Sedentary and Non-Sedentary Behaviour Patterns of Children with Cerebral Palsy Who Use Wheelchairs.

by

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Abstract

Purpose: To examine the suitability of a direct observation method to quantify and describe sedentary behavior and non-sedentary breaks for children who have cerebral palsy (Gross Motor Function Classification System [GMFCS] levels III, IV, and V). Secondary goals were to evaluate the agreement between direct observation and each of two measuring devices, the ActiGraph and the SenseWear, for the sedentary and non-sedentary intervals coded using the direct observation method. **Methods:** Four children participated. They all had a diagnosis of cerebral palsy (ages 7-14), with GMFCS levels IV or V. The children were videotaped at school and/or at home while wearing the ActiGraph and the SenseWear. Noldus Observer XT 11.5 software was used to code the sedentary and non-sedentary intervals observed on the videos using the direct observation coding scheme. SenseWear and ActiGraph data were compared with direct observation coding using the sedentary and non-sedentary intervals identified by direct observation. **Results:** All four children had considerable amounts of sedentary time. They all took frequent but very short breaks from sedentary time. The majority of the breaks were shorter than 60 seconds; it is not known whether these short breaks have any physiological benefit. The direct observation, ActiGraph, and SenseWear showed inconsistent agreement with no trend noted. **Conclusions:** Measuring sedentary behavior for children who use wheelchairs is challenging and requires further investigation. It is important to evaluate the length of break required for physiological benefit for these children.

Preface

This thesis is an original work by Jennifer Innes. The research project of which this thesis is a part received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Activity Levels of Children with Cerebral Palsy", No. Pro00038097, 25 April 2013.

Chapter 2 of this thesis has been published as Innes, J. & Darrah, J. (2013). Sedentary behavior: implications for children with cerebral palsy. *Pediatr Phys Ther*. 25(4), 402-408. doi: 10.1097/PEP.0b013e31829c4234. Wolters Kluwer Health Lippincott Williams & Wilkins © (no modifications will be permitted). The paper is presented in this thesis formatted differently from the published version, to conform to FGSR thesis-formatting requirements. The paper evolved from an independent study reviewing the literature in the area. I was the lead author; Dr. Darrah was the supervisory author and assisted with concept formation and manuscript composition.

The study reported in Chapter 3 reflects my original work. My supervisory committee assisted in the research proposal, the plan for data analysis, and the data analysis. Dr. Darrah also assisted with concept formation and manuscript composition.

Dedication

To my family and friends who supported me through this process. To my dad who never failed to believe I could, my mum who provided encouragement and support, and who has never stopped correcting my English usage, and of course to Domhnall, who provided me with such help, patience, and understanding through very busy times.

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Chapter 1: Introduction

Research suggests that there are significant health risks associated with sedentary behavior,[1,2] risks that are independent of those associated with a lack of physical activity. Sedentary behavior has been defined in the literature by body position and energy expenditure, as “any waking behavior characterized by an energy expenditure less than or equal to 1.5 metabolic equivalents of task (METs) while in a sitting or reclining posture.”[3(p540)] Researchers have reported negative health associations with sedentary behavior and measures of adiposity,[4,5] bone mass,[6] aerobic fitness, and metabolic syndrome[4] for children who are developing typically, and research is ongoing in an attempt to detangle the deleterious effects of sedentary behavior from the adverse effects of a lack of physical activity.[7] There is very little known about the health effects of sedentary behavior for children with cerebral palsy who use wheelchairs.

Children with cerebral palsy experience movement challenges such as muscle co-contraction and difficulties with balance and coordination. As a result, a child with cerebral palsy may expend significantly more energy than a child who is developing typically, when performing activities usually considered sedentary. In contrast, children with cerebral palsy often use supportive adaptive equipment to perform activities usually considered non-sedentary. This equipment provides significant external support, and some of the children may rely on the straps for support and expend little energy while using the equipment.[8,9] It is not known if the current definition for sedentary behavior is relevant for children with cerebral palsy who use wheelchairs.

It is challenging to measure sedentary behavior in children who use wheelchairs. Physical activity has been measured in children with cerebral palsy who are ambulatory; however, the most commonly used device, a hip-worn accelerometer, may not be accurate for children who use wheelchairs.[10,11] Direct observation has not previously been used to measure the sedentary and non-sedentary behaviors of children with cerebral palsy who use wheelchairs. It is currently not known how to define or measure sedentary behavior for children with cerebral palsy who are non-ambulatory.

PROBLEM STATEMENT

The sedentary and non-sedentary behaviors of children with cerebral palsy who use wheelchairs (Gross Motor Function Classification System [GMFCS] levels III, IV, and V) have not yet been evaluated. It is not known to what extent these children accumulate sedentary and non-sedentary time, and the patterns of their sedentary and non-sedentary movement is unknown. Appropriate measurement techniques have also not been determined for this group of children.

AIM OF THE STUDY

The aim of this exploratory descriptive study was to document the sedentary behaviors and breaks from sedentary time in children who have cerebral palsy and who use wheelchairs as their primary mode of mobility (Gross Motor Function Classification System [GMFCS] levels III-V).[22] The specific objectives were to look at the utility of a direct-observation method to quantify and describe sedentary behavior and non-sedentary breaks for children who have cerebral palsy (GMFCS levels III-V), and to examine the agreement between direct observation and the ActiGraph, and direct observation and the SenseWear for the sedentary and non-sedentary intervals described by direct observation.

OVERVIEW OF THE THESIS

This thesis follows a paper format and comprises two separate papers. The first paper is a review of the sedentary-behavior literature as well as a discussion about the implications for children who have cerebral palsy (Chapter 2). The second paper is an overview of the thesis research project and results (Chapter 3). The final chapter presents a conclusion, clinical implications, plans for dissemination of results, and implications for future research (Chapter 4).

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Chapter 2: Overview of the Literature

ABSTRACT

Purpose: To review the research associated with sedentary behavior with adults and children in the general population and to discuss the application of this research for children with cerebral palsy. **Summary of key points:** Increased sedentary behavior and decreased physical activity are independent constructs with different definitions, physiological mechanisms and health outcomes. The parameters of sedentary behavior developed for children with typical motor abilities may not be valid for children with cerebral palsy. **Statement of Conclusions:** Research to identify measurement tools, health associations, and potential interventions for children with cerebral palsy is needed. **Recommendations for Clinical Practice:** Interventions to decrease sedentary behavior differ from the current interventions to increase physical activity with children with cerebral palsy. Before designing interventions to decrease sedentary behavior, research is needed to determine valid definitions and measurement approaches for children with cerebral palsy, as those derived for children with typical motor development may have limited application. **(Pediatr Phys Ther 2013;25:402-408)** *Key words: cerebral palsy, child, physical activity, sedentary lifestyle*

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INTRODUCTION

Interest in the health implications of sedentary behavior has exploded in the past decade. Despite the proliferation of discussion and research during this period, our understanding of the physiological mechanisms, health outcomes, and measurement of sedentary behavior in both adults and children is limited. Most of the research has focused on adults, with an emphasis on evaluating the association of sedentary behavior with health outcomes such as longevity, metabolic syndrome, diabetes, cardiovascular disease, and obesity. The child research has primarily evaluated the effect of sedentary behavior on body composition in children who are developing typically. The effect of sedentary behavior on children with a diagnosis of cerebral palsy (CP) is unknown.

Sedentary behavior is usually defined by position (sitting or reclining) and by energy expenditure (< 1.5 metabolic equivalent of task [METs]).[1] Although it is often associated with decreased moderate to vigorous physical activity (MVPA), the 2 constructs are not synonymous. They have different physiological mechanisms, definitions, methods of measurement, and outcomes. Owen et al[2] coined the term, "active couch potato" to describe adults who meet the recommended guideline of 150 minutes per week of MVPA, but who still are at risk for metabolic consequences from too much prolonged sitting. Sedentary behavior and decreased physical activity are separate constructs with independent outcomes, and individuals can receive the benefit of performing MVPA but still be negatively affected by sedentary behavior.

The aims of this article are to introduce the definitions, health outcomes, physiological mechanisms, measurement methods, and interventions associated with sedentary behavior in the typical population (adults and children, 6 to 12 years) and to review the literature related to sedentary behavior in children with CP. The challenges of developing an assessment and intervention framework for school-aged children with CP are discussed.

