THE RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND SLEEP AMONG PRESCHOOL-AGED CHILDREN

by

Laura Miller

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Abstract

Poor sleep is common among children in today's society. It is important to develop ways to promote healthy sleep in children. It could be that physical activity is a healthy sleep practice for children similarly to adults. The purpose of this research was to examine the relationship between physical activity and sleep among preschool-aged children. In sub-study 1, children wore a waist accelerometer to objectively measure physical activity. Parents completed a survey to subjectively measure their children's sleep. In sub-study 2, children wore a wrist accelerometer to objectively measure sleep simultaneously to wearing the waist accelerometer in sub-study 1. Physical activity predicted subjective variables of sleep (sleep onset latency (b=0.69, SE=0.41, p=0.09) and night awakenings (b=-1.75, SE=0.54, p<0.01)). Physical activity also predicted objective variables of sleep (sleep efficiency ($F_{(1,25)}$=4.37, b=0.36, p<0.05)). This research supports promoting physical activity in young children to potentially help prevent consequences of poor sleep on health.

List of Abbreviations Used

LPA	Light physical activity
MVPA	Moderate to vigorous physical activity
PA	Physical activity
SB	Sedentary behaviour
SES	Socioeconomic status
SOL	Sleep onset latency
TIB	Time in bed
TST	Total sleep time
WASO	Wake after sleep onset

Chapter 1: Introduction

Sleep

Poor sleep is common among children in today's society, as around 25 percent of children experience some type of sleep problem (Owens, 2007). It is important for children to obtain sufficient quantity and quality sleep, not only to prevent daytime sleepiness, but also as sufficient sleep is important for healthy childhood development (Chaput et al., 2017; Tikotzky & Sadeh, 2001; Vriend, Davidson, Rusak, & Corkum, 2015). This common phenomenon of poor sleep among children is therefore concerning, as recent research demonstrates various negative effects of poor sleep on health. For example, a systematic review conducted by Chaput et al. (2017) examined the relationship between sleep duration and health indicators among children between the ages of zero and four years. This research indicates a favourable relationship between increased sleep duration and body composition, emotional regulation and growth. Experimental sleep research shows that poor sleep results in deficits in cognitive and emotional functioning (Vriend et al., 2013; Vriend et al., 2015). Correlational sleep research indicates that poor sleep is associated with deficits in behavioural and executive functioning (Astill et al., 2012; Gruber et al., 2014). Finally, it is supported that poor sleep can lead to suppressed immune system functioning and increases risk for the development of overweight/obesity (Krueger, Jidong, & Floyd, 1999; Liu, Zhang, & Li, 2012).

Overall, it is important to develop ways to improve sleep among this population through healthy sleep practices to promote optimal development and improved overall health. It is also important that this issue of poor sleep be addressed by intervening during the preschool-aged years to prevent unhealthy practices from transforming into persistent habits (Craigie, Lake, Kelly, Adamson, & Mathers, 2011).

Physical Activity, Sedentary Behaviour and Sleep

A systematic review conducted by Timmons et al. (2012) examined the relationship between physical activity (PA) and health indicators among children between the ages of zero and four years. This review supports that more time spent in PA is positively associated with improved measures of adiposity, motor skill development, bone and skeletal health, psychosocial health and cardiometabolic health indicators (Timmons et al., 2012). Additionally, a systematic review conducted by Poitras et al. (2017) examined the association between sedentary behaviour and health indicators among children between the ages of zero and four years. Although somewhat inconsistent in results, this research supports that sedentary behaviour may be related to adiposity, motor and cognitive development, and psychosocial health (Poitras et al., 2017).

Finally, a systematic review conducted by Kuzik et al. (2017) examined the relationship between combinations of movement behaviours (i.e., PA, sedentary behaviour and sleep) and health indicators among children zero to four years of age. Ideal combinations of low sedentary behaviour and high PA were found to be associated with health indicators including motor development, fitness and adiposity. Furthermore, ideal combinations of high sleep and low sedentary behaviour were also found to be associated with adiposity (Kuzik et al., 2017). This research therefore helps demonstrate the relationships between the three movement behaviours, and how interactions with each other relate to various health indicators.

Overall, as PA, sedentary behaviour and sleep interact with each other to associate with various health outcomes, it is likely that there is a relationship between the activity variables themselves (e.g., PA and sleep). Although there is extensive literature exploring the effects of PA on various aspects of health in early childhood, there is currently limited research exploring the effects of PA on sleep in early childhood, particularly among preschool-aged children. As PA is widely supported as a healthy sleep practice among adults (Kredlow, Capozzoli, Hearon, Calkins, & Otto, 2015), it could be that PA is also a healthy sleep practice among preschool-aged children too. However, only nine studies have specifically examined this relationship within this population, with PA as the predictor variable and sleep as the outcome variable. As such, the relationship between PA and sleep among preschool-aged children is under researched. Additionally, among this limited literature, there are inconsistencies in the tools used to measure PA and sleep. Finally, results from these studies are also inconsistent, making it difficult to establish firm conclusions.

A systematic review conducted by Chaput et al. (2017a) examined the relationship between sleep duration and other various indicators of health, including PA, among children between the ages of zero and four years. This review examined four studies that researched this relationship. Only one of these studies utilized PA as the predictor variable with sleep as the outcome variable (Plancoulaine, Lioret, Regnault, Heude, & Charles, 2015). Results of this study revealed no association between parent report of hours spent in weekly PA and parent report of sleep duration. This could be due to the subjective nature of parental reports, which are not uncommonly prone to error (Fitzhugh, 2015; Iwasaki et al., 2010).

Tatsumi et al. (2015) examined the relationship between objectively measured PA and objectively measured sleep. In contrast to the null findings revealed by Plancoulaine et al. (2015), this study found a positive relationship between PA counts per minute and percent sleep (the percentage of total sleep between sleep onset and sleep end time). The inconsistencies among tools used to measure PA and sleep respectively could potentially contribute to the inconsistencies among results found. As waist accelerometers are recommended for measuring PA, and wrist accelerometers are recommended for measuring sleep, future research should incorporate the recommended tools for measuring PA and sleep respectively (Trost, McIver, & Pate, 2005; Slater et al., 2015). This represents a gap in the literature that needs to be addressed.

Purpose of the Study

The purpose of the current study was to examine the relationship between PA and sleep among a sample of preschool-aged children. It consisted of two sub-studies, with the following research questions:

Sub-Study 1:

1. Is children's accelerometry-measured total PA (% of day spent active) positively associated with parent-reported weekday-night sleep duration?

It was hypothesized that as total PA (% of day spent active) increased across participants, weekday-night sleep duration would also increase.

2. Is children's accelerometry-measured total PA (% of day spent active) negatively associated with parent-reported sleep onset latency and parent-reported night awakenings?

It was hypothesized that as total PA (% of day spent active) increased across participants, the amount of time to fall asleep and the number of night awakenings would decrease.

Sub-Study 2:

1. Is children's accelerometry-measured total PA (% of day spent active) positively associated with objectively-measured total sleep time?

It was hypothesized that as total PA (% of day spent active) increased across participants, total sleep time would also increase.

2. Is children's accelerometry-measured total PA (% of day spent active) negatively associated with objectively-measured sleep onset latency, and positively associated with objectively-measured sleep efficiency?

It was hypothesized that as total PA (% of day spent active) increased across participants, sleep onset latency would decrease and sleep efficiency would increase.

The first research questions in sub-studies 1 and 2, which focus on sleep duration and total sleep time, respectively, served as primary research questions. The second research questions of each sub-study, which focus on sleep onset latency and night awakenings, served as secondary research questions. Should the results of this research support the hypotheses, this research will contribute to a better understanding of the need to promote increased levels of PA in young children to help potentially prevent the negative outcomes of poor sleep on health.

Significance of the Study

There is currently little research examining the relationship between PA and sleep among preschool-aged children. Furthermore, research findings examining this relationship among preschool-aged children are inconsistent (Chaput et al., 2017a). This research is therefore significant as it will add to the limited knowledgebase surrounding PA and sleep among this population. Additionally, this research is of further importance as it can be used to help inform parents, health promoters, healthcare professionals and policy makers on additional ways to potentially help improve children's sleep, so as to optimize childhood development. It is also important that this research be conducted focusing on preschool-aged children to help prevent unhealthy practices from becoming established and persisting into later childhood and adult life. The preschool-aged years are critical years during which to intervene (Craigie et al., 2011).

Finally, previous studies examining this topic in preschool-aged children have used various tools for measuring these variables (i.e., parental report or various accelerometers). When measuring PA and sleep, accelerometers are recommended, as parental reports can be imprecise (Fitzhugh, 2015; Iwasaki et al., 2010). Furthermore, accelerometers worn on the waist are recommended when measuring PA, and accelerometers worn on the wrist are recommended for measuring sleep (Trost et al., 2005; Slater et al., 2015). The use of recommended tools could potentially reveal more accurate and consistent results. As previous studies used these accelerometers interchangeably when measuring PA and sleep, the current study is the first to incorporate the recommended types of accelerometers for measuring both PA (waist-worn) and sleep (wrist-worn), respectively.

Importance and Relevance to Health Promotion

The World Health Organization defines the field of Health Promotion as striving to enable people to increase their control over and improve their physical, mental and social health (as cited in Nutbeam, 1998, p. 351). Research suggests that children between the ages of three and five experience large amounts of inactivity, particularly in the child care setting (Tonge, Jones, & Okely, 2016; Vanderloo et al., 2015). Additionally, although sleep is important for healthy development in children, approximately 25 percent of children experience some kind of sleep problem (Owens, 2007). Research focusing on the common phenomenon of physical inactivity and its effects on health has shown PA as a healthy sleep practice among adults (Galland & Mitchell, 2010). Although research examining this relationship is limited and inconsistent among preschool-aged children, it could be that PA is beneficial for sleep among this population as well. This research therefore aimed to contribute to the field of Health Promotion by addressing the need to further promote PA in young children for the purpose of preventing poor sleep. By doing so, this could help promote physical, mental and social health in young children, thereby helping to tackle the social determinant of health of childhood development (Public Health Agency of Canada, 2014).

Summary

Chapter 1 provided a brief summary of the background literature related to the current study. Sufficient quantity and quality of sleep is supported as serving an important role in healthy childhood development, but unfortunately, poor sleep has become a common phenomenon among children (Owens, 2007). Links have been made between PA and sleep in adults, supporting the positive effect of PA on sleep (Kredlow et al., 2015). Limited research has focused on the relationship between PA and sleep in preschool-aged children. The current study therefore aimed to add to the limited knowledge base by examining this relationship. Chapter 1 has demonstrated the importance of this topic and its contribution to Health Promotion as the research strives to further address the need to improve children's sleep to prevent unhealthy development in children. The following chapter will review in depth the existing body of literature on PA and sleep in children.

Chapter 2: Literature Review

Children's Health

The health behaviours of children have changed over the last several decades, including an increase in the consumption of unhealthy foods (Butland et al., 2007; Franks et al., 2010), an increase in sedentary time and screen time (Kirk, Penney & Langille, 2009), and a decrease in outdoor play (Burdette & Whitaker, 2005; Rideout, Vandewater & Wartella, 2003; Tandon, Zhou, & Christakis, 2012), physical activity (PA) (Burdette & Whitaker, 2005), and sleep (Owens, 2007). These current health behaviours are associated with adverse physical and mental health outcomes (Franks et al., 2010; Poitras et al., 2017; Tremblay et al., 2012; Timmons et al., 2012; Vriend, 2015). The current research aims to examine two of these health behaviours, including PA and sleep, to advance the current knowledge in children's health.

The Importance of Sleep Among Children

Sleep research indicates sleep as an important factor for optimal daytime functioning and overall health, therefore playing an important role for healthy childhood development (Krueger et al., 1999; Lushington, Pamula, Martin, & Kennedy, 2013; Tikotzky & Sadeh, 2001). Insufficient sleep (i.e., sleep of poor quality and quantity) at any age can lead to adverse health outcomes. However, such adverse outcomes are more likely to occur and persist in children than in adult populations (Jan et al., 2010). These outcomes can include increases in daytime sleepiness and physical and psychosocial health deficits (Matricciani, Olds, Blunden, Rigney, & Williams, 2012; Vriend et al., 2015). For example, Chaput et al. (2017a) conducted a systematic review examining the relationship between sleep and indicators of health among children between the ages of zero and four years. Among these studies, sleep was measured objectively (via polysomnography or actigraphy), subjectively (via parent report) or by both actigraphy and sleep log/diaries. Results of this systematic review revealed that shorter sleep durations are associated with adiposity gain and poor emotional regulation and cognitive functioning. Furthermore, longer sleep durations were associated with healthy indicators of growth (Chaput et al., 2017a).

The main findings of the existing experimental sleep studies in children, which involve restricting sleep and testing the outcomes, are that shorter sleep durations among typically developing children results in deficits in cognitive functioning (e.g., memory, learning and attention). Specifically, among children, sleep loss can result in deficits on tests of verbal creativity and learning new abstract concepts (Randazzo, Muehlbach, Schweitzer, & Walsh, 1998), problems with inattention reported by teachers (Fallone, Acebo, Arnedt, Seifer, & Carskadon, 2001), deficits in sustained attention and vigilance (Gruber et al., 2011), increased simple reaction times (Sadeh, Gruber, & Raviv, 2003), and deficits in short-term and working memory, mathematical fluency, and attention (Vriend et al., 2013). Experimental sleep research also indicates that inadequate sleep can result in deficits in emotional functioning, as children can objectively display less positive affect, and poorer emotional regulation as reported by parents (Vriend et al., 2013; Vriend et al., 2015). Additionally, correlational sleep studies demonstrate that insufficient sleep in children is associated with impairments in school performance, deficits in executive functioning and increases in internalizing and externalizing behavioural problems (Astill et al., 2012; Gruber et al., 2014).

