 3: Caregiver Informed Consent

UNIVERSITY of WISCONSIN UWMILWAUKEE

Parental Permission for Research Participation
IRB #: 19.124
IRB Approval Date: December 6, 2018

Study title	How much do you move in an Outdoor Preschool Program?
Researcher[s]	Nathan R. Tokarek, M.S. PhD Student, Kinesiology College of Health Sciences Ann M. Swartz, Ph.D. Professor, Kinesiology College of Health Sciences

We're inviting you and your child to participate in a research study. Participation is completely voluntary. If you agree to let your child participate now, you can always change your mind later. There are no negative consequences, and your decision to participate or not will not impact the relationship you have with your child's teacher or school.

What is the purpose of this study?

We want to understand the amount and types of physical activities your child performs while attending this preschool program. We will evaluate 100 children while they go about their daily program activities.

Across two separate weeks, once during the winter and again in the spring (Dates:____), we will measure how much your child moves while they attend their preschool program. At the same time, a trained researcher will write down the types and time at which different activities are performed throughout the day.

What will I and my child do?

If you agree to allow your child to participate, he or she will be asked to:

- Be observed during their program session by a researcher from our school while they participate in their normal activities within their program. This procedure is called direct observation. A researcher from UWM will be with their group and document activities performed throughout the day while children go about their daily routine. We will not disrupt learning nor interact with the children during this procedure. This will occur each day across two separate weeks.
- Wear a small monitor called an accelerometer on a belt around the waist while they are attending the program.

If you as a parent/guardian agree to participate you will be asked to complete the following:

Child Health and Demographics Questionnaire

This is a paper/pencil survey that will take approximately 10 minutes to complete. We are requesting this information about you and your family so investigators can control for various health, demographic, or family structure variables when evaluating the data. You will complete this questionnaire at the beginning of the study.

The questionnaires can be completed and placed in a provided sealed envelope and returned to the Program Center to be picked up by a researcher prior to the start of the study.

Risks

Possible risks	How we're minimizing these risks
Breach of confidentiality (your child's data being seen by someone who shouldn't have access to it)	• All identifying information is removed and replaced with a study ID. • We'll store all electronic data on a password-protected, encrypted computer. • We'll store all paper data in a locked filing cabinet in a locked office. • We'll keep your child's identifying information separate from the research data, but we'll be able to link it to them by using a study ID. We will destroy this link after we finish collecting and analyzing the data.

There may be risks we don't know about yet. Throughout the study, we'll tell you if we learn anything that might affect your decision to let your child participate.

Other Study Information

Possible benefits	There are no benefits to you or your child. Results from this research may benefit future children through the development of programs and policies that encourage physical activity.
Estimated number of participants	100 Children
How long will it take?	Two separate weeks, once in the winter and once in the spring (2-4 days, 3-4 hours/day per week)
Costs	No additional cost is associated with your child's participation in this study.
Compensation	None
Future research	De-identified (all identifying information removed) data may be shared with other researchers. You won't be told specific details about these future research studies.
Removal from the study	Participants will be excluded from analysis of the results if they do not wear an accelerometer for a minimum of two complete program days.
Funding source	The Clinical and Translational Science Institute of Southeast Wisconsin is funding this research study.

Confidentiality and Data Security
We'll collect the following identifying information for the research: your child's name and birth date. This information is necessary so that we can compile all your child's data and compare children by age when we analyze the data. Once collected, this information will be coded to protect you.

Where will data be stored?	Data will be stored in a locked cabinet; electronic data will be stored on a password protected computer.
How long will it be kept?	The data will be stored at UWM for 5 years after completion of the study.

Who can see my data?	**Why?**	**Type of data**
The researchers	To analyze the data and conduct the study	Coded (names removed and labeled with a study ID)
The IRB (Institutional Review Board) at UWM The Office for Human Research Protections (OHRP) or other federal agencies	To ensure we're following laws and ethical guidelines	Coded (names removed and labeled with a study ID)
Anyone (public)	If we share our findings in publications or presentations	• Aggregate (grouped) data

Contact information:

For questions about the research	Nathan Tokarek OR Ann Swartz	414-229-4392 ntokarek@uwm.edu 414-229-4242 aswartz@uwm.edu
For questions about your child's rights as a research participant	IRB (Institutional Review Board; provides ethics oversight)	414-229-3173 irbinfo@uwm.edu
For complaints or problems	Ann Swartz	414-229-4242 aswartz@uwm.edu
	IRB	414-229-3173 irbinfo@uwm.edu

Signatures

If you have had all your questions answered and give permission for your child to participate in this study, sign on the lines below. Remember, your child's participation is completely voluntary, and you're free to remove them from the study at any time.