DEFINITION

Sedentary behavior has not been consistently defined in the literature, with many studies evaluating reduced physical activity rather than true sedentary behavior.[3,4] Sedentary behavior is most often defined functionally as "sitting without being otherwise active"[5(p190)]; it is unknown whether movements such as fidgeting `or arm/leg movement while sitting are enough to negate the deleterious effects of being sedentary. Researchers frequently use screen-time (television viewing, gaming, computer use) as a proxy activity to represent sedentary time. However, screen-time may not be an accurate estimate of total sedentary time because it does not account for a person's total daily sedentary time.[6] Some definitions have also included transportation time,[2,3] lying down, and desk work,[4] and sedentary hobbies and sitting and socializing,[7] as proxy activities for sedentary time. Yates et al[8(p293)] defined sedentary behavior in terms of muscle activity, stating that sedentary behavior is "non-exercise activity that involves sitting or lying", and that in these postures most of the body's large muscle groups are relaxed. They contrast these positions with static standing where, even though a person may not be moving, a large proportion of the body's muscles are working to maintain an upright posture. Sedentary behavior is defined physiologically as 1.0 to 1.5 METs.[2-4,8] Light-intensity activity (LIA) is defined as greater than 1.5 to 3.0 METs, and MVPA is defined as 3.0 to 8.0 METs.[2,3] The definition of sedentary behavior used in the literature is the same for adults and for children who are developing typically.

The Sedentary Behaviour Research Network recently published a standard definition for sedentary behavior including both physiological and functional components as "any waking behavior characterized by an energy expenditure less than or equal to 1.5 METs while in a sitting or reclining posture."[1(p540)] They also suggest that the term "inactive" be used to describe people who are not achieving the recommended amount of daily MVPA, thus distinguishing between sedentary behavior and decreased physical activity.

HEALTH OUTCOMES ASSOCIATED WITH SEDENTARY BEHAVIOR

The health outcomes of sedentary behavior in adults have been examined[2-4] predominantly by evaluating associations and outcomes rather than causal relationships. A review by Proper et al[4] included 19 prospective studies, of which 14 were considered to be of high methodological quality, and a recent review by Wilmot et al[6] included 18 studies, of which 16 were prospective. Fifteen of these studies were considered to be of moderate to high quality. The reviews concluded that sedentary time is associated with diabetes,[6] cardiovascular disease, all-cause mortality,[4,6] and mortality from cardiovascular disease. The majority of the studies reviewed measured sedentary behavior by self-report.

Other negative health outcomes have been associated with adult sedentary behavior, including metabolic dysfunction (eg, decreased lipoprotein lipase (LPL) activity, decreased insulin sensitivity, decreased glucose uptake, decreased levels of high-density lipoprotein cholesterol, and increased plasma triglyceride levels),[2,3] bone health concerns,[3] vascular health, cardiovascular health,[2-4] body weight issues (including increased waist circumference, obesity, and body mass index [BMI] gain),[2-4] and cancer (colon in men,[3] endometrial in women[3,4]).

The majority of child sedentary behavior outcomes research has focused on health associations between sedentary behavior and measures of body fat mass.[9,10] Health outcomes for child sedentary behavior have been reported for BMI and other indicators of fat mass,[9,10] bone mass,[11] aerobic fitness, and metabolic syndrome.[9] Other outcomes such as self-esteem, academic achievement, and prosocial behavior have also been evaluated for children.[9] Less is known about the health outcomes of sedentary behavior for children than for adults. Chinapaw et al[10] caution that there is not yet enough evidence for negative health effects in children and adolescents.

However, because sedentary time increases with age,[7] and childhood sedentary behavior patterns tend to continue into adulthood,[12] it may be important to intervene early.

PATTERN OF ACCRUAL OF SEDENTARY TIME

The pattern of sedentary time accrual, not just the total sedentary time, may influence some of the health outcomes of sedentary behavior. Healy et al[13] report that an increased number of breaks in sedentary time, independent of the length and intensity of the breaks, and of MVPA time, was associated with more positive health outcomes, specifically decreased body fatness, decreased triglycerides, and improved 2-hour plasma glucose. The authors hypothesized that the absence of skeletal muscle contraction in prolonged sitting contributes to the decreased clearance of plasma triglycerides and oral glucose from plasma. They acknowledge that it was not possible to determine the required frequency, length, or duration of breaks needed for the improved metabolic outcomes. A recent study[14] found that breaks in sedentary time, independent of total sedentary time, were associated with a decrease in waist circumference, and improvements in fasting plasma glucose and C-reactive protein levels. The inflammatory marker C-reactive protein is associated with an increased risk of coronary heart disease and vascular mortality. The authors hypothesize that inflammation may be an additional way that prolonged sitting can affect cardiovascular disease risk. Most recently it has been reported that 2-minute breaks every 20 minutes of sedentary time, compared with continuous sitting, result in an improvement in glucose and insulin levels in adults who are overweight and obese.[15]

Kwon et al[16] investigated the longitudinal changes in the frequency of sedentary breaks over a 10-year period in children between the ages of 5 and 15 years. Over 5 assessment periods, they reported that the frequency of sedentary breaks decreased over childhood and adolescence. Children and youth also had a lower frequency of breaks during weekday school-hours than after school or on weekends. No research has yet been conducted to determine whether the frequency of breaks in sedentary time influences health outcomes for children.

PHYSIOLOGICAL MECHANISMS

The mechanisms causing the deleterious effects of sedentary behavior have not been studied extensively. Many researchers who discuss sedentary behavior have actually evaluated the effect of a lack of MVPA,[3] but the physiological mechanisms of MVPA are different from those of sedentary behavior. The deleterious effects of sedentary behavior are not due simply to a lack of MVPA, but are more likely related to a lack of frequent intermittent LIA throughout the day.[2,14] Light-intensity activity refers to all waking activity that is not sedentary or MVPA and includes standing, stepping, and many activities of daily living.[2,17]

Two physiological mechanisms have been proposed to explain the negative effect of sedentary behavior: a lack of contractile activity of the muscles, which in part results in decreased LPL regulation[18,19] and blood vessel remodelling.[20] The mechanisms that explain the detrimental health effects of sedentary behavior are not the same (or even simply the opposite) of the mechanisms explaining the positive health effects of MVPA.

Sedentary behavior is characterized by a reduction of muscle activity and may place a person at greater risk of developing metabolic diseases. Hamilton et al[19] postulate that the lack of skeletal muscular contraction during sedentary time may suppress LPL. Lipoprotein lipase is an enzyme that is necessary for the uptake of triglycerides as well as for producing high-density lipoprotein. Animal studies have shown a quick decrease in LPL activity in the skeletal muscles with inactivity, resulting in a significant decrease in the clearance of plasma triglycerides. Interestingly, only the inactive muscles are affected by decreased LPL activity, suggesting that a lack of local contractile activity may be the problem.[18] Light-intensity activity appears to activate LPL in the skeletal muscles,[19] and there is evidence that inactivity causes LPL suppression.

Hamilton et al[19] report a much greater decrease in LPL activity (10 times), specifically in the red oxidative muscles, during prolonged sedentary activity compared with LIA. Conversely, there was only a modest increase (2.5 times) in LPL activity when comparing MVPA with LIA, and the increase was in the white glycolytic muscle fibers, showing that the LPL mechanism during sedentary activity is different from that during MVPA.

In a recent review, Thijssen et al[20] examined the effects of sedentary behavior on the vascular system. They report independent effects of sedentary behavior and MVPA on the vascular system. Being sedentary may lead to a decrease in the diameter of the arterial lumen, which appears to be related to an enhancement of the vasoconstrictor pathway that contributes to the regulation of vascular tone. In contrast, physical activity may enhance vasodilation and facilitate healthy vasculature. In addition to the decrease in the diameter of the arterial lumen, being sedentary may also cause an increase in the thickness of the arterial walls. Both of these vascular changes are predictive of cardiovascular problems.

The physiological mechanisms underlying the negative effects of sedentary behavior are not yet well understood. Further investigation is required to test and refine these theories and to be better able to relate these mechanisms to the proposed health outcomes.

MEASUREMENT

Some of the researchers evaluating activity measurement have investigated the measurement of MVPA rather than the amount of sedentary activity. It is important to ensure that true sedentary behavior is measured rather than the absence of MVPA. Subjectively, it has most frequently been measured by self-report of proxy activity—most commonly television viewing. Accelerometers have become the standard objective method of measurement to collect information regarding the quantity, intensity, and patterns of movement.[3] Many accelerometers also include an inclinometer, which indicates whether someone is sitting or standing, an important distinction when measuring sedentary activity. Accelerometers cannot distinguish what type of activity is occurring and will not register movements when the body's centre of gravity is relatively stable, such as riding a bike.[21] Accelerometers also do not provide direct information about energy expenditure; they measure the acceleration of movements, and prediction models are used to estimate energy expenditure on the basis of counts.[22] Generally as the counts per minute increase, so does the intensity of the movement.[7] Cut-points based on counts per minute are used to estimate the category of activity intensity (sedentary, LIA, MVPA).[23] The cutoff of fewer than 100 counts per minute has been commonly used in the literature to describe sedentary behavior in adults.[2] More recently, Kozey-Keadle et al[24] have advocated for the use of a cutoff of 150 counts per minute for the ActiGraph (Actigraph, LLC, Pensacola, Florida) monitor as they found that this has improved accuracy in identifying sedentary behavior when compared with direct observation. Cut-points are specific to the accelerometer type.[25]