Not only can insufficient sleep lead to increases in daytime sleepiness and psychosocial health deficits, but it can also lead to physical health deficits as well. For example, research indicates that restorative sleep strengthens the immune system (United States Department of Health and Human Services, 2016). Children achieving lower amounts of restorative sleep can experience poorer immune system functioning compared to children achieving higher amounts of restorative sleep (United States Department of Health and Human Services, 2016). Children who experience poor sleep are therefore more susceptible to pathogens and infection. Furthermore, these infections can last longer and can be more severe as a result of poor sleep (Krueger et al.,1999). There is also widespread support for insufficient sleep causing adverse hormonal changes that are associated with obesity, a disease which can increase the risk for cardiovascular disease, diabetes, hypertension and various cancers later in life (Gruber, 2015; Liu et al., 2012). Overall, given these adverse health outcomes that can arise due to poor sleep, it is essential for children to obtain sufficient sleep.

The Pandemic of Insufficient Sleep Among Children

Sleep problems within the pediatric population are among the most common complaints brought to health care professionals (Tikotzky & Shaashua, 2012). Poor sleep is a common phenomenon in today's society and represents a significant public health concern (Kredlow et al., 2015; Owens, 2007). Approximately 25 percent of children experience some kind of behavioural sleep problem, such as insomnia, which includes difficulties initiating sleep, maintaining sleep, or waking too early (Owens, 2007). Additionally, it is recommended that children between the ages of three and five years should obtain between 10 to 13 hours of sleep per night to help maximize healthy development and functioning (Hirshkowitz et al., 2015; National Sleep Foundation, 2004). However, research indicates that many preschool-aged children do not meet this recommendation, and are therefore not obtaining sufficient sleep. Shorter sleep durations, difficulties falling asleep and difficulties staying asleep are common sleep problems in children and daytime sleepiness is a good indicator of poor sleep (National Sleep Foundation, 2004; Owens, 2007; Vriend et al., 2015).

Given the detrimental effects of poor sleep on overall health and development, it is essential to develop methods to promote sufficient quantity and quality sleep in children through various means to prevent these dangerous health outcomes (Astill et al., 2012; Liu et al., 2012; Vriend et al., 2013). Furthermore, it is important to intervene when children are young, as altering behaviours among children in their preschool-aged years is considerably easier than altering behaviour in older children and adults (Goldfield, Raynor, & Epstein, 2002). This is likely due to the fact that health behaviours among preschool-aged children are more adaptable and less resistant to change, as behaviours have not had enough time to become engrained habits (Goldfield et al., 2002). The preschool-aged years are therefore critical years during which to intervene. This makes it important for research examining healthy sleep practices to be conducted in preschool-aged children, to intervene at as early an age as possible to prevent unhealthy practices from becoming established and persisting into later childhood and adult life (Craigie et al., 2011).

The Three Movement Behaviours

Research indicates that physical activity (PA) is important for healthy childhood development as it can positively affect physical and psychosocial development. For example, a systematic review conducted by Timmons et al. (2012) examined the health benefits associated with increased or higher PA among children between the ages of zero and four years. A total of 18 studies met the inclusion criteria for the review. Time spent in PA was measured subjectively via parent report, objectively via waist accelerometry, or by direct observation. This review concludes that increased time spent in PA is associated with improved measures of adiposity, bone and skeletal health, motor skill development, psychosocial health (i.e., cognitive, social and emotional health) and cardiometabolic health indicators (Timmons et al., 2012).

Similar to the Timmons et al. (2012) study findings, Carson et al. (2017a) also examined the relationship between PA and health outcomes among children between the ages of zero and four years. A total of 96 studies were included in analysis. PA was measured via accelerometry, direct observation, heart rate monitors, and/or via pedometers. The experimental research consistently indicated PA positively associated with improved motor development, cognitive development, psychosocial health and cardiometabolic health. Additionally, observational studies indicated PA favourably associated with motor development, fitness, and bone and skeletal health. These studies included in the review examined PA at various intensities, and although PA was related to beneficial health outcomes, the specific intensity of PA (e.g., light PA, moderate to vigorous PA or total PA) providing such benefits was unclear (Carson et al., 2017a). Based off these systematic reviews, it is therefore evident that PA is important for the overall health of children. Given that PA is beneficial for various domains of childhood health, it could be that PA is also beneficial for sleep.

Sedentary behaviour is another activity variable related to PA as well as various health outcomes. Poitras et al. (2017) conducted a systematic review examining the association between sedentary behaviour and health indicators among children between the ages of zero and four years. A total of 96 studies were included in analysis. Sedentary behaviour was measured objectively via accelerometry, or subjectively (e.g., time spent in screen-based activities). Although results were somewhat inconsistent, this research supports that sedentary behaviour, particularly screen-based sedentary behaviours, may be unfavourably related to adiposity, motor and cognitive development, and psychosocial health including self-esteem and prosocial behaviour (Poitras et al., 2017)

Finally, in a systematic review, Kuzik et al. (2017) examined the relationship between combinations of movement behaviours and health indicators among children between the ages of zero and four years. Results of this review showed that ideal combinations of low sedentary behaviour and high PA were favourably associated with health indicators including motor development, fitness and adiposity. This review also examined the third movement variable, sleep, in combination with sedentary behaviour to examine their relationship together with health indicators (Kuzik et al., 2017). Ideal combinations of high sleep and low sedentary behaviour were also found to be associated with lower levels of adiposity. This research therefore helps demonstrate the relationships between the three movement behaviours, and how interactions with each other relate to various health indicators.

The Canadian 24-Hour Movement Guidelines

The new Canadian 24-hour movement guidelines integrate PA, sedentary behaviour and sleep together as the three movement behaviours across a whole day (Tremblay et al., 2017). These guidelines conceptualize movement on a continuum from sleep to high PA. The 24-hour guidelines are the first of its kind internationally, and are part of a paradigm shift in thinking about daily movement behaviours. They represent a shift from focusing on movement behaviours in isolation to a whole day approach (Tremblay et al., 2017).

The guidelines suggest that preschool-aged children should practice healthy sleep practices, limit sedentary behaviour (especially screen time), and participate in a range of physical activities in a variety of environments. Specifically, it is recommended that preschool-aged children between the ages of three and four years accumulate at least 180 minutes of PA at any intensity spread throughout the day (Canadian 24 Hour Movement Guidelines, 2016; Tremblay et al., 2012). This PA should include: a variety of activities in different environments, activities that develop movement skills, and progression towards at least 60 minutes of energetic play by five years of age (Canadian 24 Hour Movement Guidelines, 2016; Tremblay et al., 2012). It is also recommended that caregivers minimize the time preschoolers spend sedentary during waking hours (Canadian 24 Hour Movement Guidelines, 2016). This includes prolonged sitting or being restrained in a high chair or stroller. As previously mentioned, adhering to these guidelines is associated with various health benefits, including, but not limited to, better cognitive functioning, emotion regulation, cardiovascular and metabolic health, and cardiorespiratory and musculoskeletal fitness (Tremblay et al., 2017).

Tremblay et al. (2017) developed these guidelines through four systematic reviews (Carson et al., 2017a; Chaput et al., 2017; Kuzik et al., 2017; Poitras et al., 2017) examining the relationships within and among the movement behaviours and their numerous health indicators. Limited studies were found examining the combination of two or more movement behaviours and their relationship with health indicators. Tremblay et al. (2017) state that examining the combinations of movement behaviours that make up the total 24-hour period is uncommon and they argue that examining combinations of movement behaviours presents inherent analytical challenges. However, as the individual movement behaviours saturate the entire 24-hour period, a change in any behaviour is likely done at the expense of another one of the movement behaviours (Tremblay et al., 2017). This further indicates the likely relationship between activity (e.g., PA) and sleep, and supports the need for further research to be conducted examining this topic among preschool-aged children.

Physical Inactivity and Sleep

Physical inactivity and sedentary behaviour are evidenced to be contributing factors to various problems among children such as excess weight and potentially even poor sleep (Busto-Zapico, Amigo-Vázquez, Peña-Suárez, & Fernández-Rodríguez, 2014). There is evidence suggesting that every hour children spend in sedentary activities delays bedtime by three minutes (ParticipACTION. Are Canadian kids too tired to move?, 2016). Furthermore, the 2016 ParticipACTION Report Card on Physical Activity for Children and Youth suggest that Canadian children are inactive and may be losing sleep because of this physical inactivity (ParticipACTION. Are Canadian kids too tired to move?, 2016). Unfortunately, physical inactivity and sedentary behaviour among children have become common phenomena in today's society (Blair, 2009, Garriguet, & Colley, 2012). This trend has emerged among preschool-aged children as many spend most of the day engaging in sedentary behaviour and spend little time being active, especially in early years centres (Goldfield, Harvey, Grattan, & Adamo, 2012; Koplan et al., 2005; Vanderloo et al., 2015).

According to Chaput et a. (2017b), only 13% of preschool-aged children in

Canada meet all three recommendations from the Canadian 24-Hour Movement Guidelines of PA, sedentary behaviour and the National Sleep Foundation's sleep guidelines in Canada. When broken down into three individual movement behaviours, results showed that 40% of children did not meet the PA guidelines, 80% of children did not meet the sedentary behaviour guidelines, and 20% of children did not meet the sleep guidelines (Chaput et al., 2017b). Furthermore, the 2016 ParticipACTION Report Card on Physical Activity for Children and Youth gave Canada a D- for overall PA among children between the ages of three to 17 years (ParticipACTION. Are Canadian kids too tired to move?, 2016). Daily levels of PA are therefore low among young children and many young children do not obtain sufficient PA to remain healthy (Hinkley, & Salmon, 2011; Tudor-Locke, Johnson, & Katzmarzyk, 2010).

Overall, it is therefore clear that PA, sedentary behaviour and sleep interact with each other, and it is important to gather a better and more concrete understanding of how activity (e.g., PA) relates to sleep in children.

Physical Activity as a Healthy Sleep Practice

The importance of physical activity. Healthy sleep practices are habits that promote good sleep quality, sufficient sleep duration, and prevent daytime drowsiness (Mindell, Meltzer, Carskadon, & Chervin, 2009). The ABCs of SLEEPING mnemonic serves as an organizing framework for common healthy sleep practice recommendations for children between the ages of one and 12. The mnemonic stands for 1) **a**ge appropriate **b**edtimes and wake times with **c**onsistency, 2) **s**chedules and routines, 3) **l**ocation, 4) **e**xercise and diet, 5) no **e**lectronics in the bedroom or before bed, 6) **p**ositivity, 7) **i**ndependence when falling asleep and 8) **n**eeds of the child met during the day, 9) equal great sleep (Bessey, Coulombe, & Corkum, 2013). There is support for the majority of these recommendations in children, however, exercise, or PA, has received limited support as a beneficial sleep practice, as limited research has been conducted examining PA and sleep in children (Allen, Howlett, Coulombe, & Corkum, 2016). More research is therefore needed exploring this topic.

Physical activity and sleep among adults. Among adults, PA is evidenced as a healthy sleep practice and is considered a non-pharmacological treatment for improving adults' sleep (Kredlow et al., 2015; Morin, 1999). For example, studies show that PA promotes greater total sleep time (the total amount of time spent sleeping between sleep onset and final wake-up time), sleep efficiency (the percentage of time spent sleeping between sleep onset and final wake-up time) and slow wave sleep (also known as restorative sleep) (Kredlow et al., 2015). It is also supported that PA throughout the day can shorten sleep onset latency (the amount of time it takes to fall asleep) and reduce awakening after sleep onset (Kredlow et al., 2015). Furthermore, there is also evidence that physically active individuals experience significantly less daytime sleepiness than those less physically active and living more sedentary lifestyles (Sherrill, Kotchou, & Quan, 1998). Finally, there are reports of reduced sleep medication use when participating in exercise training (Yang, Ho, Chen, & Chien, 2012).

Although the exact mechanisms pertaining to the beneficial effect of PA on sleep are unknown, there is some evidence regarding how PA might influence sleep. PA can help to decrease arousal, anxiety and depressive symptoms, thereby helping individuals to sleep (particularly those that experience insomnia) (Passos et al. 2011). PA can also influence sleep via its body-heating effects. As individuals fall asleep, body temperature declines. As such, given that PA tends to increase body temperature, the post PA temperature drop can help to promote falling asleep (Horne & Staff, 1983). Finally, PA can affect the circadian rhythm. The circadian rhythm is the body's biological clock. It is endogenously generated but is modulated by external cues such as sunlight. For individuals that have difficulty sleeping (i.e., those with insomnia), PA can shift the circadian rhythm's timing, thereby helping persons suffering from insomnia to sleep (Guilleminault et al., 1995). PA's effect of shifting the circadian rhythm is especially noticeable when PA occurs outdoors as sunlight influences melatonin levels (a hormone involved in promoting sleep).

Overall, PA has been shown to improve sleep quality and quantity among adults (Kredlow et al., 2015; Roveda et al., 2011; Yang et al., 2012). Given this, it can be hypothesized that PA also serves as a healthy sleep practice for children. However, there is limited research examining PA and sleep in children, representing a gap in our understanding of how PA might promote sleep in children. Furthermore, among this limited research, the tools used to measure PA and sleep have been inconsistent (e.g., parental report, wrist accelerometers, waist accelerometers) which could be a factor leading to the inconsistent results that have emerged (Ekstedt et al., 2015; Tatsumi et al., 2015). More research using consistent methods for measuring PA and sleep could therefore be beneficial.

Physical activity and sleep among preschool-aged children. Research examining PA and sleep among preschool-aged children is limited and sparse. Only nine studies have specifically examined this relationship within this population with PA as a predictor variable and sleep as the outcome variable.