____
Name of Child (print)

____
Name of Parent or Guardian (print)

____ _______________
Signature of Parent or Guardian Date

Appendix H – Study 3: Health History and Demographics Questionnaire

CHILD CURRENT HEALTH HISTORY AND DEMOGRAPHICS QUESTIONNAIRE

Today's Date: ______________________________
Month – Day – Year

1. What is the zip code of the residence where this child primarily lives? ___________

2. What is your relationship to this child? Please circle one.

   Mother

   Father

   Step-Mother

   Step-Father

   Foster Mother

   Foster Father

   Grandmother

   Grandfather

   Other (please specify): _________________

3. How is this child's overall health at the present time? Please circle one.

   Excellent   Very Good   Good   Fair   Poor   Very Poor

4. How many siblings does this child have? ____________

5. How many children under the age of 18 are currently living in this child's household? Please only consider the household where the child spends the majority of their time:

____

Child Demographic Questions

6. What is this child's birth date? ____________________
Month – Year

7. How would you describe this child's race/ethnicity? Please circle all that apply.

American Indian/Alaska Native

Asian

Native Hawaiian/Other Pacific Islander

Black or African American

White or Caucasian

Unknown

Other (please specify): _______________

8. Do you consider this child Spanish/Hispanic/Latino? Yes / No

9. What is this child's sex? Please circle one. Male / Female

10. What is this child's height? ____ ft. ____ in.

11. What is this child's weight? ____ lbs.

Thank you for completing this questionnaire!

Appendix I – Study 3: Child Assent

Minor Assent for Research Participation
IRB #: 19.124
IRB Approval Date: December 6, 2018

Study Title	How much do you move in an Outdoor Preschool Program?
Researcher[s]	Nathan R. Tokarek, M.S. PhD Student, Kinesiology College of Health Sciences Ann M. Swartz, Ph.D. Professor, Kinesiology College of Health Sciences

We're inviting you to be in a research study. A research study is a way to learn new things. We are trying to learn more about how much you move while attending [Insert program name] and what types of activities you do while you are at this program.

If you agree to be in this study, we will ask you to:

- A researcher will follow your group around while you play, learn, and go about your regular activities during your program. Someone from the research team will be with your group and write down notes about what activities you do. Although a researcher will be with your group all day in case anything is needed, we would like you to act like you would if the researcher were not there.
- Wear a small monitor on a belt around your waist each day that you attend the program.
- Your parent/guardian will be filling out a short survey about you, your health and your family. This survey will take about 10 minutes for your parent/guardian to complete.

A risk is something bad that could happen to you. Being in this study might have some risks. The only risk for this study is that the belt we ask you to wear might not feel comfortable when we first help you put it on. If this happens, let the researcher know and we will try to adjust the belt as best as we can so that it fits you comfortably.

A benefit is something good that happens. Being in this study won't have any benefits for you, but it could help other kids someday.

You don't have to be in this study. It is up to you. No one will be mad, no matter what you decide. If you say yes now, but change your mind later, that's ok too. Just let us know.

When we finish this study, we will write a report about what we learned. This report won't have your name in it, or that you were in the study.

Signatures

If you decide you want to be in this study, please write your name in the box below and circle either the YES or NO, a researcher will be around to help you complete this.

NAME:

I would like to participate in this study by wearing a belt around my waist that will record how much I move at school:

YES NO

To be completed by researcher collecting assent

______________________________ ______________

Name of Participant Date

Note of verbal assent follow-up confirmation (yes/no) and explanation (if necessary):

____

Name of Researcher obtaining assent (print)

______________________________ ______________

Signature of Researcher obtaining assent Date

Appendix J – Study 3: Direct Observation Data Collection Form

Observation Site:______________________________ **Date:**____________ **AM/PM** (circle one) **Data Collection Start:**__________

Class Size:_________ **Weather:** Sunny, Cloudy, Foggy, Humid, Dry, Wet, Rainy, Snowy, Windy, Hot, Warm, Cool, Cold (circle all that apply)

Location	Activity	Time Start	Time End	Structured? (Y/N)	Notes (Intensity, Posture, Upper/Lower/Total Body, Multiple Activities etc.)

Appendix K – Images of Outdoor Play Space at a Traditional Pre-K School Setting

Appendix L – Image of Outdoor Play Space at a Nature-Based Pre-K School Setting