Sedentary behavior in children has been measured in a number of ways (see Table 2-1), both objectively and subjectively. Measurement in children is more challenging than in adults because children tend to have more sporadic movement patterns than adults,[23] which may be more difficult to remember and tally. Sedentary behavior in children has been measured most often by self-report or proxy report of television viewing.[10] Television viewing may not be a valid indicator of sedentary activity in children, because it may comprise only a portion of a child's daily sedentary time, and because children may engage in other activities while also watching television. Television viewing may also be associated with dietary habits such as snacking on high-calorie food,[26,27] which could confound the relationship between television viewing and health outcomes.[27] Although self-report and proxy-report measures have been extensively used to measure child sedentary behavior, their validity and reliability have not been extensively evaluated.[23]

Accelerometers are used to objectively measure child sedentary behavior,[7] but they have the same limitations as with adults. Various accelerometers have been validated for use with children who are developing typically, compared with observational measures such as direct observation, and physiological measures such as indirect calorimetry.[23] Cut-points used to define sedentary behavior vary widely in the literature, as do the measurement intervals or epoch lengths. The cut-point of fewer than 100 counts per minute is commonly used for children, although counts as high as 1100 counts per minute have been used.[7] Shorter epochs (eg, 15 seconds) may be more appropriate for use with children because they are more accurate in capturing the irregularity in their patterns of play and movement.[23]

Another method that has been used to measure child sedentary behavior is the measurement of calorie expenditure. One such device is the BodyBugg (BodyMedia, Pittsburgh, Pensylvania) armband.[28] Unlike traditional accelerometers it does not need movement to differentiate between different activity intensities. The BodyBugg records a variety of physiological measurements such as heat flux, skin temperature, galvanic skin response, and activity counts via a 3-axis accelerometer. An algorithm is used to estimate calorie expenditure or METs. This algorithm has been used with children, with a low average-measurement error (1.7%).

INTERVENTIONS FOR CHILDREN

In 2002, American children aged 9 to 13 years exceeded the recommended guidelines of 1 to 2 hours a day[29] of daily leisure screen time, with an average of 4.5 hours.[30] With the mounting evidence for the detrimental effects of sedentary behavior, researchers have begun to investigate effective interventions for children with typical development. Kamath et al[31] evaluated 34 randomized controlled trials in a systematic review. The aim of the review was to determine the effectiveness of behavioral interventions with the goal of changing behaviors (eg, increasing physical activity, decreasing sedentary behavior, improving eating habits, and decreasing poor eating habits) to prevent obesity in children 2 to 18 years. None of the interventions had a significant effect on BMI when compared with the control group. They did find that interventions to decrease sedentary behavior were more effective in children (6-11 years) than in adolescents, with longer treatment periods (>6 months), and for interventions that comprised multiple cognitive components compared with only 1 or no cognitive components. The researchers reported that interventions to decrease unhealthy behaviors may be more effective than interventions to encourage healthy behaviors. If this assumption is true, focusing on reducing sedentary behavior may be more effective than encouraging an increase in MVPA. Research suggests that increased sedentary behavior is associated with reduced LIA,[2] but it does not appear to affect participation in MVPA,[32] supporting the theory that sedentary behavior and physical activity are separate constructs. Interventions to decrease sedentary behavior and increase physical activity are both important.[9]

In a novel study, sitting desks were replaced with sit/stand workstations in 2 of 4 first-grade homeroom classrooms.[28] The treatment group children were instructed to sit and stand as they wished, and the students in the 2 nonadapted classrooms served as controls. The BodyBugg armband was used to measure calorie expenditure in the children. After 12 weeks, 70% of the students in the treatment group stood through the whole 2-hour analysis period. The remaining 30% of students stood an average of 75% of the time. Calorie expenditure for students in the treatment group was 17% greater than in the control group. There was also anecdotal improvement in behavior and achievement.[28] This study increased standing (LIA) and thereby decreased sedentary behavior just by altering available equipment. It would be interesting to see if this trend would continue as children age and classroom demands change. Children and youth take fewer breaks from sitting as they age and fewer breaks during the school day as compared with their leisure time,[16] and therefore effective school day interventions may contribute significantly to decreasing prolonged sedentary time. The Transform-Us! Study[33] is a randomized controlled trial to evaluate the individual and combined effects of behavioral and environmental interventions to decrease sedentary behavior and increase physical activity in 8- and 9-year-old children.[33] This study is strong methodologically and compares different intervention strategies. These types of intervention studies are needed to understand the true effects of decreasing sedentary behavior of children.

CHILDREN WITH CEREBRAL PALSY

Definition

Very little is known about the effects of sedentary behavior in children with CP. The functional and physiological parameters of the definition of sedentary behavior developed for the typical population may not be appropriate for children with CP. If so, then the sparse body of research reporting health outcomes using these parameters may also be inappropriate for this population. Children with CP demonstrate atypical muscle tonus (ie, spasticity, hypotonia, athetosis, ataxia or a combination) and challenges with muscle co-contraction, balance and coordination. These motor impairments often make sedentary behaviors such as sitting more challenging and as a result may require more energy expenditure than is reported for children without motor challenges. Thus, sitting activities may exceed the physiological parameters of sedentary behavior (1.0-1.5 METs) when measured in children with CP. In contrast, activities considered nonsedentary for the typical population, such as quiet standing, may in fact be sedentary for some children with CP, especially those who use equipment such as a standing frame to maintain the position. Some children using a standing frame may use the trunk and lower extremity muscles while positioned in a standing frame, whereas others may be inactive and supported by the standing frame straps. These sitting and standing examples illustrate that it may not be appropriate to extrapolate sedentary functional behavior definitions developed for children who are developing typically to children with motor disabilities. In addition, the heterogeneity of motor abilities in children with CP may make it impossible to determine a standard functional definition of sedentary behavior for them. Research to determine the muscle activity and energy expenditure of children with CP in different positions and with and without supportive equipment is necessary to unravel the true nature of their sedentary behavior.

Measurement

Electromyographic recordings could be used to determine the amount of trunk and lower extremity muscle activity of children positioned in various adaptive equipment, such as standing frames and seating devices, to differentiate between active and inactive postures and the influence of supportive devices. No study of sedentary behavior to date has evaluated muscle activity directly, despite the theoretical assumption that a lack of muscle activity contributes to the negative health outcomes associated with sedentary behavior. Caloric expenditure measurements could also assist in understanding the activity level of children with CP in "typical" sedentary behaviors.

Investigations of energy expenditure levels and the amount of activity or movement in children with CP have focused primarily on ambulatory activities not considered to be sedentary. Measurement tools used have been predominantly a measure of walking energy expenditure[34,35] or a step[36] or activity[37,38] count using various types of accelerometers. The majority of research supports the assumptions that children with CP use more energy to walk[34,39] and that the energy requirements of walking increase with the severity of involvement.[34] Little is known about the energy expenditure of children with CP when sedentary. Johnson et al[40] have reported that adults with athetoid CP have significantly higher resting energy expenditure than healthy adults. It is unknown if this increased resting energy expenditure is higher than 1.5 METs, the upper limit for energy expenditure for the physiological definition of sedentary behavior.

A number of accelerometry devices have been validated to measure the physical activity levels of ambulatory children with CP. The StepWatch (Orthocare Innovations, Oklahoma City, OK) monitor has been validated for children with CP who are ambulatory,[36] and a recent study validated the ActiGraph accelerometer for 8- to16- year-old children with CP who are ambulatory (Gross Motor Function Classification System [GMFCS levels I – III]), using oxygen uptake ($\dot{V}O_2$) as the reference standard.[38] To measure sedentary behavior, not physical activity, the ActiGraph was able to be used reliably identify a 10-minute rest period of quiet sitting. Sedentary behavior is one of the variables used in an Australian study,[41] and the researchers plan to evaluate the criterion validity of the ActiGraph accelerometer compared with direct observation to establish counts per minute cut-points to distinguish sedentary behavior in young children with CP. Accelerometry has not been validated for the measurement of other perceived sedentary behaviors with children with CP, such as desk work.

The measurement of sedentary behavior in children who are nonambulatory presents unique challenges. Accelerometry has not been validated for use with children who use wheelchairs. The standard placement on the hip may not accurately measure activity levels because the trunk movements may not be identified.[42,43] From an energy expenditure perspective, it is unknown if limb movements alone increase the body's energy expenditure above the defined sedentary level. Once validated, the BodyBugg armband or another similar device that provides an indirect measurement of energy expenditure may be a more suitable measurement tool for this population.

Effect of Sedentary Behavior

The long-term effects of sedentary behavior are also virtually unknown for children and adults with CP. Considering that reduced muscle activity has been identified as a factor contributing to the negative health outcomes of sedentary behavior in persons in the typical population, and considering that persons with cerebral palsy may have increased rather than decreased muscle activity in postures currently defined as "sedentary," it may be that the deleterious health effects of these postures do not apply to persons with CP. In a study involving adults with spinal cord injury, spasticity was found to be protective against metabolic syndrome.[44] The same could be true in children with CP.