Physical activity and subjectively measured sleep. Among the research examining the relationship between PA and sleep in preschool-aged children, three of these studies measures sleep subjectively. Plancoulaine et al. (2015) conducted a study examining various factors, including PA, to determine their association with shorter sleep duration among children three years of age. PA and sleep were both measured via parental reports. Parents were asked to report the amount of time their child spent in PA during a typical week. Questions regarding usual bedtimes, wake times, daytime naps and night awakenings were asked to gather data regarding sleep duration. The study did not find a significant association between PA and sleep. This could be due to the subjective nature of parental reports, which are not an ideal measure for assessing PA or sleep as they are not uncommonly prone to error (Fitzhugh, 2015; Iwasaki et al., 2010). Children participating in this study may also have been sleep satiated, therefore not benefiting from the potential effects of PA.

Similarly, Hense et al. (2011) examined determinants associated with sleep duration among young children. PA was measured by both a parental report and a waist accelerometer. Parental report PA data included weekly hours spent in a sports club and playing outside. Accelerometer data measured daily minutes spent in moderate to vigorous PA. Accelerometer data were collected for three consecutive days. Sleep was measured via parental report. Parents recorded their children's bedtimes and wake-up times for four days to calculate average sleep duration. Results of this study also failed to reveal an association between PA and sleep. This could be due to several reasons. First, similar to Plancoulaine et al. (2015), a subjective parental report was used to measure sleep variables, which again, is not ideal when measuring sleep as these tools are not uncommonly prone to error (Fitzhugh, 2015; Iwasaki et al., 2010). Second, the children may have also been sleep satiated and therefore would not have been affected from any potential benefits of PA on sleep. Third, as bedtime and wake-up time data were collected, this means that time in bed was recorded and not necessarily sleep duration. These two variables are not always equal in duration and therefore are not always interchangeable. As such, sleep duration cannot necessarily be correctly inferred from the sleep data collected, which could potentially have impacted the results. Finally, only three days of PA data were collected via a waist accelerometer. This length of time may have been insufficient to ensure reliable estimates of PA (previous studies have collected PA for longer durations) (Hinkley et al., 2012).

Finally, De Bock, Genser, Raat, Fischer, & Renz-Polster (2013) examined the relationship between time spent in sedentary behaviour and moderate to vigorous PA and sleep quality among children ages four to six years. The PA variables were measured objectively via an ActiHeart device and were measured for six consecutive days. Sleep quality was assessed subjectively via the Pittsburg Sleep Quality Index (parent report). Results revealed that as time spent in moderate to vigorous PA increased, sleep quality as reported by parents improved. Overall, the findings from De Bock et al. (2013) were the only results supporting a relationship between PA and subjectively measure sleep among preschool-aged children (see Table 1).

Physical activity and objectively measured sleep. The remaining six studies examining the relationship between PA and sleep among preschool-aged children examined sleep objectively. Iwata et al. (2011) examined independent variables associated with sleep quality and quantity among five-year-old children. PA was

Table 1

Studies Utilizing a Subjective Measure for Sleep

	Study Design	Age of Participants	PA Measure	PA Variables	Sleep Measure	Sleep Variables	Results
Plancoulaine et al., 2015	Cross-sectional Quantitative Correlational	3	Parental report	Weekly hours of PA per week	Parental Report	Sleep duration	No association between PA and sleep duration
Hense et al., 2011	Cross-sectional Quantitative Correlational	2-9	Parent report, Waist-worn accelerometer (data collected over 3 consecutive days)	Weekly hours per week in sports club and playing outside, daily minutes of MVPA	Parental report	Sleep duration	No association between PA and sleep duration
De Bock et al., 2013	Longitudinal Quantitative RCT, PA and sleep analysis correlational	4-6	Actiheart (data collected over 6 consecutive days)	Mean accelerometry counts and time spent in SB and MVPA	Parental report (Pittsburg Sleep Quality Index)	Sleep quality	Trend towards increased sleep quality with increases in PA

Note. This table displays the three studies that were found examining the association between PA and subjectively measured sleep. MVPA = moderate to vigorous PA.

measured via a parental report assessing participation in sports lessons. Sleep was measured objectively via a wrist accelerometer calculating sleep onset latency, sleep efficiency and sleep end time. These data were collected over seven consecutive days. Results revealed that engagement in regular sports lessons is associated with earlier sleep end times, and increases in sleep efficiency. No association was found between regular sports lesson participation and sleep onset latency.

In comparison, Tatsumi et al. (2015) examined the association between PA and sleep in children between the ages of four and six years. A wrist accelerometer was used to measure PA counts per minute over seven consecutive days. This accelerometer was also used to measure sleep variables including sleep onset latency, sleep end time, percent sleep (the percentage of time spent sleeping between sleep onset and sleep end time), snooze time (the time between sleep end time and getting out of bed) and total sleep time. Similar to Iwata et al. (2011), results of this study revealed a positive association between PA and sleep percentage (the percentage of time spent sleeping during time in bed) and no association between PA and sleep onset latency. However, in contrast to Iwata et al. (2011), no association was found between PA and sleep end time. Finally, no association was found between PA and total sleep time or PA and snooze time.

Nixon et al. (2009) examined factors (particularly daytime activities) that might influence sleep onset latency. The daily activity of PA was measured via a waist accelerometer. Sleep onset latency was also measured via this tool. The study incorporated a longitudinal design as participants' data were recorded from birth until they reached seven years of age and were measured over a 24 hour period at various stages. Although results revealed by Iwata et al. (2011) and Tatsumi et al. (2015) do not support an association between participation in sports lessons and sleep onset latency, and PA and sleep onset latency respectively, results by Nixon et al. (2009) revealed that increases in PA are associated with shorter sleep onset latencies. Although this study provided favourable support for the relationship between PA and sleep, it is important to note that a measurement period of one 24-hour period of time is insufficient when measuring both PA and sleep. It is recommended that PA and sleep data be collected over a minimum of four to seven days to ensure reliable estimates of PA and sleep variables (Taylor, Williams, Farmer, & Taylor, 2015).

Similar to the Nixon et al., (2009) study, Duraccio and Jensen (2017) used a waist accelerometer to examine the associations between moderate to vigorous PA, sedentary behaviour regularity and total sleep time. Data were collected over a three-day measurement period. Although this study did not find an association between regular participation in moderate to vigorous PA and total sleep time, consistently low sedentary behaviour was associated with increased odds of obtaining sufficient sleep (i.e., >8 hours of sleep). Furthermore, high sedentary behaviour was associated with decreased odds of obtaining sufficient sleep (Duraccio & Jensen, 2017).

A longitudinal study conducted by Taylor et al. (2015) examined the relationship between moderate to vigorous PA and sleep stability. Participants PA and sleep were assessed objectively via a waist accelerometer for seven consecutive days at six different time points between the ages of three and seven years. Specifically, the variables under examination included sleep duration, sleep onset, final wake-up time, sleep onset latency, sleep efficiency and wake after sleep onset. Finding from this study support that children who spend more time engaging in moderate to vigorous PA have more stable sleep over time (Taylor et al., 2015).

Finally, a study conducted by Williams et al. (2014) support contrasting results. This longitudinal study aimed to determine the relationship between time spent sedentary, and in light PA and moderate to vigorous PA, to sleep duration and time spent awake throughout the night, among children at three different time points: at the age of three, five and seven years. PA and sleep were both measured via waist accelerometers and these data were collected over a minimum of five consecutive days, including two weekend days. Contrary to the investigator's hypothesis, results of this study revealed that children who are more physically active spend less time sleeping and have increased night awakenings compared to children who are less physically active. Although an objective measure was used to measure both PA and sleep (similar to the aforementioned research above), waist accelerometers are not the recommended tool when measuring sleep (as is discussed in greater detail below) and as such, could be contributing to the lack of association between PA and sleep.

Overall, all of the studies examining the relationship between PA and objectively measured sleep among preschool-aged children support a relationship between the two variables. The findings from Williams et al., (2014) were the only results to support an unfavourable relationship between PA and sleep, while the others all support a favourable relationship between the two variables (see Table 2).

Objective Measurement of Physical Activity and Sleep

There is therefore considerable inconsistency pertaining to the association between PA and sleep in young children. Methods and tools used to examine this

Table 2

Studies Utilizing an Objective Measure for Sleep

	Study Design	Age of Participants	PA Measure	PA Variables	Sleep Measure	Sleep Variables	Results
Williams et al., 2014	Longitudinal Quantitative Correlational	3, 5, 7	Waist-worn accelerometer (data collected over 5 consecutive days)	Time spent in SB, LPA, MVPA	Waist-worn accelerometer (data collected over 5 consecutive days)	Sleep duration, night awakenings	Most active children spend less time sleeping and were more awake at night
Taylor et al., 2015	Longitudinal Quantitative Correlational	3-7	Waist-worn accelerometer (data collected over 7 consecutive days)	Level of PA	Waist-worn accelerometer (data collected over 7 consecutive days)	Bedtime, sleep end time, sleep latency, sleep efficiency, WASO	Higher levels of PA associated with more stable sleep
Nixon et al., 2009	Longitudinal Quantitative Correlational	Birth-7	Waist-worn accelerometer (data collected over 1 24-hour period)	Total PA counts, mean activity counts, minutes of sedentary, moderate and vigorous activity	Waist-worn accelerometer (data collected over 1 24-hour period)	SOL	Increased PA associated with shorter SOL
Duraccio & Jensen, 2017	Cross-sectional Quantitative Logistic Regression	4-6	Waist-worn accelerometer (data collected over 3 consecutive days)	MVPA and SB	Waist-worn accelerometer (data collected over 3 consecutive days)	Sleep duration	MVPA does not predict sleep duration, low SB predicts longer sleep duration, high SB predicts shorter sleep duration

Iwata et al., 2011	Cross-sectional Quantitative Correlational	5	Parental report	Participation in sports lessons	Wrist-worn accelerometer (data collected over 7 consecutive days)	SOL, sleep efficiency, sleep end time	Regular participation in sports lessons associated with earlier sleep end time and higher sleep efficiency
Tatsumi et al., 2015	Cross-sectional Quantitative Correlational	4-6	Wrist-worn accelerometer (data collected over 7 consecutive days)	PA counts per minute	Wrist-worn accelerometer (data collected over 7 consecutive days)	Percent sleep, SOL, TST, sleep end time, snooze time	Increased PA associated with higher sleep percentage

Note. This table displays the six studies that were found examining the association between PA and objectively measured sleep. SB = sedentary behaviour, LPA = light PA, MVPA = moderate to vigorous PA, WASO = wake after sleep onset, SOL = sleep onset latency, TST = total sleep time.

relationship are inconsistent which could potentially be contributing to the inconsistent results. When measuring PA and sleep, objective measures such as accelerometers are recommended instead of parental reports, as parental reports are not uncommonly prone to error (Fitzhugh, 2015; Iwasaki et al., 2010). However, the types of accelerometers recommended for measuring PA and sleep differ. When measuring PA, waist accelerometers are recommended, as these accelerometers are better able to measure energy expenditure during walking and running compared to wrist accelerometers (Trost et al., 2005). Furthermore, when using accelerometers to measure PA, it is recommended that PA data be collected for a minimum of four to seven days to ensure reliable estimates of PA variables (Hinkley et al., 2012).

When measuring sleep, polysomnography (PSG, a comprehensive sleep study measuring the biophysical aspects of sleep) is considered the ‘gold standard’ (Waldon et al., 2016). However, measuring sleep via PSG may not always be a realistic tool to incorporate into studies due to high costs and the invasive procedures involved (Ancoli-Israel et al., 2003). Fortunately, there is a high rate of agreement between PSG and accelerometers (i.e., actigraphs), and actigraphs have been validated as an objective measure for sleep estimation outside of the laboratory (Kosmadopoulos, Sargent, Darwent, Zhou, & Roach, 2014; Sadeh & Acebo, 2002; Waldon et al., 2016). However, when using actigraphs to measure sleep, in contrast to measuring PA, wrist actigraphs are recommended as this type provides a more valid measure of sleep parameters (Slater et al., 2015). Furthermore, similarly to measuring PA via accelerometers, it is important when using actigraphs to measure sleep for a minimum of four to seven days to ensure reliable estimates of sleep variables (Taylor et al., 2015).

Given the inconsistency in this area of research regarding methods used and results found, it is therefore important to further examine this area using the recommended tools to measure sleep. More research is therefore needed to determine whether PA is a healthy sleep practice for preschool children, and if so, which sleep variables are affected.

Purpose and Hypotheses

Overall, there is limited and inconsistent research examining the relationship between PA and sleep among preschool-aged children. As such, the current study (consisting of two sub-studies) aimed to add to the limited knowledge base regarding this area of research and aimed to help fill the gap regarding the inconsistent tools used to measure PA and sleep. The study aimed to do so by answering the following research questions:

Sub-Study 1:

1. Is children's accelerometry-measured total PA (% of day spent active) positively associated with parent-reported weekday-night sleep duration?

It was hypothesized that as total PA (% of day spent active) increased across participants, weekday-night sleep duration would also increase.

2. Is children's accelerometry-measured total PA (% of day spent active) negatively associated with parent-reported sleep onset latency and parent-reported night awakenings?

It was hypothesized that as total PA (% of day spent active) increased across participants, the amount of time to fall asleep and the number of night awakenings would decrease.

Sub-Study 2:

1. Is children's accelerometry-measured total PA (% of day spent active) positively associated with objectively-measured total sleep time?

It was hypothesized that as total PA (% of day spent active) increased across participants, total sleep time would also increase.

2. Is children's accelerometry-measured total PA (% of day spent active) negatively associated with objectively-measured sleep onset latency, and positively associated with objectively-measured sleep efficiency?

It was hypothesized that as total PA (% of day spent active) increased across participants, sleep onset latency would decrease and sleep efficiency would increase.

The first research questions in Sub-Study 1 and 2 served as primary research questions, and the second research questions served as secondary research questions. Should the results of this research support the hypotheses, this research will contribute to a better understanding of the need to promote increased levels of PA in young children to help potentially prevent the negative outcomes of poor sleep on health.

Summary

The purpose of this chapter was to discuss in depth the literature surrounding PA and sleep and their relationship with each other. Poor sleep is evidenced to be common among children in today's society (Owens, 2007). This is concerning as poor sleep can lead to various negative health outcomes and can negatively affect childhood development (Liu et al., 2012; Vriend et al., 2015). It is therefore essential to discover various methods to help promote healthy sleep among children. As PA is widely supported as a healthy sleep practice among adults, PA could potentially be beneficial for sleep among children (Klesges et al., 1990; Kredlow et al., 2015). However, more research is needed to determine this, as the research is limited and inconsistent. Additionally, research incorporating the recommended tools for measuring both PA and sleep are needed to increase rigor in methods used. The current study aimed to address these gaps in the literature by examining the relationship between objectively measured PA and subjectively and objectively measured sleep among preschool-aged children. The following chapter will discuss the methods used for the current study.

Chapter 3: Method

Design

The current study was part of a larger study called the Physical Literacy in the Early Years (PLEY) Project. The PLEY Project is a randomized control trial aiming to examine the efficacy of a 'loose parts' intervention implemented in Nova Scotia Early Years Centres to increase physical literacy in preschool-aged children. The loose parts intervention involves the provision of loose parts materials for children in outdoor play areas for children. Loose parts are materials that can be moved and carried, and can be used in combination with other loose parts and materials. A key feature of loose parts is that they have no specific set of directions for use. These materials therefore allow for children to manipulate the parts themselves, thereby sparking their imagination and potentially leading to more active outdoor play. Loose parts delivered to the early years centres participating in the PLEY Project include, but are not limited to: buckets, rope, milk crates, planks, wood pieces, tires, pulleys and hose tubes. The project consists of an intervention group receiving the loose parts along with a control group that did not receive any loose parts. The PLEY Project obtained ethics approval from the Dalhousie University Research Ethics Board (ethics approval #: 2016-3924) before the commencement of the current study. An amendment regarding the current study was therefore submitted to the Dalhousie University Social Sciences and Humanities Research Ethics Board given the additional data that was collected for purposes of this study.

The current study was composed of two sub-studies. The first sub-study (sub-study 1) examined the relationship between children's objectively measured total PA (%

of day spent active) and subjectively measured sleep duration, sleep onset latency and night awakenings. PA was measured via accelerometry, and sleep variables collected via a parent report. The second sub-study (sub-study 2) examined the relationship between objectively measured total PA (% of day spent active) and objectively measured total sleep time, sleep onset latency and sleep efficiency. The same accelerometry-measured PA data from sub-study 1 were used in sub-study 2; whereas sleep variables were collected via an actigraph. Both sub-studies included children in the intervention group of the PLEY Project during the baseline phase (i.e., before the loose parts were delivered to the early years centres) and children in the control group of the PLEY Project. The loose parts intervention was not administered to the control group. The same children were included in both sub-studies.

A quantitative, cross-sectional, within-subjects design was incorporated to examine the relationship between PA and sleep in preschool-aged children. The study was descriptive as it aimed to describe PA and sleep characteristics of the population being studied.

Participants, Recruitment and Setting

Participants included children between the ages of three and six years (as this is the typical age range of preschool children attending Early Years Centres) and their parents. As sleep behaviour can vary with medical and psychiatric conditions (Ivanenko & Johnson, 2008; Sivertsen, Hysing, Elgen, Stormark, & Lundervold, 2009), any children with known medical or psychiatric conditions were excluded from the current study. Screening for this exclusion criterion took place during the consent process by asking parents about the existence of any known medical or psychiatric conditions (Appendix A).

Participants from the PLEY Project were recruited from Early Years Centres. Early Years Centres that serve children between the ages of three and five years with a minimum enrolment of 20 children were eligible to participate in the larger study. Parents were also included as participants in the PLEY Project. Recruitment from 20 Early Years Centres with a minimum enrolment of 20 children was decided upon by for statistical purposes of the larger study. Upon the commencement of data collection for the current study, two of the participants included in the sample were six years of age. These two participants were five years of age when they began participating with the PLEY Project, but since had their birthday. These participants were included in the current study to increase the sample size.

The PA and parent report data collection pertaining to sub-study 1 was already incorporated into the larger study, while sub-study 2 was an additional research project added to the PLEY Project. As such, once participants were recruited for the larger study, participating parents were sent recruitment emails (Appendix B) regarding the current study (i.e., sub-study 2). Parents who were interested in participating in sub-study 2 were instructed to contact the researcher of the current study. The researcher then emailed the interested parents the consent forms for the parent and their child (Appendix A), disclosing in detail the purpose of the study and the procedures involved. Parents were informed that should they have any questions regarding the consent forms or the current study, they could contact the researcher of the study by email or phone. Parents who decided to participate in sub-study 2 provided informed consent by signing the informed consent form. Parents signed the assent form on behalf of their child after gaining their child's assent.

As researchers affiliated with the larger study are located at Dalhousie University in Halifax, Nova Scotia, data collection for the current study took place across Nova Scotia. Objectively measured PA data were collected throughout the day in Early Years Centres, the homes of the parents and children, and in the context of the everyday lives of participants. Subjective sleep data were collected at a time and location convenient for parents, and the objective sleep data were collected in the participants' homes throughout the night.

Data were collected from a total of 34 participants. Five participants were excluded from this sample. Of these five, one participant only wore the accelerometer and actigraph for one day, therefore not meeting the minimum requirement of four days of accelerometer and actigraph wear. The remaining four participants' data were corrupt (e.g., no data was recorded or the actigraph recorded invalid data) and were therefore excluded from data analysis. A total of 29 participants in each sub-study were included in the study's data analysis. Both sub-studies consisted of the same children.

Ethical Considerations

Risk and benefits. The possible harms associated with involvement in the current study were no greater than those encountered by the participants in their everyday life (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & Social Sciences and Humanities Research Council of Canada, 2014, p. 22). Potential risks involved in participating in the current study included injury due to PA. However, participants were instructed to behave as they normally would during a typical week (including engagement in PA). Additionally, wearing the actigraph could potentially have interfered with the children's sleep. However, as the device is small, the intrusiveness of the device is minimal. The current study therefore posed a minimal increase in risk.

Although no direct benefits were received from participating in the current study, parents received indirect benefits as they contributed to research. Their participation may also benefit other preschool-aged children through contributing to the advancement of knowledge, potentially indicating the need to enforce PA policies and programs targeting young children to promote optimal sleep.

Informed consent. As children are a vulnerable population, precaution was taken throughout the study (Canadian Institutes of Health Research et al., 2014, p. 51). Parents were fully informed about the purpose and procedure of the current study and were explicitly told that if their children were uncomfortable with any of the procedures throughout the study, they were free to withdraw at any time. As previously mentioned, the consent process began with recruitment emails sent to parents. Parents that were interested in participating in the study were then sent consent forms. Signed consent forms were then returned to the researcher of the current study. Parents were asked to sign the assent form on behalf of their child after gaining their child's assent.

Confidentiality. To ensure participant confidentiality, participants (parents and children) were de-identified, hard copies of diaries and questionnaires were stored in a secure filing cabinet, and electronic data were stored in an excel and SPSS file on a password protected computer. All data will be destroyed five years after the completion date of the current study.

Incentives. Incentives/compensation were not offered to participants in this research study.

Data Collection

Measures.

Demographics survey. The PLEY Project incorporated a parent survey in the data collection procedures to collect data regarding participant's SES, PA, sedentary time, physical literacy and sleep. For purposes of the current study, this survey was used to collect demographic data regarding the children and their families. This information was used to describe the children with respect to their age, sex and parental socioeconomic status (SES). Family income was used to examine parental SES (Appendix C, question 3f).

Objective measure of physical activity. Children's time spent sedentary and time spent in light and moderate-vigorous physical activity were measured objectively using ActiGraph GT3X+ accelerometers (ActiGraph LLC, Pensacola, FL), worn on an elastic waistband around the child's hip. This accelerometer is a small and light-weight device, and is unobtrusive and practical for extended measurement periods in children (Freedson, Pober, & Janz, 2005). It is widely used to measure free-living behaviour outside of the laboratory in both adults and children (Troiano et al., 2008). The accelerometer is validated by Kinder et al. (2012) and is recommended for the objective measurement of PA and sedentary behaviour in children (Freedson et al., 2005; McClain & Tudor-Locke, 2009).

To improve compliance and ensure data quality, parents were given an instruction sheet that explained how to attach the accelerometer over their child's right hip and when to remove the device (night-time sleep, bathing/swimming). Parents were also given an accelerometer wear time log (Appendix D) to report times the accelerometer was removed from the child throughout each day over the nine-day measurement period. Parents also reported the time their child put the accelerometer on in the morning and what time the accelerometer was removed before bedtime each day. Parents and educators were also informed of the importance of consistent accelerometer wear to generating information on typical PA and sedentary behaviour patterns. Accelerometer data were collected from October 6th, 2017 until March 25th, 2018. Accelerometer data were reduced and analyzed using ActiLife (Version 6).

To improve comparability of data, accelerometer data reduction decisions were consistent with a previous study of Canadian preschoolers (Carson et al., 2017b). Data were collected in 15s epochs. Non-wear time was defined as ≥20 minutes of consecutive zero counts (Carson et al., 2017b). To be included in analyses, participants were required to have ≥4 days with ≥6 hours of wear time each day (Hinckley et al., 2012). A weekend day was not necessary for inclusion. Sedentary time was defined as ≤100 counts/min, light PA as 100-1679 counts/min, and moderate to vigorous PA as ≥1680 counts/min (Janssen et al., 2013). Accelerometer data were then classified into minutes per day and % of day spent sedentary, in light PA, in moderate to vigorous PA, and in activity of any intensity (total PA), for each valid day. Specifically, accelerometer data for all valid days were then summed and divided by the number of valid days to create an individual average daily score for each variable PA variable. Total PA (% of day spent active) was then calculated by summing the average daily scores of light PA and moderate to vigorous PA and dividing by the average daily wear time. As the 24-hour movement guidelines suggest children accumulate at least 180 minutes of PA of any intensity (i.e., LPA of MVPA) per day (Tremblay et al., 2012), total PA was used as the predictor variable to align with this guideline.

Subjective measures of sleep: Parent survey. Children's sleep was measured subjectively using the parent survey mentioned above. The parent survey contained various questions pertaining to the larger study. Along with collecting data regarding the participants' demographics, this survey was also used to subjectively collect data regarding sleep duration, sleep onset latency (i.e., the amount of time it takes to fall asleep) and night awakenings for the current study. Specifically, this survey asked how many hours of sleep duration (i.e., the amount of time between sleep onset and final wake-up time) the children achieved weekday-nights, if the children typically fall asleep within 20 minutes, and if the children typically wake up more than once a night (Appendix C, Section 2, questions 3, 7, and 10). These sleep questions were based off the sleep screening survey, the Child Sleep Habits Questionnaire (Owens, Spirito, & McGuinn, 200). This parent survey is validated in preschool-aged children (Goodlin-Jone, Sitnick, Tang, Liu, & Anders, 2008). This survey was therefore used in sub-study 1 to subjectively determine the relationship between PA and sleep among preschool-aged children.

Objective measures of sleep: Actigraphy. Children's sleep was measured objectively using a MicroMini-Motionlogger actigraph (Ambulatory Monitoring Inc; http://www.ambulatory-monitoring.com/motionlogger.html). This actigraph is a type of accelerometer that has a wristwatch appearance. There is evidence to suggest that when placed on the dominant wrist, higher levels of activity are recorded by the actigraph, thereby biasing the data (Sadeh, Sharkey & Carskadon, 1994). The actigraph was therefore worn on the non-dominant wrist. The actigraph uses an accelerometer to measure motor activity, and this movement is used to determine if the child is awake or asleep. The Sadeh algorithm uses an 11-minute window, including the five previous and five future epochs. Detected movements are translated into digital counts and are entered into the sleep index formula[1]. If the result of the formula is greater than -4, the epoch is considered asleep (Sadeh et al., 1994).

Actigraphy has good validity and reliability regarding its use in estimating an individual's wake and sleep times (Acebo et al., 1999; Sadeh et al., 1995; Tryon, 2004). There is also a high rate of agreement between actigraphy and polysomnography (the gold standard of sleep which measures the biophysical aspects of sleep) (Ancoli-Israel, et al., 2003). Sleep diary data were used to identify the 'lights out' time and the wake-up time each day (see below for a description of this measure). The data were then extracted using the Act Millennium operational software, and summary analysis were computed using the Action-W2 that uses a validated sleep estimation algorithm (Sadeh, Alster, Urbach, & Lavie, 1989). Summary analysis included the variables of interest for this study: total sleep time, sleep onset latency and sleep efficiency. This wrist accelerometer was therefore used in sub-study 2 to objectively determine the relationship between PA and sleep among preschool-aged children. Sleep data from this measure were collected on

[1] The Sleep Index (SI) = [7.601 - (0.065 x AVG) - (1.08 x NATS) - (0.056 x SD) - (0.703 x LG)]
AVG = average of activity counts for the window
NATS = number of epochs that have counts ≥ 50 and < 100
SD = standard deviation for the first 6 epochs of the window
LG = natural logarithm of a current epoch

both weekday and weekend-nights.

Total sleep time is defined as the amount of time spent sleeping between sleep onset (the time when an individual falls asleep) and final wake-up time (the final time an individual wakes up in the morning after a night's sleep). This variable excludes the amount of time spent awake after sleep onset. The 'lights out' variable is defined as the time a child is left alone in their bed to fall asleep on their own. Sleep onset latency is defined as the amount of time it takes to fall asleep after 'lights out'. Finally, sleep efficiency is defined as the percentage of time spent sleeping between sleep onset and final wake-up time.