Possible Interventions

With such limited understanding of an appropriate definition of sedentary behavior for children with CP, how to measure it, and what the long term health implications are, a discussion of potential intervention strategies is clearly premature, but very intriguing. Fitness programs to increase the physical activity levels of children with CP are a popular rehabilitation intervention strategy.[45-47] The short-term improvements reported from exercise programs do not seem to be long lasting,[45] and improvements in aerobic capacity may not result in functional improvements.[48,49] Improvements in muscle strength are also equivocal.[50] In addition, commitments to a regular exercise schedule may be challenging for parents, and community accessibility is an issue.[51] Considering these factors and the idea that intervention is more effective when focused on decreasing unhealthy behaviors rather than increasing healthy behaviors,[31] interventions focused on decreasing sedentary behavior may be more effective than the current intervention emphasis on increasing physical activity. This change in intervention emphasis may be particularly effective with nonambulatory children with more severe motor impairments. What could interventions focused on decreasing sedentary behaviors look like for children with CP in wheelchairs? Having a classroom assistant encourage "wiggling" or "sit to stand" once an hour instead of taking children out of their wheelchairs at lunchtime for a prolonged period? The use of supported standing desks for some classroom time instead of prolonged sitting? Wheelchair exercises often during the day? Walking classroom breaks? Interventions will be limited only by the imagination of therapists, but not until the "landscape" of sedentary behaviors in children with CP is clearly mapped out. This involves a definition of what comprises sedentary behavior, validated measures, and longitudinal studies to understand the long-term implications of sedentary behavior in adulthood for persons with CP. Achievement of this knowledge base can only occur with the formation of collaborative research teams, instituting an international sedentary behavior research agenda for persons with CP.

CONCLUSION

Despite myriad reports discussing the implications of sedentary behavior published in the last decade, the mechanisms of sedentary behavior and the resulting outcomes are still not clear. The identification of valid measurement options and effective intervention strategies are just emerging with adults and children in the general population. Almost no information is available for children with motor impairments such as CP. The study of sedentary behavior within this population may lead to innovative rehabilitation intervention strategies. Sedentary behavior represents an important construct that requires more evaluation.

Table 2-1. Measures of Sedentary Behavior Used With Children With Typical Motor Development

Construct Measured	**Measurement**	**Direct Measurement (Objective)**	**Indirect Measurement (Subjective)**
Sedentary time	Time spent sedentary	Direct observation of sedentary activities (television time, computer time, desk-time, sitting and socializing) • Real-time observation • Video	Activity logs or questionnaires about time in sedentary activities • Self-report • Proxy-report
Amount of movement	Number of steps per unit of time	Time-sequenced pedometer	
	Activity counts per unit of time	Accelerometer	
Energy expenditure	Oxygen consumption ($\dot{V}O_2$)	Metabolic Cart	
	Carbon dioxide production	Doubly labeled water	
	Heat flux, skin temperature, galvanic skin response, and activity counts via a 3-axis accelerometer	BodyBugg	

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Addendum: Overview of the Literature

This addendum reviews relevant literature identified since the article in Chapter 2 was published.

Interest in sedentary behavior continues, particularly in the area of identifying patterns of activity in adults. The link between sedentary behaviour and cardio-metabolic risk factors has been questioned; a re-examination of the National Health and Nutrition Examination Survey (NHANES) dataset suggested that association was attenuated when researchers adjusted for total activity time.[1] The authors caution that looking at only moderate to vigorous physical activity (MVPA) discounts much of the range of physical-activity intensity and that health effects could be due to lower *total* physical activity rather than to sedentary time. The influence of breaks between bouts of sedentary behavior continues to be studied. Peddie et al [2] found that when normal-weight adults walked for 1 minute and 40 seconds for every 30 minutes of sitting over a 9-hour period, their concentration of postprandial glucose and insulin was decreased compared with only one 30-minute continuous period of walking in a 9-hour period. Bailey and Locke[3] compared the effects of prolonged sitting, prolonged sitting with 2-minute breaks of standing still, and prolonged sitting with 2-minute breaks of walking at a light intensity over separate 5-hour periods on cardio-metabolic risk markers in healthy young adults. They found that the light-intensity walking breaks, but not the standing breaks, improved postprandial glycaemia.

Devices used to identify breaks in a free-living environment have been evaluated using direct observation as the criterion measure.[4] The activPal monitor was able to accurately measure sedentary time as well as the breaks from sedentary time, while the ActiGraph GT3X did not accurately measure sedentary time or breaks from sedentary time. More research is needed to determine the required length and frequency of breaks for health benefits.

Investigators have continued to explore the health risks associated with sedentary behavior in children. Ekelund et al[5] reviewed studies that examined the relationships between sedentary behavior, physical activity, and adiposity for children and young adults up to 20 years. They concluded that it is unlikely that sedentary time is related to adiposity after controlling for physical activity, particularly at higher intensities. The cardio-metabolic effects of prolonged sitting, sitting with 2-minute walking breaks every 20 minutes, and sitting with 2-minute walking breaks every 20 minutes and adding two 20-minute sessions of moderate physical activity on a treadmill, was studied in 19 healthy and active 10 to 14-year-old children over 3 separate 8-hour laboratory visits.[6] The three different sedentary and activity conditions revealed no differences in markers of cardio-metabolic disease risk such as levels of insulin, glucose, or lipids. The investigators caution that it is likely that the findings would be different in children who were less physically active, highly sedentary, or obese, or had other raised risk factors for cardio-metabolic disease. This recent literature has focused on re-examining the assumption that sedentary behavior rather than the intensity of physical activity is the prime reason for cardio-metabolic risk factors. Clearly more research is needed to tease out the effects of sedentary time from the effects of activities of different intensities. Future research will need to identify all different levels of activity (sedentary, light, moderate, and vigorous) to be able to truly understand the differing health effects of each.

Researchers continue to explore interventions for sedentary behavior in children. The Transform-Us! cluster-randomized controlled trial is still underway, but the authors reported some results from the mid-intervention stage of the trial. None of the hypothesized mediators of sedentary time (child enjoyment, parent and teacher outcome expectations, and a child perception of access to standing in the classroom) had an effect on sedentary time.[7] Biddle et al[8] reviewed 10 systematic reviews of interventions to reduce sedentary behaviors in children and youth. A wide range of interventions was studied, including informational, behavioral, environmental, and social-support strategies. The most useful strategies included involving the family, television-monitoring devices, and behavioral strategies. They found that although interventions to reduce sedentary behavior in this group were generally effective, the effects were small.

Interest in the sedentary behavior of children who have cerebral palsy continues. A new perspectives paper examined the literature related to fitness and sedentary behavior for children with cerebral palsy.[9] The authors identified the challenges related to using the standard definition of sedentary behavior and the difficulties in measuring activity levels in children with cerebral palsy. They cautioned readers that the accepted standard definition and measurement methods for sedentary behavior may be different for children with cerebral palsy and that these may differ within this population depending on the level of functional mobility and the type of muscle tone. The authors raise the idea of a "whole day" approach to promoting activity, which includes reducing sedentary time by increasing breaks and adding light-intensity activity, as well as continuing participation in MVPA.

In their cross-sectional study of children and youth with cerebral palsy who were ambulatory, Ryan et al[10] found that more sedentary time and less time in total physical activity and MVPA were associated with elevated blood pressure in children with cerebral palsy who were ambulatory. They noted that the greatest association with elevated blood pressure was with a lack of vigorous physical activity, and they propose that children should be encouraged to engage in vigorous activities rather than activities of lower intensity.

In a cross-sectional prospective study Obeid et al[11] evaluated sedentary time and frequency of non-sedentary breaks of children with cerebral palsy who were ambulatory compared with age- and sex-matched peers. They used 3-second epochs with the ActiGraph GT1M worn on the hip to measure sedentary time, and they defined a break as any movement of light- or higher-intensity physical activity lasting 3 seconds or longer. Children with cerebral palsy had more sedentary time and fewer breaks from sedentary time. The authors encouraged health professionals to advise families and children that it is not enough to meet the recommendations for *total* daily physical-activity time: increased frequency of breaks needs to be encouraged, regardless of activity intensity. They cautioned that the physiological effect of a 3-second break is unknown.

Sedentary behavior researchers continue to attempt to determine the true health effects of prolonged sitting. Researchers have started to employ more prospective designs, particularly when looking at non-sedentary breaks. There continues to be little known about sedentary behavior and its implications for children who have cerebral palsy. Measurement continues to be a challenge, particularly for children who use wheelchairs. Researchers need to be able to define and measure sedentary behavior for children with cerebral palsy before research can progress.

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Chapter 3: Evaluation of activity levels of children with a diagnosis of cerebral palsy who use wheelchairs

ABSTRACT

Aims: The goal of this exploratory descriptive study was to describe the sedentary and non-sedentary behaviors of children with cerebral palsy who use wheelchairs as their primary means of mobility; to look at the utility of a direct observation scheme for documenting behavior; and to examine the agreement between direct observation and the SenseWear, and direct observation and the ActiGraph. **Methods:** Four girls with quadriplegic cerebral palsy (ages 7-14) participated in this study. They were videotaped at school or at home while wearing the SenseWear and the ActiGraph. The video was analyzed using the Noldus ObserverXT 11.5 software and the direct observation coding scheme. The ActiGraph and SenseWear data were compared with the direct observation, using the intervals that were coded by direct observation. **Results:** All participants had large amounts of sedentary time. The participants took frequent but very short breaks from sedentary time, with the majority of the breaks shorter than 60 seconds. The direct observation, ActiGraph, and SenseWear did not capture the same information. **Conclusions:** Measuring sedentary behaviour for children who use wheelchairs is challenging and requires further investigation. Further research is needed to evaluate the length of break required for physiological benefit.

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INTRODUCTION

The health implications of sedentary behavior for children are a current topic of interest,[1,2] but little is known about the effect of sedentary behavior for children and youth with cerebral palsy.[3] Sedentary behavior is most often defined as "any waking behavior characterized by an energy expenditure less than or equal to 1.5 metabolic equivalents of task (METs) while in a sitting or reclining posture."[4(p540)] Both body position and energy expenditure are represented in the definition.

Researchers have reported negative health associations between sedentary behavior and body fat mass, bone mass, aerobic fitness, and metabolic syndrome for children who are developing typically.[5-7] Beneficial associations between non-sedentary breaks from sedentary time and metabolic health have been reported for adults.[8-10] Dunstan et al[8] reported that 2-minute breaks for every 20 minutes of sedentary time reduced postprandial glucose and insulin levels in overweight and obese adults. It is unknown if breaks shorter than 2 minutes yield the same health benefits as longer breaks. In an observational study, researchers defined the minimum length of a break as 1 minute.[9] However, the *mean duration* of a break was significantly higher (4.5 minutes), making it difficult to identify the minimum break length required for metabolic health benefits. How researchers have defined the minimum duration of a break has varied widely in research not evaluating health outcomes. Obeid et al[11] used 3-second accelerometer epochs to measure activity in children with and without cerebral palsy who are ambulatory. They defined a break as any movement above the sedentary threshold longer than 3 seconds of light, moderate, or vigorous physical activity. However, they cautioned readers that it is not known whether there are any physiological benefits from a 3-second break. In contrast, Lyden et al[12] used 1 minute as the minimum length of a break from sedentary time in their study of adults, as measured by the ActiGraph accelerometer. However, for the direct observation component of the study, a break was defined as “any instance where a sitting or lying behavior was followed by a nonsitting or nonlying behavior”[(p2245)] with no identified minimum duration to define a break. In this study a non-sedentary break is defined as the duration of time a child spent in non-sedentary activity, determined by direct observation.

Sedentary behavior in children has been measured in a number of subjective and objective ways. Self-report of activities has been used, but the validity and reliability of self-report and proxy-report have not been well evaluated.[6] Accelerometry is the most commonly used objective measurement of sedentary behavior, and its use has been validated with children who are developing typically.[13] The recommended cut-point to identify sedentary behavior is 100 counts per minute (cpm).[14] The BodyBugg, SenseWear, and SenseWear Mini are BodyMedia armbands which incorporate accelerometers as well as measuring galvanic skin response, skin temperature, and heat flux to produce an estimate of energy expenditure in METs. The SenseWear and SenseWear Mini provided fairly good estimates of total energy expenditure in children over a 14-day period when compared with doubly labeled water, the gold standard.[15] The definition for sedentary behavior of less than or equal to 1.5 METs was used as the cut-point for the SenseWear data.[4]

Direct observation has not been used extensively as a measure of sedentary behavior in children, but it has been used to describe the physical-activity level of children who are developing typically. Most methods of direct observation use time-sampling rather than continuous recording of activities and categorize activity by position and type of activity.[16] Kozey-Keadle et al[17] developed a direct observation tool to measure sedentary behavior in adults using seven position/activity categories to define observed behavior (lying, sitting, standing still, standing still with upper body movement, standing/moving, moving moderate, moving vigorous). Time spent in sitting and lying behaviors were classed as sedentary.

The influence of sedentary behavior on the health outcomes of children with cerebral palsy is virtually unknown. Recent research has identified an association between more time in sedentary activity and elevated blood pressure in children with cerebral palsy who are ambulatory, but the strongest association was between increased blood pressure and a lack of *vigorous* physical activity.[18] The sedentary behaviour patterns of children with a diagnosis of cerebral palsy are also not well understood. It is not known if the position and energy expenditure parameters of the definition of sedentary behavior used for children with typical development are relevant for this population. The motor challenges and muscle tone of children with cerebral palsy may result in high energy demands even in positions considered sedentary (sitting and lying) by the current definition.[3] The effect of supportive positional devices (eg, a standing frame or seating system) on energy expenditure for children who do not ambulate independently is unknown; devices may enable children to maintain these positions, but the energy demands may still be high and their energy expenditure in these devices has not been investigated. The objective measurement of sedentary behavior with children with cerebral palsy also presents unique challenges. Hip-worn accelerometers have been validated, using oxygen uptake as a reference standard, to measure both physical activity and periods of sedentary behaviour (quiet sitting) for children with cerebral palsy who are ambulatory.[19] Two studies noted that the traditional hip placement of the accelerometer may not provide an accurate measure of activity for wheelchair users.[20,21] Sedentary behavior has not been measured using devices that provide an estimate of energy expenditure such as the SenseWear, and direct observation has not been used to distinguish the sedentary and non-sedentary behaviors of children with cerebral palsy.

The activity levels and sedentary behavior patterns of children with cerebral palsy who are non-ambulatory need evaluation. No research has yet documented how much sedentary and non-sedentary time these children accrue, how often they have breaks from sedentary time, or how long the non-sedentary breaks are. How to measure sedentary and non-sedentary time in children with cerebral palsy who use wheelchairs has not been determined.

PURPOSE

The purpose of this exploratory descriptive study was to document the sedentary behaviors and breaks from sedentary time in children who have cerebral palsy and who use wheelchairs as their primary mode of mobility (Gross Motor Function Classification System [GMFCS] levels III-V).[22] The specific objectives were to look at the utility of a direct-observation method to quantify and describe sedentary behavior and non-sedentary breaks for children who have cerebral palsy (GMFCS levels III-V), and to examine the agreement between direct observation and the ActiGraph, and direct observation and the SenseWear for the sedentary and non-sedentary intervals described by direct observation.

METHODS

Video analysis, direct observation, and objective measures (ActiGraph and SenseWear) were used to document sedentary and non-sedentary time. The study was approved by the Human Research Ethics Board and the Cooperative Activities Program, the Faculty of Education, University of Alberta. Edmonton Public Schools provided administrative approval.

Participants

Eligible participants were children aged 6-14 years who had a diagnosis of cerebral palsy, were classified in GMFCS levels III, IV and V, and used a wheelchair most of the time. Children with cerebral palsy who walk as their primary means of mobility were excluded. Children with cerebral palsy who have behavioral issues that would make videotaping challenging were also excluded. Physical therapists working in the school system identified eligible children from their caseloads and sent letters of invitation to the families. Considering the time required for data collection and coding, the recruitment target was 4 to 6 children.

JI met parents who responded to the letter of invitation, provided them with further information, and obtained parent consent (and child assent when possible). The parents provided information about their child's height, weight, and birthdate at this visit. The site where data collection would take place (home, school, or both) was determined. If data collection occurred in the school setting, school administrators and teachers identified times that were least disruptive. Four girls with a diagnosis of cerebral palsy, representing GMFCS levels IV and V, participated. GMFCS level was determined by JI and JD from observation.

Procedure

Videotaping captured the usual activities of each child at either home (Participant 1[P1]), school (Participant 2 [P2] and Participant 3[P3]) or both locations (Participant 4 [P4]). Individual recording sessions lasted two hours; all children except P1 had four hours of recording. Direct observation, ActiGraph, and SenseWear data were collected. If a child needed to engage in private activities such as toileting, the video camera remained outside the room but the SenseWear and ActiGraph monitors stayed on. The SenseWear was placed over the back of the left tricep and the beginning of data recording was identified with a beep from the device. The ActiGraph was placed on a child's left wrist. To identify the start of ActiGraph data collection the recorder shook the device before placement. As much as possible the usual routines of each child in the different environments were captured.