A sleep diary (Appendix E) was used to help score the actigraph sleep data. The sleep diary contained questions pertaining to various sleep variables such as bedtime (i.e., the time when an individual goes to bed but not necessarily trying to fall asleep), 'lights out' time, sleep onset, night awakenings and final wake-up time. Information regarding any removal times of the accelerometer each day throughout the nine-day period were gathered via this diary. It was based off the Corkum (1996) Sleep Diary, which has high face validity and internal consistency, and has good agreement with videotapes of children's sleep (Wiggs & Stores, 1995). Parents were asked to provide a written response to questions asked in the sleep diary. As noted above, these data were used to help score the actigraphs. Specifically, the times of day reported for 'lights out' and final wake-up time were used when scoring the 'down' interval (i.e., the time in bed interval) on the actigraph. Similar to the ActiGraph GT3X+ data collection, actigraph and sleep diary data were collected from October 6th, 2017 until March 25th, 2018.

Procedure

Sub-Study 1. The parent survey was distributed to parents via email. Parents were asked to complete the sleep related questions based on their children's typical sleep and sleep behaviour during a typical week. For purposes of the PLEY Project, the survey was sent to parents in the first cohort of participants involved in the PLEY Project in August 2017. Initially, these parents were given two weeks to complete the survey, however the deadline was extended to November 2017 to increase the number of surveys submitted. This subjective sleep data was analyzed with the objective PA data collected from the accelerometers in sub-study 2 in October 2017. There was therefore a bit of a lag between the collection of parent-reported sleep data and the PA data collection within this cohort of participants.

For purposes of the larger study, a second cohort of participants was recruited in December, 2017. This cohort of parents received the parent survey in February 2018 and were given two weeks to complete. This subjective sleep data was then analyzed with the children's objective PA data collected the same month (February 2018) in sub-study 2. There was therefore a minor lag between the collection of parent-reported sleep data and the PA data collection within this cohort of participants.

Sub-Study 2. Children wore a waist accelerometer to measure PA for nine consecutive days (including week-days and weekend-days). This accelerometer was put on in the morning after getting out of bed, and was taken off at night before bedtime. Parents were given a tracking log to fill out certain times each day when the accelerometer was not worn. Specific times that the accelerometer was put on each morning and the times that it was removed each night was recorded by parents each day in the tracking log. Children also wore an actigraph to objectively measure sleep. The actigraph was worn during the same measurement period as the accelerometer and data were collected on both week-nights and weekend-nights. As such the actigraph was worn for nine consecutive nights to ensure reliable estimates of sleep quality and quantity (Taylor et al., 2015). Participants were instructed to wear the actigraph only to bed, placing the actigraph on their non-dominant wrist an hour before bedtime, and removing it an hour after their final wake-up time in the morning. An instruction manual explaining how to wear the actigraph was also sent to parents (Appendix F). A sleep diary was completed each night and morning by the parents for the duration of the nine-day measurement period to help score the actigraphs. This diary took parents an estimated time of five minutes to complete each night and morning combined.

Data Analysis

PA accelerometer data were reduced and analyzed using ActiLife (Version 6). To increase comparability of the data, the accelerometer data reduction decisions were consistent with a previous study of Canadian preschoolers (Carson et al., 2017b). Sleep data were scored via the validated Sadeh et al. (1994) algorithm for use in children. The researcher of the current study scored the actigraphy data, and scored the accelerometer data with the guidance of a thesis committee member. For inclusion in data analysis, each child was required to have a minimum of four days with six hours of accelerometer wear time each day (Hinkley et al., 2012). Additionally, children required a minimum of four days of sleep data gathered via the actigraph as reliable estimates of sleep quality and quantity can only be captured with multiple (typically four to seven) days of actigraph data collection (Taylor et al., 2015). Within participants, individual days of data were included in analysis if the given day had valid PA and sleep data. Data from individual days were removed from data analysis if the individual day did not have valid data for both PA and sleep.

Descriptive statistics (mean, standard deviation, range) were used to present demographics (child age, sex, and parent SES) and physical activity data (time (min, % of day) spent sedentary, in light PA, in moderate-vigorous PA, and total activity), and accelerometer wear time (minutes/day). As described previously, accelerometer data for all valid days were summed and divided by the number of valid days to provide an average daily score sedentary behaviour, light PA and moderate to vigorous PA. Light PA and moderate to vigorous PA were summed to calculate a total PA score. The total PA score was then converted to a percentage of accelerometer wear time spent in total PA (i.e., total PA (% of day spent active)) to account for the differences in accelerometer wear time between children. This made the variable of total PA more comparable across participants. Additional descriptive statistics were computed to analyze the following sleep variables: parent reported week-day night sleep duration, parent reported sleep onset latency, parent reported night awakenings, actigraph time in bed, actigraph total sleep time, actigraph, sleep onset latency, and actigraph sleep efficiency.

Logistic regression was used in sub-study 1 to determine the relationship between total PA (% of day spent active) and sleep duration, sleep onset latency and night awakenings (as measured via the parent survey), as the outcome variables were categorical. Linear regression was used in sub-study 2 to determine the relationship between total PA (% of day spent active) and total sleep time, sleep onset latency and sleep efficiency (as measured via actigraphy), as the outcome variables were continuous.

The data were checked for linearity and normality before running the data analyses. Statistical significance was defined as $p<0.05$.

Researcher Details

The roles of the researcher include collecting, scoring and analyzing data, completing a written thesis, and future dissemination of results. The researcher communicated with parents via email, and occasionally in person. However, the relationship between the participants and the researcher was minimal, as the parents completed the parent survey on their own time and as the children wore the acceleometer and actigraph in the context of their everyday lives. Research assistants and research team members were also involved in the collection of data. However, the researcher and a thesis committee member were the only individuals involved in scoring and analyzing the data. Finally, the researcher's thesis committee acted as a guide through their areas of expertise.

The researcher of the current study completed an undergraduate honours thesis examining the effect of sleep restriction on emotion in typically developing children and children with Attention-Deficit/Hyperactivity Disorder between the ages of six and 12 years. The researcher has also worked in various sleep labs for a total of two years. Therefore, the researcher has a background in sleep research that was beneficial for the current study as she is familiar with collecting and analyzing sleep data. Additionally, the researcher has considerable experience scoring actigraphs through her opportunities with her undergraduate honours thesis. This experience provided further benefit for the current study as the researcher is familiar with the procedure regarding the interpretation and scoring of actigraph data. Finally, the researcher has also completed the Tri-Council

Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: CORE). The completion of this course was beneficial for the ethics process, as she is familiar with the required criteria and conduct for ethical research.

Summary

The purpose of this chapter was to outline the method used for this research. The study incorporated a quantitative, cross-sectional, within-subjects design to describe the effect of PA on sleep in preschool children. The first sub-study used an objective tool to measure PA and a subjective tool to measure sleep. The second sub-study used an objective tool to measure both PA and sleep. Data were collected from children and their parents. Data collection for each participant occurred over a nine-day period, apart from the parent survey. The parents in the first cohort of the PLEY Project were given three months to complete this survey, while the second and smaller cohort of participants were given two weeks to complete. The data were then scored through various validated methods. Data were analyzed utilizing logistic regression and linear regression for sub-study 1 and sub-study 2, respectively.

After the completion of the one-year recruitment, data collection and analysis period, findings of the current study were disseminated via a thesis document and will be presented at various academic conferences. Additionally, results will be given to participants and relevant knowledge users. Should the current study reveal results indicating the importance of PA in promoting sufficient sleep in preschool children, these findings will help to address the need for health promoters, health professionals and policy makers to promote and enforce PA programs and policies for young children. By doing so, this could help to promote optimal sleep and prevent poor health outcomes.

Finally, results of the current study will help to build evidence regarding the importance of PA among preschool-aged children and could help to facilitate future experimental studies demonstrating the effect of PA on sleep.

The following chapter will discuss the results revealed from data analysis regarding the relationship between children's total PA and subjectively and objectively measured sleep.

Chapter 4: Results

Sample Characteristics

The final sample for analysis included 29 children. There were 20 males and nine females, with their ages ranging from three to six years of age (*M*=4.28, *SD*=0.80). Family income was used to represent the family socio-economic status. The majority of families had a household income greater than $100,000 (see Table 3).

Table 3

Parent demographics (household income) (*n*=29)

	Frequency (%)
Household Income	
<$20,000	0 (0)
$21,000-$40,000	0 (0)
$41,000-$60,000	1 (3.4)
$61,000-$80,000	3 (10.3)
$81,000-$100,000	0 (0)
>$100,000	20 (69.0)
Unsure	1 (3.4)
Prefer not to answer	3 (10.3)

On average, participants spent 188.33 minutes sedentary (*SD*=55.80), 276.96 minutes in light PA (*SD*=48.66), 222.33 minutes in moderate to vigorous PA (*SD*=47.76), and 494.37 minute in total PA (*SD*=87.98). Participants had a mean accelerometer wear time of 679.91 minutes (*SD*=117.48), ranging from a minimum of 362.13 minutes to 1095.56 minutes (see Table 4). PA scores were converted to PA percentages of wear time to allow for a more comparable value of total PA across participants. Descriptive statistics showed that on average, participants spent 27.18% (*SD*=6.89) of their day sedentary, 39.98% (*SD*=3.99) of their day in light PA, and 32.84% (*SD*=6.25) of their day in moderate-vigorous physical activity. The vast majority (72.82% (*SD* = 6.89)) of the child's day was spent active in total PA (sum of light and moderate-vigorous PA percent scores) (see Table 5).

Table 4

Accelerometry-measured sedentary behaviour and physical activity characteristics (*n*=29)

	Mean (SD) (minutes, hours)	Minimum (minutes, hours)	Maximum (minutes, hours)
SB	188.33 (55.80), 3.14	50.90, 0.85	300.10, 5.00
LPA	276.96 (48.66), 4.47	167.30, 2.79	432.08, 7.20
MVPA	222.33 (47.76), 3.71	127.20, 2.12	364.40, 6.07
Total PA	494.37 (87.98), 8.24	290.50, 4.84	796.47, 13.27
Accelerometer wear time	679.91 (117.48), 11.63	362.13, 6.04	1095.56, 18.26

Note. SB = sedentary behaviour, LPA = light PA, MVPA = moderate to vigorous PA. Wear time refers to the average amount of time participants wore the accelerometer each day during the nine-day measurement period.

Table 5

Accelerometry-measured sedentary behaviour and physical activity percentages (*n*=29)

	Mean (SD) (%)	Minimum (%)	Maximum (%)
SB	27.18 (6.89)	11.69	45.41
LPA	39.98 (3.99)	33.68	47.65
MVPA	32.84 (6.25)	19.20	51.76
Total PA	72.81 (6.89)	54.59	88.31

Note. SB = sedentary behaviour, LPA = light PA, MVPA = moderate to vigorous PA.

Parent survey data revealed that just over half (53.1%) of the children met the sleep recommendation guidelines on weekday-nights (i.e., 53.1% obtained 10 to 13 hours of sleep during weekday nights). More than half (59.4%) of parents reported that children usually fell asleep within 20 minutes. The vast majority (75.0%) of parents reported that their child awakened more than once throughout the night (see Table 6). The actigraph data revealed that children had a mean duration of time in bed of 588.78 minutes (*SD*=39.80). Additionally, the children had a mean total sleep time of 505.42 minutes (*SD*=57.96), a mean sleep onset latency of 26.93 minutes (*SD*=17.19), and a sleep efficiency of 85.80% (*SD*=6.80; see Table 7 and Table 8).

Table 6

Parent-reported measures of children's sleep (weekday night sleep duration, sleep onset latency, night awakenings) (*n*=29)

	Frequency (%)
Weekday Night Sleep Duration	
<8 hours	1 (3.4)
8 to less than 10 hours	11 (37.9)
10 to 13 hours	17 (58.6)
>13 hours	0 (0)
Does your child fall asleep within 20 minutes?	
Rarely (0 to 1/week)	0 (0)
Sometimes (2 to 4/week)	10 (34.5)
Usually (5 to 7/week)	19 (65.5)
Does your child awaken more than once during the night?	
Rarely (0 to 1/week)	24 (82.8)
Sometimes (2 to 4/week)	5 (17.2)
Usually (5 to 7/week)	0 (0)
Unknown	0 (0)

Table 7

Actigraphy-measured time in bed, total sleep time, and sleep onset latency (*n*=29)

	Mean (SD) (minutes, hours)	Minimum (minutes, hours)	Maximum (minutes, hours)
TIB	588.78 (39.81), 9.81	509.43, 8.49	668.33, 11.14
TST	504.42 (57.96), 8.41	397.33, 6.62	628.88, 10.48
SOL	26.94 (17.19), 0.45	5.57, 0.09	70.00, 1.17

Note. TIB = time in bed, TST = total sleep time, SOL = sleep onset latency

Table 8

Actigraphy-measured sleep efficiency (*n*=29)

	Mean (SD)	Minimum	Maximum
Sleep Efficiency (%)	85.80 (6.81)	69.32	98.19

Sub-Study 1

Research Question 1: Is children's accelerometry-measured total PA (% of day spent active) positively associated with parent-reported sleep duration?

When answering the question, "On a weekday, how much sleep does your child usually get?", 1 parent reported "<8 hours of sleep", 11 parents reported "8 to <10 hours of sleep", 17 parents reported "10 to 13 hours of sleep" and 0 parents reported ">13 hours of sleep" (see table 6). To create a set of dichotomous variables "<8 hours of sleep" and "8 to <10 hours of sleep" were grouped into one category labelled "<10 hours of sleep", and "10 to 13 hours of sleep" and ">13 hours of sleep" were grouped into another category labelled "≥10 hours of sleep".

Age and sex were placed in the first block of the logistic regression model, with total PA (% of day spent active) placed in the second block. As age and sex did not add to the model, these variables were removed from the analysis to allow for the most parsimonious model. The logistic regression revealed no significant relationship between total PA and weekday-night sleep duration (b_1=0.35, *SE*=0.38, *Exp(B)*=1.42, *-2LL*= 37.12, *p*=0.36).