The children varied in their abilities and typical movement activities (Table 3-1). All four children attended specialized classrooms. P1 is 14 years old (GMFCS level V) and communicates using head-pointing to a communication device. She is pushed in a manual wheelchair for mobility and has a full-support walker for activity. She was observed following her usual after-school routine of lying on her bed for a rest and then watching television. P2 is 8 years old (GMFCS level IV) and is pushed in a tilt-in-space manual wheelchair for mobility. She was observed at school during storytime, lying on a mat in gym class, being fed, and lying on the mat in the Snoezelen room. P3 is 12 years old (GMFCS level V) and is also pushed in a tilt-in-space wheelchair for mobility. She was observed at school taking part in storytime, propelling herself in her full-support walker, lying on a mat during gym class, and performing hand-over-hand craft activities. Both P2 and P3 do not have consistent methods of communication, and P3 has a significant visual impairment. P4, 7 years old (GMFCS level IV), uses a manual wheelchair independently at home and a power wheelchair at school. She was observed using a computer keyboard and mouse, an iPad, reading age-appropriate books independently, writing in her workbooks, mobilizing in both wheelchairs, and walking in her full-support walker. P1 has mixed spasticity and athetosis; the other three children have spastic muscle tone.

Measures

Direct-Observation Coding Scheme. The direct-observation coding scheme developed for the study was modeled after a direct-observation scheme described in the literature.[17] It was designed to capture both the positions and the specific activities of children with cerebral palsy who use a wheelchair most of the time. The initial descriptions included different positions, the amount of support in each position, the potential movement activities a child might demonstrate, and whether the child completed the activities with or without assistance. Positions included sitting, standing, lying or semi-reclining; support was described by the type of equipment they used (eg, full-support walker, chest strap, headrest); it was noted which body part was moving; and assistance was categorized as full-assist, partial-assist, hand-over-hand assistance, or none. A movement was also coded as intentional, non-intentional, or a combination of both. School-based consultant physical therapists reviewed the scheme for clarity and suggested other movement activities for inclusion. The final coding measure captured the range of activities that might be observed (Appendix 3-1). The measure also included a not-coded category used when participants were engaging in private activities such as dressing and toileting. This category was also used for times when the participant was not visible on the videotape. This sometimes occurred when another person blocked the view, when the participant was moving, or when avoiding having a non-participant in the videotape (one classroom had a number of children who did not have consent to be videotaped).

ActiGraph GT3X (ActiGraph, LLC, Pensacola, Florida). The ActiGraph is a tri-axial accelerometer traditionally worn on the hip. A 10-second ActiGraph epoch (measurement interval) was used, as short epochs may better capture the potentially quick-changing patterns of movements of children.[13] The ActiGraph data was downloaded using proprietary software and saved in an Excel sheet format. In this study the ActiGraph was placed on the left wrist of each child.

SenseWear Mini Armband (BodyMedia, Pittsburgh, Pensylvannia). The SenseWear uses a tri-axial accelerometer and specific physiological measurements (galvanic skin response, skin temperature, and heat flux) to determine energy expenditure in METs or calories.[23] An algorithm incorporating the physiological measurements and a child's age, height, and weight provides the output. This algorithm was developed using the data of children who are developing typically.

The SenseWear provides data for each 1-minute interval. The SenseWear data was downloaded using proprietary software and saved in an Excel sheet format.

Data Analysis

The videotaped activities of the participants were coded continuously using commercially available software (Noldus Information Technology, Nederlands; Observer XT 11.5). The Observer XT 11.5 software allows for continuous coding of observational data, as well as analysis and presentation of the data. Observed activities were coded according to position, movements, level of support, and amount of assistance, and the observer (JI) decided whether each coded interval was sedentary or non-sedentary. This coding decision was based on a number of factors including the position, the supports, the amount of movement (speed and amount of excursion), whether the movement was against gravity or against a force, and an estimate of the muscle activity involved (small muscles vs. large muscles). Intervals varied in length depending on a child's positions and movements. An interval is defined as the duration of a specific activity performed by a child coded as sedentary or non-sedentary. Only intervals longer than 10 seconds were coded. If there was ambiguity regarding the coding of an interval as sedentary or non-sedentary, both JI and JD reviewed the video segment and reached consensus about coding. Because an interval was initially coded by position and activity, two or more sedentary intervals could be coded sequentially if the position or movement changed but the sedentary designation did not. For example, if a participant was sitting and gently moving her arms, and then sitting without arm movement, these were coded as two sequential sedentary intervals. Similarly, non-sedentary intervals could be adjacent to non-sedentary intervals (eg, if a participant was standing with a walker and then started walking, these were coded as two separate non-sedentary intervals). Although this discrete coding information by position is valuable for looking at the effect of position on activity levels, the main objective of this study was to examine the extent of sedentary and non-sedentary intervals and the frequency of non-sedentary breaks. Thus sequential intervals coded as sedentary were collapsed into one sedentary interval, and the same convention was applied to sequential non-sedentary intervals. To avoid bias of the observational information, all direct observational coding was completed before examination of the SenseWear and ActiGraph data.

The SenseWear and ActiGraph data were imported into the Observer XT 11.5 program, and the data was lined up with the videos. The ActiGraph data was lined up with the video by using the period of time where the researcher was shaking the device as a reference point. The SenseWear data was lined up with the video by using the audible beep in the video when the SenseWear started collecting data.

The Observer XT 11.5 software was used to analyze the data. Any time intervals designated as 'not coded' by direct observation were removed from the analysis for all 3 measures. Sedentary and non-sedentary time, the number of sedentary and non-sedentary intervals, the frequency of non-sedentary intervals by length, and the range of length of intervals were derived for the direct observation data. Sedentary and non-sedentary time were derived for the ActiGraph and SenseWear data. For the ActiGraph, a cut-point of less than or equal to 17 counts per 10 seconds defined an interval as sedentary. This cut-point was derived from the standard cut-point for sedentary behavior of 100 counts per minute used in most child-activity research.[14] The standard definition of less than or equal to 1.5 METs was used as the cut-point to define a sedentary interval for the SenseWear data.[4]

Agreement of sedentary and non-sedentary designations between direct observation and ActiGraph data, and direct observation and SenseWear data were examined. The direct-observation intervals were used as the time period examined. Agreement was reached if the

ActiGraph or SenseWear data agreed with the direct-observation designation of sedentary or non-sedentary for more than 50% of the length of the direct-observation interval.

RESULTS

P1 had two hours of observation in her home. P2 and P3 had 4 hours of observation in their special education classroom, and P4 had two hours observation in her home and 2 hours in her special education classroom.

Table 3-2 provides descriptive information about the sedentary and non-sedentary time intervals for each participant obtained from direct-observation, ActiGraph, and SenseWear data. As expected, all four children had more direct observation time coded as sedentary than non-sedentary. The ActiGraph data had similar percentages of sedentary time as direct observation for P1, P2, and P3 but less sedentary time for P4. The SenseWear also recorded less sedentary time for P4 compared to the direct observation coding. The SenseWear data reported less non-sedentary time than direct observation or the ActiGraph for P1. All participants had more directly observed short non-sedentary intervals (<60 sec.) than long intervals of non-sedentary time, with the highest number of breaks in the shortest category (10 to <30 seconds) (Table 3-3).

The position of the ActiGraph on the wrist likely contributes to the discrepancy noted for P4 between the ActiGraph and direct observation information. The ActiGraph recorded activity counts for isolated hand or arm movements, which would be recorded as sedentary by direct-observation coding. P4 had very little unintentional movement and independently engaged in activities with isolated hand movements such as reaching to get items on her desk, sitting reading a book, writing, or using a computer; all activities coded as sedentary with direct observation coding. During the observation periods P4 was more engaged in independent desk activities (as described above) compared with the other participants. She was involved in sedentary behaviors of longer duration than the other girls, and this behavior pattern affected the number of non-sedentary intervals recorded for her.

The SenseWear recorded only 3.4 minutes of non-sedentary time for P1, compared to 48.8 minutes measured by direct observation. Much of P1's movement is involuntary and many movements were whole-body movements, often with less frequency and amplitude of movement at the upper arm. This may have contributed to the low non-sedentary readings, as the SenseWear incorporates a tri-axial accelerometer as one of the measurements, and this would not capture resistance against a supporting surface, which may have been coded as non-sedentary by direct observation.

In order to evaluate the coding agreement of the three measures for the same time interval, percent agreement with direct-observation intervals was calculated (Table 3-4). No consistent pattern was noted among the four children. For P1 and P2 both the ActiGraph and SenseWear data had better agreement with direct-observation coding of sedentary intervals than non-sedentary intervals, indicating that both the ActiGraph and SenseWear did not record many of the non-sedentary intervals coded by direct observation. P3 data revealed better agreement on non-sedentary intervals with the ActiGraph data and sedentary intervals with the SenseWear. P4 had very high agreement on non-sedentary intervals for both the ActiGraph and SenseWear. P1 had no agreement for non-sedentary intervals – this result was influenced by the very low time (3.4 minutes) recorded as sedentary by the SenseWear. It is important to note that the direct-observation intervals are not of equal length, either within the same participant or amongst participants.

DISCUSSION

The results indicate that the four girls in this study spent a significant amount of time sedentary. This finding was not unexpected as children with cerebral palsy, especially with

GMFCS classification IV and V, experience significant motor challenges and have limited movement opportunities available to them. Interestingly, in the literature, children who are developing typically were sedentary for a mean of 43.6 minutes per hour, and children with cerebral palsy who were ambulatory were sedentary for a mean of 47.5 minutes per hour, measured by a hip-worn accelerometer over a 7-day period.[11] Two of the children in this study (P1 and P3) had much less sedentary time per hour (32.8 min and 28.3 min per hour respectively) as the children who are typically developing and P2 and P4 had similar amounts of sedentary time (41.5 min and 49.9 min per hour respectively) as the children with cerebral palsy who are ambulatory. It was expected that all children in this study would have more sedentary time than children who were typically developing due to their more severe motor challenges. There are a number of possible reasons for this discrepancy. The children in this study were observed for only a short length of time (2 or 4 hours) compared to a 7-day period. It is possible that the observed period of time was a particularly active period. P1 has athetosis and this involuntary movement decreased her sedentary time. P2 and P3 both had periods of repetitive movements of high amplitude that were considered non-sedentary, but P3 had significantly more directed active time than P2 (walking in walker, self-wheeling manual wheelchair), possibly accounting for the difference in total sedentary time.

The identified pattern of non-sedentary breaks identified is new information. Children in this study had frequent but very short non-sedentary breaks. The minimum known length of a break that provides health benefits is 2 minutes[8]; in this study, the majority of the participants' breaks were under 2 minutes. The health benefits, if any, associated with such short breaks are unknown. Obeid et al[11] recently used 3-second ActiGraph GT1M epochs to capture sedentary time and non-sedentary breaks in 17 ambulatory children with cerebral palsy (GMFCS I, II, III) and their age-matched peers over 7 days of monitoring. They found that the children with cerebral palsy had higher total sedentary time as well as fewer breaks than their peers who were developing typically. They acknowledged that it is not known whether there are any health benefits to non-sedentary breaks as short as 3 seconds in duration. A greater understanding of the relationship between length of breaks and health outcomes is important for physical therapists. Although there are well-known benefits to periods of moderate to vigorous physical activity,[24] children with cerebral palsy and their families often find it challenging to maintain such a physical-activity regimen.[25] Breaking sedentary time with short breaks may be more realistic and feasible for families and children. It may also be more feasible in school settings, where there are often only time-limited opportunities for movement between classes. Further research in this area should use short enough time intervals to capture breaks of short duration.

The findings suggest that the ActiGraph and SenseWear may not be the right tools to measure sedentary and non-sedentary activity in children with cerebral palsy who use wheelchairs. The data revealed no consistent pattern in the over- or underestimation of sedentary time by the devices across the four participants, compared to the direct observation. The ActiGraph was worn on the wrist, and this placement may have contributed to the discrepancies in sedentary and non-sedentary time between the ActiGraph and direct observation. Previous researchers who have used hip-worn accelerometers for children with cerebral palsy who use wheelchairs identified that it was difficult to determine if the accelerometers accurately captured activity because of the hip position.[20,21] The use of accelerometers with children who use wheelchairs is particularly challenging and requires further research to determine its reliability and validity. The SenseWear incorporates measures of skin temperature, galvanic skin response, and heat flux, as well as an accelerometer. It is reasonable to suggest that skin temperature, galvanic skin response, and heat flux may experience a lag time from when an activity was started or ended to when the subsequent physiological changes take place and are measured by the SenseWear. All four children generally had short coded intervals, particularly for non-sedentary time, and these short breaks may have influenced the SenseWear results. It is likely that for very short non-sedentary breaks, physiological changes would not be recorded by the SenseWear until after the directly observed non-sedentary interval ended. Likewise, the physiological changes from longer non-sedentary intervals may have persisted into the subsequent sedentary interval determined by direct observation. Further research is needed to determine if this is the case. Another possible cause for the discrepancies noted between the direct observation and the SenseWear is that it uses an algorithm to determine energy expenditure from the physiological and accelerometer information it collects, combined with the child's height and weight. These algorithms have been developed for children who are developing typically, and algorithms are not currently available for children with cerebral palsy. Research has shown that children with cerebral palsy have altered body composition when compared with their peers who are developing typically. Stallings et al[26] found that children who had spastic quadriplegic cerebral palsy had decreased fat mass and fat-free mass. These algorithms may not be valid for children with cerebral palsy.

Direct observation has not been previously used to categorize the sedentary and non-sedentary behaviors of children with cerebral palsy who use wheelchairs. Direct-observation methods often use time-sampling rather than the continuous time recording used in this study. Continuous observation was able to capture short bursts of non-sedentary time and provided information as to the length and frequency of breaks that may have been undetected with time-sampling. Direct observation provides rich information about the type and patterns of movements used; this information may be particularly important for children with cerebral palsy. It is important to note that further research needs to be conducted regarding the validity of all 3 measures for this population and this study does not identify the most valid measure used.

When coding sedentary and non-sedentary intervals in direct observation, the movements of children who are developing typically were used as a guideline. For example, a child with typical development may have some movement when sitting and using a computer, but the activity would be considered sedentary. The coding scheme was created specifically for children with cerebral palsy and was used to collect information regarding different positions/activities, the amount of movement taking place, and whether a movement was intentional, non-intentional, or a combination. This information is important for future studies. However, the main goal of this study was to evaluate the sedentary and non-sedentary patterns of movement, and in retrospect more detailed information was collected than required to meet this goal.

The Observer XT software has previously been used to document the sedentary and non-sedentary behaviors of adults, including non-sedentary breaks.[12,27,28] This software allows for continuous coding of activities with user-made coding schemes. Continued development of these types of tools will assist clinicians and researchers in documenting and describing sedentary and non-sedentary behaviors. It proved to be an excellent application for integrating information among direct observation and ActiGraph and SenseWear recordings.

Sedentary behavior is a relatively new field of interest, and researchers are only just beginning to unravel sedentary behavior from physical activity. The benefits of regular breaks from sedentary time were first described in 2008, and researchers are now looking at the length of a sedentary interval, as well as the duration of a break, to understand the related health outcomes.[8,9] Research to define and explore sedentary behavior and its implications for children with cerebral palsy is only just emerging. The current standard definition for sedentary behavior includes position and energy expenditure; however, the position aspect of the definition may not be relevant for this population. Yates et al[29] described muscle activity during sedentary behavior as "the majority of the body's large muscle groups are under relaxation,"[(p292)] and this may be a better way to consider sedentary behavior for children with cerebral palsy. Defining and measuring sedentary behavior for children with movement challenges is particularly difficult for children who use wheelchairs, because they may use more energy in positions that would usually be considered sedentary (such as unsupported sitting), and less in positions considered non-sedentary if using supportive equipment (standing in a standing frame.)[3,30] Accelerometers have been the gold standard for measuring sedentary behavior, but the hip placement may not be valid for children who use wheelchairs. Future research should consider using measures of energy expenditure, such as indirect calorimetry, or measures of muscle activation, such as electromyography, or a combination of these.

The limitations of the study must be considered. The small sample size and the heterogeneity of the children limit the extent to which the findings can be generalized. No gold-standard criterion measure for energy expenditure was used in this study. The criterion measure for energy expenditure is indirect calorimetry, and it was not feasible to use this measure in a non-clinical, free-living setting.

These results should be interpreted with caution by clinicians. There is not yet enough evidence to implement interventions. The health risks of sedentary behaviour, if any, are not known for children with cerebral palsy. Children with cerebral palsy are often already tired from their regular activities of daily living.[25] It may be unrealistic for children and their families to add additional demands into their day, particularly if they are not functional or meaningful.

CONCLUSION

In this exploratory study, children with cerebral palsy who use wheelchairs had a significant amount of sedentary time with very short non-sedentary breaks. The SenseWear and the ActiGraph data did not align with direct observation coding of sedentary and non-sedentary behaviors.

Table 3-1. Participants.

		Participant 1	Participant 2	Participant 3	Participant 4
Age		14	8	12	7
GMFCS level		5	5	4	4
Muscle Tone		athetoid and spastic	spastic	spastic	spastic
Types of Activities Observed	lying on mat or bed	✓	✓	✓	✗
	sitting in manual wheelchair	✓	✓	✓	✓
	self-wheeling manual wheelchair	✗	✗	(non-functional, used as activity while tilted)	✓
	driving power chair	✗	✗	✗	✓
	locomotion in full-support walker	✗	✗	✓	✓
	sitting writing, reading, using computer keyboard and mouse	✗	✗	✗	✓
Number of Observations		1	2	2	2
Location of Obervations		home	school	school	home and school

Table 3-2. Sedentary and non-sedentary behavior descriptives from Direct Observation, ActiGraph, and SenseWear data.