Research Question 2: Is children's accelerometry-measured total PA (% of day spent active) negatively associated with parent-reported sleep onset latency and night awakenings?

When answering the question: "Does your child typically fall asleep within 20 minutes after going to bed", 0 parents reported "rarely", 10 parents reported "sometimes" and 19 parents reported "usually" (see Table 6). As none of the parents responded with "rarely", this response was eliminated, leaving "sometimes" and "usually" as the set of dichotomous variables.

Similar to the first research question analysis, age and sex were placed in the first block of the logistic regression model, with total PA placed in the second. Age and sex did not add to the model and were therefore removed to allow for a more parsimonious model. Although not significant, results revealed that as total PA (% of day spent active) increased by one unit, the odds of participants usually falling asleep within 20 minutes increased by 0.69, with this trend approaching significance (b_1=0.69, *SE*=0.41, *Exp(B)*=2.00, *-2LL*=34.20, *p*=0.09). In other words, the logit (i.e., the regression equation in logarithmic terms representing the slope) shows that for each percent increase in total PA (% of day spent active), the odds of participants falling asleep within 20 minutes increased by 0.69. This b_1 value of 0.69 helps to model the relative relationship between total PA (% of day spent active) and night awakenings, and serves as a constant value.

When answering the question: “Does your child awaken more than once during the night?”, 24 parents reported “rarely”, 5 parents reported “sometimes”, 0 parents reported “usually” and 0 parents reported “unknown” (see Table 6). The responses “usually” and “unknown” were therefore eliminated, with “rarely” and “sometimes” as the set of dichotomous variables.

Again, age and sex did not add to the model and were therefore removed to allow for a more parsimonious model. Logistic regression analysis revealed that as total PA (% of day spent active) increased by one unit, the odds of participants sometimes waking up more than once a night significantly decreased by 1.57 (b_1=-1.57, SE=0.49, $Exp(B)$=0.21, $-2LL$=26.66, p<0.01). In other words, the logit shows that for each percent increase in total PA (% of day spent active), the odds of participants waking up more than once a night decreased by 1.57. This b_1 value of 1.57 helps to model the relative relationship between total PA (% of day spent active) and night awakenings, and serves as a constant value.

Sub-Study 2

Research Question 1: Is children’s accelerometry-measured total PA (% of day spent active) positively associated with objectively-measured total sleep time?

Age and sex were place in the first block of the linear regression, with total PA time in the second block. As age and sex did not add to the model, these variables were removed to allow for a more parsimonious model. The standardized residuals were examined to look for outliers in the data that may have affected the estimates of the regression coefficients. Standardized residuals with an absolute value greater than 3.29 were defined as outliers to be removed from data analysis. No outliers were found in the data when examining the relationship between total PA (% of day spent active) and total sleep time. The linear regression analysis revealed total PA (% of day spent active) as a poor predictor of total sleep time ($F_{(1,28)}$=1.55, b_1=1.96, p=0.22, 95% CI [-1.27, 5.19]; see Figure 1). The effect size was equal to 0.24, indicating a small effect.

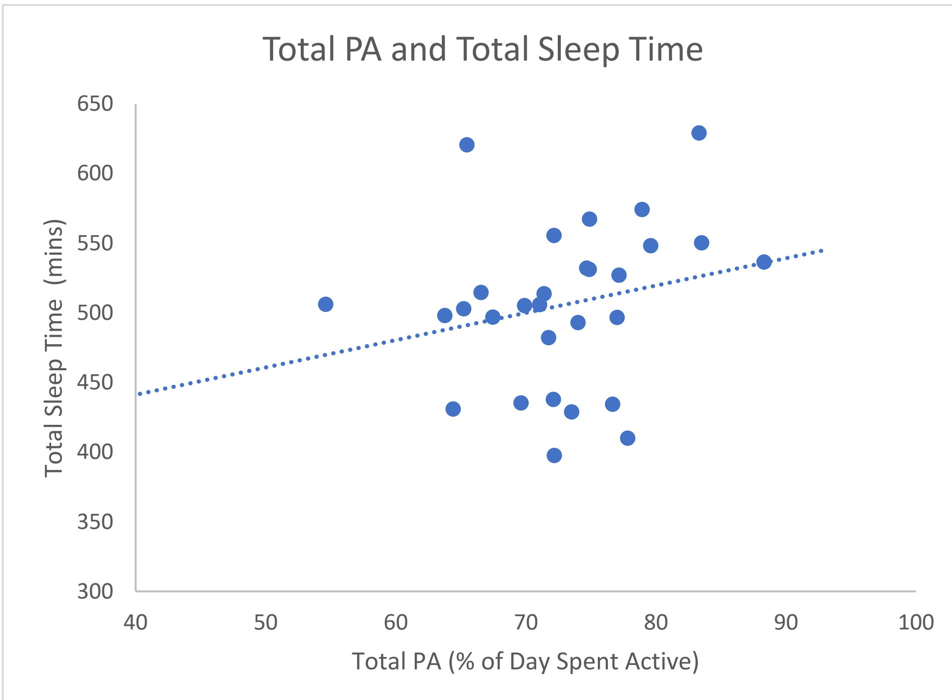

Figure I. Total PA (% of day spent active) and total sleep time. This figure illustrates the relationship between total PA (predictor variable) and total sleep time (outcome variable).

Res*earch Question 2: Is children's accelerometry-measured total PA (% of day spent active) negatively associated with objectively-measured sleep onset latency, and positively associated with objectively-measured sleep efficiency?*

Similar to the previous analysis for research question 1, age and sex were placed in the first block of the linear regression, with total PA in the second block. Age and sex did not add to the model and these variables were therefore removed for a more parsimonious model. Again, the standardized residuals were examined to look for outliers in the data. Three outliers were found, however, removing the outliers did not change the model and as such were left in for the final analysis. Linear regression analysis revealed total PA (% of day spent active) as a poor predictor of sleep onset latency ($F_{(1,29)}$=0.03, b_1=0.09, p=0.86, 95% CI [-0.90, 1.07]; see Figure 2). The effect size was equal to 0.05, indicating a small effect.

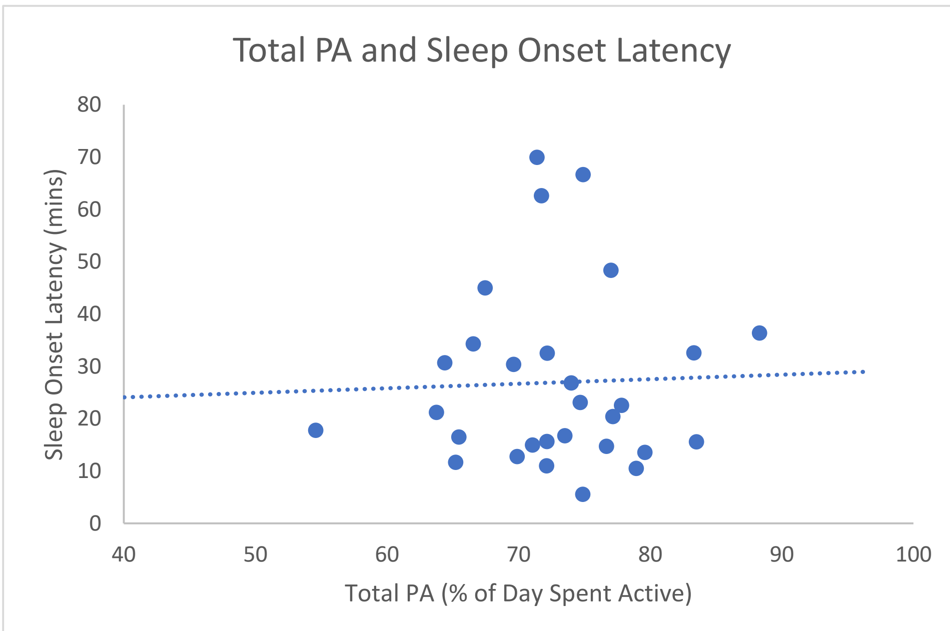

Figure II. Total PA (% of day spent active) and sleep onset latency. This figure illustrates the relationship between total PA (predictor variable) and sleep onset latency (outcome variable).

Finally, when analyzing the relationship between total PA and sleep efficiency, four outliers were found when examining the standardized residuals and the removal of these impacted the results. As such, these four outliers were removed from the analysis. Age and sex did not add to the model and these variables were therefore removed for a more parsimonious model. Results revealed total PA (% of day spent active) as a significant predictor of sleep efficiency. For each percent increase in total PA (% of day spent active), sleep efficiency also increased by 0.37% ($F_{(1,25)}$=5.07, b_1=0.37, p=0.03, 95% CI [0.03, 0.70]; see Figure 3). The effect size was equal to 0.61, indicating a strong effect.

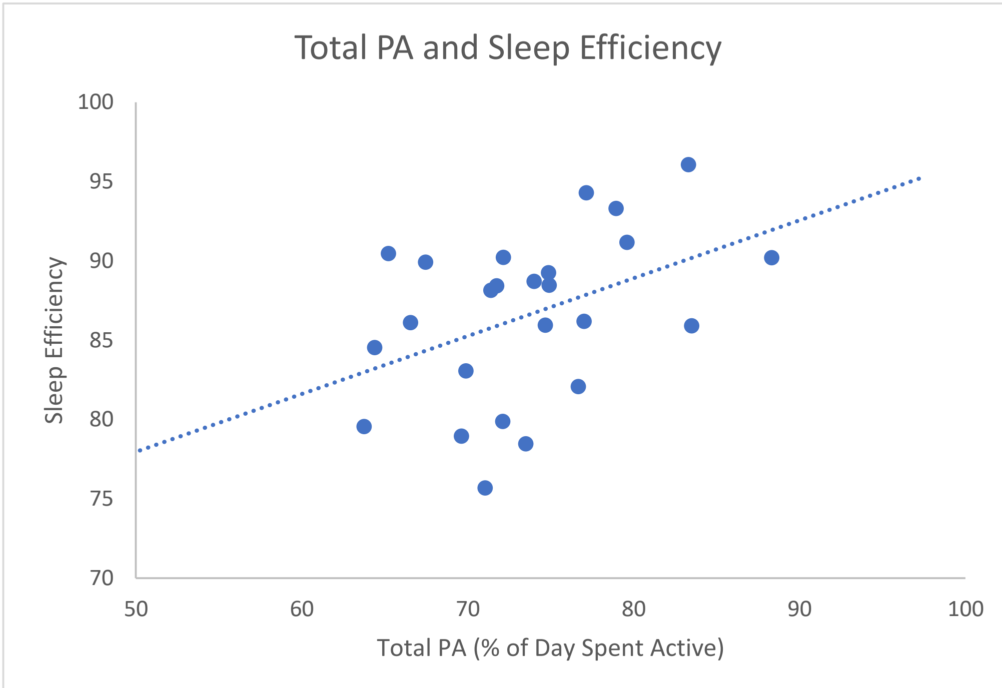

Figure III. Total PA (% of day spent active) and sleep efficiency. This figure illustrates the relationship between total PA (predictor variable) and sleep efficiency (outcome variable).

Summary

The purpose of this chapter was to present the results for sub-study 1 and sub-study 2. Sub-study 1 revealed no significant relationship between children's total PA (% of day spent active) and weekday-night sleep duration. The relationship between total PA (% of day spent active) and sleep onset latency neared significance, indicating that children were more likely to usually fall asleep within 20 minutes as the proportion of their day spent active increased. The relationship between total PA (% of day spent active) and night awakenings was significant, indicating that children were less likely to awaken more than once throughout the night as the proportion of their day spent active increased. Finally, sub-study 2 revealed no significant relationship between total PA (%

of day spent active) and total sleep time or sleep onset latency. A significant relationship between total PA (% of day spent active) and sleep efficiency was revealed: as the proportion of children's day spent active increased, so too did sleep efficiency.

The following chapter will discuss the significance and importance of these results and their implications for stakeholders, including healthcare providers, health promoters, policy makers, teachers and parents and their children.

Chapter 5: Discussion

The purpose of the study was to better understand the relationship between PA and sleep among preschool-aged children. Sub-study 1 examined the relationship between total PA (% of day spent active) and weekday-night sleep duration, sleep onset latency and night awakenings. PA was measured objectively via accelerometry for nine consecutive days while the sleep variables were measured subjectively via parent report. Sub-study 2 examined the relationship between total PA (% of day spent active) and total sleep time, sleep onset latency and sleep efficiency. The PA data collected in sub-study 1 was used in sub-study 2. Sleep was measured objectively via actigraphy during the same nine-day measurement period as the PA data collection. Overall, results from both the two sub-studies found that total PA (% of day spent active) was a good predictor of sleep quality, but not sleep quantity.

Sub-study 1 hypothesized that as total PA (% of day spent active) increased across participants, weekday-night sleep duration would increase, and sleep onset latency and night awakenings would decrease. Although total PA (% of day spent active) was found to be a poor predictor of weekday-night sleep duration, the relationship between total PA and sleep onset latency neared significance, with the odds of having a shorter sleep onset latency increasing as children spent a greater proportion of their day active. Additionally, the relationship between total PA and night awakenings was significant, showing that across participants, those with a greater percentage of total PA (% of day spent active) were less likely to have more than one night awakening. These findings are consistent with results from previous research examining sleep subjectively measured via parental report. For example, Plancoulaine et al. (2015) found no relationship between parental report of weekly hours of PA and sleep duration, however, Xu et al. (2016) support a negative relationship between parent report of weekly hours of outdoor PA and night awakenings. Furthermore, De Bock et al. (2013) findings support moderate to vigorous PA as a good predictor of sleep quality. Findings from the current study therefore indicate that as PA increases, sleep quality also increases. These results add to the existing literature by providing further support for PA as a potential healthy sleep practice, specifically with respect to sleep quality.