	Participant 1	Participant 2	Participant 3	Participant 4
Direct Observation Data				
Total observation time in minutes	120.9	254.0	236.7	240.0
Total sedentary time in minutes (%)	66.1(54.6)	175.8(69.2)	111.7(47.2)	199.8(83.2)
Total non-sedentary time in minutes (%)	48.8(40.4)	46.5(18.3)	98.2(41.5)	27.2(11.3)
Total time not coded in minutes (%)	6.0(5.0)	31.7(12.5)	26.7(11.3)	13.0(5.4)
ActiGraph Data				
Total observation time in minutes	120.9	254.0	236.7	240.0
Total sedentary time in minutes (%)	83.2(68.8)	156.7(61.7)	94.6(40.0)	84.7(35.3)
Total non-sedentary time in minutes (%)	31.7(26.2)	65.6(25.8)	115.3(48.7)	142.3(59.3)
Total time not coded in minutes (%)	6.0(5.0)	31.7(12.5)	26.7(11.3)	13.0(5.4)
SenseWear Data				
Total time analysed by SenseWear in minutes	120.0	252.4	233.0	237.0
Total sedentary time in minutes (%)	110.6(92.2)	190.5(75.5)	153.2(65.8)	140.7(59.4)
Total non-sedentary time in minutes (%)	3.4(2.8)	30.2(12.0)	53.0(22.8)	83.3(35.1)
Total time not coded in minutes (%)	6.0(5.0)	31.7(12.6)	26.7(11.5)	13.0(5.5)

Table 3-3. Frequency of non-sedentary intervals by participant.

		Participant 1	Participant 2	Participant 3	Participant 4
Frequency of non-sedentary intervals (%)	10 to <30 seconds	25(45.0)	22(43.1)	22(37.9)	14(46.7)
	30 to <60 seconds	14(20.0)	16(31.4)	13(22.4)	8(26.7)
	60 to <120 seconds	10(18.2)	8(15.7)	8(13.8)	4(13.3)
	120 to <240 seconds	5(9.1)	3(5.9)	7(12.1)	4(13.3)
	240 to <480 seconds	1(1.8)	2(3.9)	6(10.3)	0(0.0)
	480+ seconds	0(0.0)	0(0.0)	2(3.4)	0(0.0)
Range of duration of sedentary intervals		11.5 sec- 5.2 min	11.3sec - 11.1 min	10.7 sec - 18.8 min	10.0 sec - 28.6 min
Range of duration of non-sedentary intervals		10.0 sec- 4.4 min	10.0 sec - 4.8 min	10.5 sec - 9.8 min	10.4 sec - 3.4 min

Table 3-4. Agreement between direct observation intervals and ActiGraph, and direct observation intervals and SenseWear.

	Actigraph		**SenseWear**	
Participant	Number of sedentary intervals that agree with total DO sedentary intervals	Number of non-sedentary intervals that agree with total DO non-sedentary intervals	Number of sedentary intervals that agree with total DO sedentary intervals	Number of non-sedentary intervals that agree with total DO non-sedentary intervals
1	45/54 = 83.3%	19/55 = 34.5%	52/54 = 96.3%	0/55 = 0.0%
2	58/70 = 82.8%	38/51 = 74.5%	62/70 = 88.6%	14/51 = 27.5%
3	31/62 = 50.0%	39/58 = 67.2%	45/60 = 75.0%	17/57 = 29.8%
4	7/35 = 20.0%	30/30 = 100%	16/35 = 45.7%	27/30 = 90%

Abbreviation: DO, direct observation

Appendix 3-1: Direct Observation Coding Scheme

The positions and activities are mutually exclusive – only one could be coded for each interval. The observer coded the appropriate position or activity for each interval, and then identified the appropriate modifiers for the interval. A designation of sedentary or non-sedentary was given to each interval. 'Not coded' was used to identify intervals when the child could not be videotaped.

Positions and Activities (mutually exclusive)

- Prone lying
- Supine lying
- Sitting unsupported
  - Level of assistance
- Sitting backrest
  - supports
- Sitting reclined
  - supports
- Sitting tilt-in-space
  - supports
- Standing
  - standing
- rolling
- creeping
- walking
  - walker type
  - level of assist
- self-wheeling
- power wheelchair use
  - supports
- sit-stand
  - level of assist
- stand-sit
  - level of assist
- sit-floor
  - level of assist
- floor-sit
  - level of assist
- bunny hopping
- bottom shuffling
- walking on knees
- jumping

<u>Modifiers</u>

Sedentary/Non-sedentary

Level of assistance

- no assistance
- hand over hand
- partial assist
- full assist

Standing

- unsupported
- leaning
- prone standing frame
- supine standing frame
- upright standing frame

Supports

- lapbelt
- chest harness
- headrest
- foot straps/ankle huggers

Walker type

- basic
- forearm supports
- full supports (Rifton/Pony)

Intention of movement

- no movement
- intentional
- non-intentional
- intentional with observable increased muscle activity

Movements

- hand/hands
- arm/arms
- head
- trunk
- leg/legs
- foot/feet

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Chapter 4: Conclusion

SUMMARY OF RESULTS

The results of this study confirm the need for further research in the emerging area of the effects of sedentary behaviour with children with cerebral palsy who use wheelchairs as their main method of mobility. The study revealed that their non-sedentary breaks are very short and fairly frequent, but the physiological significance of these very frequent short breaks need to be determined.

An appropriate definition of sedentary behaviour and a gold standard for measurement with children with cerebral palsy need to be determined. A direct observation measure was developed for use in the research presented and the results suggest that direct observation identifies more non-sedentary intervals than the ActiGraph GT3X accelerometer or SenseWear data. Further investigation of the three measurement options to identify non-sedentary and sedentary intervals is needed to determine the relationship among the measures and their validity with children who use wheelchairs most of the time. The direct-observation measure developed for the study needs continued development and a rigorous assessment of its reliability and validity. Preliminary use of such a measure suggests that it is a valuable adjunct to more physiological or objective measures.

CLINICAL IMPLICATIONS

Children in this study accrued significant amounts of sedentary time and took very short breaks from sedentary time. Families have reported that there are significant barriers to participation in physical activity for children with cerebral palsy.[1] Children and their families may find it more realistic and feasible to add more non-sedentary breaks to their day. Further research needs to determine what constitutes a break in terms of both the duration of the break and the activity. If short breaks such as those identified in this study prove to provide positive health outcomes, new intervention strategies that encourage short, frequent non-sedentary breaks from sedentary behaviour need to be considered. For example, many children who use wheelchairs at school currently get out of their wheelchairs at lunchtime and perhaps for one longer activity time during their time at school. It may be more advantageous to introduce frequent non-sedentary breaks such as “sit to stand” breaks. Researchers need to explore innovative approaches to introducing light physical activity into typical activities. Similar to the “Transform Us” study with children in school, novel approaches need to be considered. Before intervention ideas can be designed and implemented, further examination regarding the duration and frequency of breaks necessary to achieve positive health outcomes is needed. It is intriguing to consider the intervention possibilities for reducing sedentary time however implementing these strategies is premature. Sedentary behavior research for children with cerebral palsy is only just emerging. It is not yet known if there are any health risks for children with cerebral palsy due to sedentary behavior. Interventions should consider the whole child and their family and the competing demands on their time and energy, as well as whether and activity is functional and meaningful to the child. Some children with cerebral palsy are very fatigued completing only the necessary daily activities[1] and adding physical demands may not be realistic for them.

Pediatric physical therapists need to become familiar with the emerging science of sedentary behaviour. They are in an ideal position to bridge the knowledge evolving from children with typical development to children with motor challenges. It is an exciting time to consider innovative approaches to both sedentary behaviour and physical activity for children with cerebral palsy.

DISSEMINATION OF RESULTS

Chapter 2 has been published as a special communication in Pediatric Physical Therapy: Innes, J. Darrah, J. 2013. *Pediatr Phys Ther*. 25(4), 402-408. doi:

10.1097/PEP.0b013e31829c4234. Wolters Kluwer Health Lippincott Williams & Wilkins ©. Chapter 3, the results of the thesis research, will be submitted to the Physical and Occupational Therapy in Pediatrics journal as a research report.

The information gained in the study will also be presented to pediatric physical therapists working with children with cerebral palsy in schools as well as other pediatric physical therapists in the community. This research will also be submitted as a platform presentation at national and international conferences.

I plan to do further work with the dataset evaluating the influence of position and activity on sedentary and non-sedentary intervals as identified by direct observation.

IMPLICATIONS FOR FUTURE RESEARCH

The standard definition of sedentary behavior may not be relevant for children with cerebral palsy who use wheelchairs, and measuring sedentary behavior in this population is particularly challenging. A definition of sedentary behavior that can more easily be applied to children with cerebral palsy would assist researchers in measuring sedentary behavior. The wrist-worn ActiGraph and the SenseWear did not accurately measure sedentary and non-sedentary behavior when compared with direct observation. Researchers should consider using criterion measures such as electromyography to determine muscle activation, and indirect calorimetry to determine energy expenditure.

Children in this study took very short breaks from sedentary time. Future research to determine if there are any benefits to these breaks would be extremely valuable.

Further work to look at how sedentary or non-sedentary children are in different postures and activities could help to inform families, clinicians, and schools when planning programming and movement breaks.

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