Similar to the first sub-study, sub-study 2 hypothesized that as total PA (% of day spent active) increased, total sleep time would increase, and sleep onset latency would decrease. It was also hypothesized that sleep efficiency would increase with an increase in total PA (% of day spent active). However, total PA (% of day spent active) was found to be a poor predictor of total sleep time and sleep onset latency. As there is limited research examining the relationship between PA and sleep objectively measured, and as results of previous studies are inconsistent, it is difficult to draw comparisons between sub-study 2 findings and previous research. Two previous studies specifically examine the relationship between PA and total sleep time among pre-school children measured by a waist accelerometer. One of these studies suggests no association between moderate to vigorous PA and total sleep time (Duraccio & Jensen, 2017), while the other study suggests that as levels of total PA increases, total sleep time decreases (Williams et al., 2014). Further research is required to determine the relationship between PA and total sleep time. With respect to sleep onset latency, only one previous study specifically examined the relationship between PA and sleep onset latency among preschool-aged children (Nixon et al., 2009). This study suggests that as levels of total PA increases, sleep onset latency decreases. Based off this finding by Nixon et al. (2009), the current study is inconsistent with previous findings regarding the relationship between PA and sleep onset latency. However, further research is required to draw firm comparisons and conclusions.

Finally, the relationship between total PA (% of day spent active) and sleep efficiency was significant in sub-study 2, with results showing that as proportions of activity increased across participants, so too did sleep efficiency. Only one other study has specifically examined the relationship between physical activity and sleep efficiency in preschool-aged children (Iwata et al., 2011). Iwata et al., 2011 found that as the frequency of participation in sports lessons increases, sleep efficiency also increases. The current study is therefore consistent with this previous finding. Overall, sub-study 2 also adds to the existing literature, providing additional support for PA as a potential healthy sleep practice with respect to improving sleep efficiency.

Strengths

This research was of methodological soundness compared to many of the previously published studies examining PA and sleep among children as it utilized an objective measure to examine both PA and sleep. To ensure reliable estimates of PA and sleep, it is important to assess these variables objectively (e.g., via an accelerometer), as both subjectively measured PA and subjectively measured sleep are prone to error (Fitzhugh, 2015; Iwasaki et al., 2010). Specifically, parents tend to overestimate their children's sleep status and there are similar measurement errors when parents subjectively measure their children's PA as well (Fitzhugh, 2015; Iwasaki et al., 2010). Furthermore, to the author's knowledge, this study was the first of its kind, as it utilized the recommended tools for measuring PA and sleep (i.e., waist accelerometer and wrist accelerometers, respectively) (Slater et al., 2015; Trost et al., 2005). Previous research has used waist and wrist accelerometers interchangeably when measuring PA and sleep (Duraccio & Jensen, 2017; Tatsumi et al., 2015). However, accelerometers worn on the hip are better able to measure energy expenditure during walking and running compared to wrist accelerometers (Trost et al., 2005). Additionally, wrist accelerometers (e.g., actigraphs), as opposed to waist accelerometers, are recommended for measuring sleep, as waist accelerometers provide a more valid measure of sleep parameters (Slater et al., 2015). Therefore, as the current study incorporated these recommendations into the method, this research is of increased methodological soundness compared to previous research examining the relationship between PA and sleep among children.

When measuring PA and sleep objectively, it is important that the data collection period be long enough to gather reliable estimates of the variables being examined. It is recommended this data be collected for a minimum of four to seven days (Hinkley et al., 2012; Taylor et al., 2015). Previous research does not meet the recommended duration for data collection measurement periods. Nixon et al. (2009) examined PA and sleep objectively for one 24-hour period, and Duraccio & Jensen (2017) examined PA and sleep objectively for three days. Furthermore, although Taylor et al. (2015) met the recommended duration for data collection of seven days, children were still included in the data analysis procedures if they had less than four days of sleep data. With respect to the current study, children wore the accelerometer and actigraph during the same measurement period for nine consecutive days. More specifically, to be included in data analysis, children required a minimum of four days of accelerometer data, with a minimum of six hours of accelerometer wear time each day (Hinkley et al., 2012). Children also required a minimum of four days of actigraphy (Taylor et al., 2015). Overall, this research met the recommendations regarding the tools used to measure PA and sleep, and the duration for which the PA and sleep variables should be measured.

Study Limitations

This study was limited by its small sample size, as it included only 29 children. It could be that had the sample size been bigger, total PA (% of day spent active) may have been a good predictor for other sleep variables. For example, although the relationship between total PA (% of day spent active) and sleep onset latency was non-significant in sub-study 1, this relationship approached significance. Had the sample size been larger, results may have revealed a significant relationship between these two variables. Additionally, although the relationship between total PA (% of day spent active) and total sleep time was non-significant in sub-study 2, total sleep time increased across participants as children spent a greater proportion of their day active (see Figure 1). The trend was therefore in the direction that was hypothesized. It could be that had the sample size been larger, this trend may have been significant.

Within sub-study 1, there was a bit of a lag between when the parent-reported sleep data were collected and when the PA data were collected, particularly within the first cohort of participants. As such, the children's PA and/or sleep behaviours may have changed between the time the sleep data were collected and when the PA data were collected. Therefore, this lag may have impacted the results of sub-study 1 modeling the relationship between total PA and the various sleep variables. Had the PA and sleep data been collected at the same time, for example, perhaps a different relationship between total PA and the three sleep variables may have been revealed.

The families participating in the study were of higher SES as was evident from the descriptive analysis of SES (i.e., 69.0% of families reported having a family income of greater than $100,000). Therefore, results of the study may not necessarily be generalizable to larger populations of families with varying SES. Furthermore, this study included a highly active sample of children (total PA: M=494.37, SD=87.98, min=290.50, max=796.47), with all children obtaining more than the recommended PA guidelines of 180 minutes spent in PA with at least 60 minutes of energetic play per day (Tremblay et al., 2017). Although the National Sleep Foundation (2004) recommends 10 to 13 hours of sleep per night for preschool-aged children, these participants were still, on average, within the "may be appropriate" sleep duration range of 8 to 14 hours of sleep per night (National Sleep Foundation, 2004). As such, it is likely that this sample was not necessarily a representative sample of the general population of children between the ages of three and six years. As this sample was within the appropriate range of recommended hours of sleep per night, it could be that this sample is already sleep satiated, thereby obtaining sufficient sleep and therefore not benefiting from the potential impact of PA on total sleep time and objectively measured sleep onset latency. Had the sample been more diverse in terms of SES, the PA and sleep data may have been more varied as well, as family SES is associated with opportunities for PA and healthy sleep practices among children (Hale et al., 2009; Jarrin, McGrath, & Quon, 2014; van Rossem et al., 2012). Therefore, it could be that had these variables been more diverse, results may have revealed total PA (% of day spent active) as a good predictor of other sleep variables as well (e.g., sleep duration, total sleep time and objectively measured sleep onset latency).

This research solely examined the relationship between total PA and sleep. Previous research indicates an association between other PA variables, such as sedentary behaviour, and sleep among preschool children (Duraccio & Jensen, 2017). Specifically, Duraccio and Jensen (2017) found that although moderate to vigorous PA did not predict sleep duration (as measured via a wrist accelerometer), there was a negative relationship between sedentary behaviour and sleep duration; as the amount of time spent sedentary decreased, sleep duration increased (Duraccio & Jensen, 2017). Had the current research included sedentary behaviour and PA variables of other intensities (such as light PA and moderate to vigorous PA) to predict sleep, perhaps more of the variance pertaining to the sleep outcome variables may have been accounted for. Furthermore, the Canadian 24-Hour Movement Guidelines (2016) suggest preschool-aged children engage in PA through a variety of activities in different environments (e.g., the outdoors). As the outdoors allows for PA of higher intensities (Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008), outdoor PA may also have accounted for more of the variance pertaining to the sleep outcome variables had this PA variable been included.

Children participating in this study attended early years centres that have scheduled nap times throughout the day at the centres. These children may also have taken naps at home on weekends or on days that they did not attend their early years centres. Data regarding naptimes throughout the day and the length of these naptimes were not collected within this study. This may have impacted results of this study, particularly regarding sub-study 2, as sleep time throughout the day was not included in analysis. It could be that some participants appeared to sleep less than others at night, however, this may have been because such children slept longer during the day during naptimes. Had naptimes been included in data collection and analysis procedures, perhaps a significant relationship may have been revealed between total PA (% of day spent active) and total sleep time and sleep onset latency.

Finally, data were collected from participants in late summer, fall and in the winter seasons. There is evidence to suggest that children's PA levels can vary between seasons, with physical activity levels declining in the winter months, for example (Shen, Alexander, Milberger, & Jen, 2013). Furthermore, there is evidence to suggest that sleep can vary between seasons, in part due to the length of day and light exposure that effects endogenous levels of melatonin (Allebrandt et al., 2014; Lavie, 2001). As such, seasonality may have been a confounding variable within this study.

Future Directions

PA and sleep can vary from day to day. As such, it may be beneficial for future studies to narrow the statistical analysis to individual days, comparing daily PA scores to their respective sleep scores to examine daily trends as opposed to looking at weekly averages. This analysis would provide meaningful information to examine if PA during individual days can predict the respective night's sleep. Additionally, as previously mentioned, the current sample consisted of highly active children. However, total PA still predicted sleep quality. Future research should aim to examine children obtaining various amounts of total PA, specifically those obtaining less and more than the recommended PA to compare between these groups the relationship between PA and sleep.

The new Canadian 24-Hour Movement Guidelines provide recommendations for children at various stages of development, including preschool-aged children (Tremblay et al., 2017). These guidelines suggest a relationship between the three activity variables of PA, sedentary behaviour and sleep. In other words, the amount of PA, sedentary behaviour and sleep an individual obtains throughout a 24-hour period can all impact each other. Furthermore, these guidelines recommend preschool-aged children engage in PA at various intensities (Canadian 24 Hour Movement Guidelines, 2016; Tremblay et al., 2012). As the current study strictly examined the relationship between total PA and sleep, other important activity variables, were not included in analysis, such as sedentary behaviour, light PA and moderate to vigorous PA. Future research should explore whether sleep characteristics are associated with other physical activity intensities (e.g. time and % of day spent sedentary and in light and moderate-vigorous physical activity), rather than simply total PA (i.e., the % of a child's day spent active).

Outdoor time has been supported to encourage PA (Burdette, Whitaker, & Daniels, 2004). Additionally, the outdoors is where gross motor activity – defined as activities requiring control and movement of the large muscles for walking, running and jumping for example – in young children is most likely to occur (Maas et al., 2008). Unfortunately, children's outdoor play time is becoming less common with only around half of all preschool-aged children being taken outside to play each day (Burdette & Whitaker, 2005; Tandon, Zhou, & Christakis, 2012). Lower levels of PA experienced by children in today's society can be attributed to many factors and the reduction of time spent outdoors experienced by children serves as one potential factor (Burdette & Whitaker, 2005).

Sharma-Brymer and Bland (2016) argues that children enjoy and prefer nature features for play and PA. Furthermore, outdoor playtime allows for this interaction of play and nature features (Thigpen, 2007). Outdoor playtime could be a great way to increase PA levels and decrease sedentary behaviour, thereby helping to foster healthy practices among children in ways they will enjoy. As such, in terms of helping to promote healthy sleep among children, active outdoor play could serve as a healthy sleep practice as it can help to increase PA levels among children. For example, Xu et al. (2016) examined the relationship between parent report of weekly hours of outdoor play and sleep duration, sleep latency and night awakenings among children three to four years of age. Although no relationship was found between weekly hours of outdoor play and sleep duration and sleep latency, children engaging in more time in outdoor play and fewer night awakenings. More research is needed to determine the relationship between outdoor play and sleep among preschool-aged children. Future research could therefore incorporate active outdoor play into studies examining the relationship between PA and sleep. Specifically, such research could examine whether children who engage in more time outdoors in active play are objectively more physically active, less sedentary, and have objectively better sleep quality and quantity compared to children engaging in less time outdoors in active play.

Finally, similar to previous research examining the association between PA and sleep among children, this research demonstrates the relationship between PA and sleep among preschool children. However, results from these studies cannot determine cause and effect. Future experimental research will be necessary to determine the effect of PA on sleep, and to provide clear recommendations for various stakeholders including parents and their children, health professionals (e.g., physicians, psychologists and health promoters) and policy makers. For example, future experimental research could incorporate a between-subjects design by comparing sleep variables between an experimental group and a control group. This would require manipulating PA between the two groups, with the experimental group receiving a structured PA intervention and the control group being minimally active. Such an experiment could take place in a laboratory setting over a few days. This research would allow for firm conclusions to be drawn regarding the impact of PA on sleep. Such research should address the future directions mentioned above, as well as accounting for confounding variables including naptimes and seasonality.

Significance and Conclusion

This study is significant, as it helps add to the limited knowledgebase surrounding PA and sleep among preschool-aged children. The study suggests that PA might be beneficial for sleep quality, and therefore by extension, may help to promote healthy childhood development. These results are meaningful as they can help to inform parents, teachers, health professionals (e.g., psychologists, physicians, health promoters), and policy makers of potential methods for improving children's quality of sleep. However, it is important to remember that these results do no infer causality, and therefore experimental research will be necessary to confirm clear recommendations for stakeholders regarding PA and its potential as a healthy sleep practice.

These results can be published in relevant journals for psychologists, physicians and health promoters to access. Results can also be transformed into lay terms and presented to early years centres and elementary schools where teachers and parents can learn about the potential sleep benefits associated with PA. Specifically, psychologists and physicians can incorporate these findings into clinical practice, suggesting increased involvement in PA as a potential method for improving sleep quality. With respect to health promoters, these results can help to initiate evaluation of existing programs in schools and in communities with the aim of increasing the engagement in active play and PA from children involved. These findings can also help health promoters to advocate for increased opportunity for PA among children in schools and in the broader community, partnering with policy makers and other important stakeholders. Health promoters can help to initiate the implementation of PA programs and can encourage more active play during play times (including outdoor play times). Furthermore, health promoters can work collaboratively with community members, including parents and their children, teachers, and early years centres, to develop such methods for increasing PA and active play. For example, as many preschool-aged children spend a great amount of their time in early years centres, health promoters and policy makers can work collaboratively with early years centres and teachers to increase PA among children in the centres. Health promoters can provide educational and training sessions for teachers at centres, educating teachers of the importance of PA among preschool-aged children, and helping teachers and centres to develop the capacity for facilitating physical activities and active play among children throughout the day.

Such methods for increasing PA and active play in early years centres could include delivering loose parts to early years centres and educating centres and teachers of their use, similarly to the PLEY Project. These loose parts could help to increase PA and decrease time spent sedentary among preschool-aged children throughout the day at their early years centres. It could be that children might then be more likely to engage in play in outdoor settings with nature features similar to loose parts outside of their early years centre settings (e.g., at home). Therefore, the delivery of loose parts at early years centres could help to facilitate the amount of time spent active throughout the every-day lives of preschool-aged children, thereby helping to potentially improve sleep among this population. Future research examining the effect of a loose-parts intervention on sleep among preschool-aged children would be necessary to determine if loose-parts kits can improve sleep.

As previously mentioned, it is important to note that results from this study do not imply causation. The results from this study are descriptive stating the relationship between PA and sleep. Findings from this research can inform other researchers, helping to facilitate future research incorporating a larger sample size and/or utilizing an experimental design.

Overall, research supports that the insufficient sleep pandemic experienced by many children in today's society is a public health concern that needs to be addressed. PA is a healthy sleep practice among adults, and findings from this research indicate PA as a potential healthy sleep practice among preschool-aged children as well. Future experimental research is still needed to draw firm conclusions regarding the relationship between PA and sleep among preschool-aged. However, findings from this research reinforce the need to help ensure children are physically active and are meeting the recommended 24-hour activity guidelines. It is important to help instill healthy PA behaviours at a young age, not only to help facilitate healthy childhood development, but to also help increase the potential for these healthy practices to persist into later childhood and adult life.

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Appendix A

Consent Form for Parents and Children

Project Title: Physical Activity and Sleep: Predicting Total Sleep Time from Physical Activity Among Preschool-Aged Children

Lead Researcher
Laura Miller, Masters in Health Promotion, Dalhousie University,
laura.miller@dal.ca

Supervising Investigator
Dr. Sara Kirk, School of Health and Human Performance, Dalhousie University,
sara.kirk@dal.ca

Introduction
We invite you and your child to take part in a research study being conducted by MA Health Promotion Candidate Laura Miller. Choosing whether or not to take part in this study is entirely your choice. There will be no impact on you or your child should you decide not to participate in the research. The information below tells you about what is involved in the research, what you and your child will be asked to do, and about any benefit, risk, inconvenience or discomfort you or your child may experience.

You should discuss any questions you have about this study with Laura Miller. Please ask as many questions as you like. If you have any questions later, please contact Laura Miller.

Purpose and Outline of the Research Study
Sleep is important for healthy childhood development and overall health. Unfortunately, many children experience sleep problems. It is therefore important to discover ways to help improve sleep among children experiencing these sleep problems. The purpose of the current study aims to investigate the relationship between physical activity and sleep among preschool aged children. Children will engage in their regular day to day physical activity and sleep routines and schedules. The researcher hopes to add to the limited research examining the relationship between physical activity and sleep among this age group. The research hopes to have a total of 34 children participating in the study. This project stems from the larger study the PLEY Project.

Who Can Take Part in the Research Study
You and your child may participate in this research study if your child is between the ages of 3 and 5 years and has no known medical or psychiatric conditions that may interfere with sleep.

What Will You Be Asked to Do
In addition to the regular procedures of the PLEY Project, your child will also wear an actigraph (a device measuring motor activity) for a total of nine consecutive nights. This is a small device that is worn on the non-dominant wrist. This device will be used to measure the children's sleep. This accelerometer is only to be worn when sleeping and is not to be worn when engaging in water-based activities (e.g., swimming or taking a shower). An instructional wear manual will be provided along with a Sleep Diary for you to report each day times when the actigraph was put on, bedtime, lights out time, and wakeup time in the morning.

Possible Benefits, Risks and Discomforts
Benefits: Although this study may not directly benefit you, we might learn things that will benefit other children and potentially yours. By participating in this study you will gain altruistic benefits by contributing to knowledge.

Risks: As per the procedures of the larger study, the PLEY Project, your child will be asked to engage in his/her regular physical activity schedules and routines. As such, the possible harms associated with your child's involvement in the current study are no greater than those encountered by your child in his/her everyday life. The risks associated with your involvement in this study are also minimal, and there are no known risks for your participating in this research.

Discomforts: At first your child may experience some discomfort due to wearing the actigraph. This device may feel slightly awkward at first. After a few minutes of wear time your child will probably get use to wearing the actigraph and may not notice it as much. However, should your child experience too much discomfort when wearing the actigraph, you are free to remove it at any time. However, should you decide to remove the actigraph from your child, you and your child will no longer be able to participate in the study (see the "If You Decide to Stop Participating" section for more information on how to withdraw).

How Your and Your Child's Information Will Be Protected
Information that you provide to us will be kept private. Only the research team at Dalhousie University will have access to this information. We will describe and share our findings in a written thesis, presentations and journal articles. We will only talk about overall results so that no one will be identified. ***This means that you or your child will not be identified in any way in our reports.*** The people who work with us have an obligation to keep all research information private. Also, we will use a participant number (not your name) in our written and computer records so that the information we have about you or your child contains no names. All your identifying information will be securely stored. All electronic records will be kept secure in a file on a researcher's password-protected computer.

We will not disclose any information about you or your child (including participation in this study) to anyone unless compelled to do so by law. That is, in the unlikely event that we witness child abuse, or suspect it, we are required to contact authorities.

If You Decide to Stop Participating
You and your child are free to leave the study at any time with no negative consequences. If you decide to stop participating at any point in the study, you can also decide if you want any of the information that you or your child have contributed up to that point be removed or if you will allow us to use that information. However, once the data is analyzed or published, it will be impossible for us to remove your data. It is therefore important that you inform us if you would not like use to use either your or your child's data for the study before this data is analyzed.

How to Obtain Results
You have the option to decide if you would like us to share results of the study with you or not. You can indicate this on the Sleep Diary in the space provided.

Questions
We are happy to talk with you about any questions or concerns you may have about your or your child's participation in this research study. Please contact Laura Miller at **laura.miller@dal.ca** or Sara Kirk at **sara.kirk@dal.ca** at any time with questions, comments or concerns about the research study. We will also tell you if any new information comes up that could affect your decision to participate.

Signature Page for Parent and Child

Project Title: Physical Activity and Sleep: Predicting Total Sleep Time from Physical Activity Among Preschool-Aged Children

Lead Researcher
Laura Miller, Masters in Health Promotion, Dalhousie University,
laura.miller@dal.ca

CHILD PARTICIPATION:

I, _________________________ (Your Name), the parent/guardian of
___________________________(Your Child's Name)

__ **Give** consent to my child's participation in the above study.
__ **Do not give** consent to my child's participation in the above study.
(check one of the above sentences to indicate whether or not you give consent)

Please note that if you do not wish for your child to participate in this study, you are not eligible to participate as a parent.

I have read and understood the attached study information or had the attached information verbally explained to me. I understand that my child will be asked to engage in their regular physical activity and sleep schedules. I have been fully informed of the details of the study and have had the opportunity to discuss any concerns. I understand that I am free to withdraw my child at any time up to the point of data analysis, and that my child's performance outcomes will not be affected if I do. I understand that if I withdraw my child from the study, I will also no longer be able to participate in the study. I have received a copy of the study information and consent form.

___________________________ ___________________________
____
Name of Parent/Guardian Signature of Parent Date

PARENT PARTICIPATION: I have read the explanation about this study. I have been given the opportunity to discuss it and my questions have been answered to my satisfaction. I understand that my participation is voluntary and that I am free to withdraw from the study at any time, until data is analyzed. I understand that I have been asked to take part in completing a Sleep Diary. I agree to participate in the Sleep Diary portion of this study. I realize that my participation is voluntary and that I am free to withdraw from the study at any time, until data is analyzed. I understand that if I withdraw from the study, my child will no longer be able to participate in the study. I realize that I am free to not answer questions that make me feel uncomfortable.

Name of Parent/Guardian	Signature of Parent	Date

Email address

Appendix B

Email to Recruit Parents and Children

Dear parent(s),

My name is Laura Miller and I am a Master's student in Health Promotion under the supervision of Dr. Sara Kirk. My thesis is a smaller project stemming from the Physical Literacy in the Early Years (PLEY) Project examining the relationship between physical activity and sleep among preschool-aged children. The children will engage in their regular physical activity and sleep schedules and these activities will be assessed for nine days.

We would like to invite you and your child/children to participate in this smaller sub-study. **Physical activity data will already be collected for the PLEY Project by the accelerometers. The only extra piece we would be asking you to take part in is the sleep data collection**. This will involve your child/children wearing a small watch-like accelerometer on the wrist to bed.

If you are interested in participating in this smaller research project, please contact me at **laura.miller@dal.ca** for more information.

Thank you and I look forward to hearing from you,

Laura

Appendix C

PARENT SURVEY

Thank you for taking the time to complete this survey. It asks questions about you and your child that will help us to better understand how your child engages in active outdoor play and the factors potentially involved. This survey is intended to be completed by the primary caregiver.

Section 1: About yourself

1. What is your address? (This will only be used for to determine access to playground spaces)

   a. postal code ____________________________________

   b. street address_________________________________

2. How long have you lived in your neighbourhood?
   - o >6 months
   - o 6 months – 1 year
   - o 1-3 years
   - o 3-5 years
   - o 5-7 years
   - o >7years

3. All families are different and we would like to know about yours.

   a. Please tell us about the home where you live all or most of the time, and who lives there with you
   - o Couple with child/children
   - o Single parent family with child/children
   - o Extended family (with child/children)
   - o Grandparents (with child/children)
   - o Other

   b. How do you identify your ethnic/cultural background? *Check all that apply*
   - o Aboriginal
   - o Acadian descent
   - o European descent
   - o African decent (Black)
   - o Middle Eastern descent
   - o Asian descent
   - o East Asian descent
   - o Not listed above, please specify _________________________

   c. What is your level of education? (Please check all that apply).
   - o Completed junior/middle school
   - o Completed secondary/high school
   - o Completed community college or technical college
   - o Completed undergraduate university degree
   - o Completed graduate/advanced university degree

- Prefer not to answer

d. How many people, including yourself, usually live in your household?

____

e. Please check the boxes in the following diagram that reflect all individuals who usually live in your household. For children, please include ages of all children who usually live in the household and circle the child who is participating in this study.

Grandparents
☐☐☐☐

Parents
☐☐

Children
☐☐☐☐
☐☐☐☐

Others
☐☐☐☐
☐☐☐☐

f. What is your current household income before taxes from all sources?

- Less than $20,000
- $21,000 - $40,000
- $41,000 - $60,000
- $61,000 - $80,000
- $81,000 - $100,000
- More than $100,000
- Unsure
- Prefer not to answer

4. What is the birthdate (please include year) of your child who is participating in this study?

____

5. How many days do you get at least 30 minutes of moderate-to-vigorous physical activity in a week? This would involve activities that make you sweat and breathe harder.

   a. 0
   b. 1
   c. 2
   d. 3
   e. 4
   f. 5 or more

6. Please complete the following table regarding your sleep.

On a weekday, what time do you usually go to sleep?	
On a weekday, what time do you usually wake up?	
Is this usually uninterrupted sleep	
On a weekend day, what time do you usually go to sleep?	
On a weekend day, what time do you usually wake up?	
Is this usually uninterrupted sleep?	

7. How much screen time (TV, computer, game console, tablet, smart phone) do **you** typically have each day on a **weekday**?
    a. No screen time
    b. Less than an hour
    c. 1-2 hours
    d. 3-4 hours
    e. more than 4 hours

8. How much screen time (TV, computer, game console, tablet, smart phone) do **you** typically have each day on a **weekend day**?
    a. No screen time
    b. Less than an hour
    c. 1-2 hours
    d. 3-4 hours
    e. more than 4 hours

9. How much time do you typically spend sitting down each day doing non-screen based activities? (i.e. reading, drawing, etc.)
    a. No time
    b. Less than an hour
    c. 1-2 hours
    d. 3-4 hours
    e. more than 4 hours

10. How active would you rate **yourself**?

Minimally active **Very active**

1	2	3	4	5	6	7	8	9	10

11. How active would you consider yourself compared to others your age?

- **a.** Less active
- **b.** Same
- **c.** More active

12. On a scale of 1 to 10, how much does risk influence what activities you participate in?

Very Little **Very much**

1	2	3	4	5	6	7	8	9	10

Section 2: About your child

1. On days that you are with your child, do they get at least 180 minutes (3hrs) of physical activity (at any intensity) throughout the day?

- a. Yes
- b. No

2. Individuals are physically literate when they have acquired the skills and confidence to enjoy a variety of sports and physical activities. How would you rank your child's overall physical literacy? Please select the best option for each question.

	Low	Medium	High
Coordination when moving			
Safety while moving in the environment relative to others			
Number of movement skills acquired			
Ability to balance during movement			
Ability to run			
Ability to start, stop, and change direction			
Ability to use hands to throw, catch and carry objects			
Ability to use feet to kick or move objects			
Left side is as capable as the right side			
Amount of participation in water activities			

Amount of participation in indoor activities			
Amount of participation in outdoor activities			
Amount of participation in snow/ice activities			

3. On a weekday, how much sleep does your child usually get?

a. Less than 8 hours
b. 8 to less than 10 hours
c. 10 to 13 hours
d. more than 13 hours

4. On a weekend day, how much sleep does your child usually get?

a. Less than 8 hours
b. 8 to less than 10 hours
c. 10 to 13 hours
d. more than 13 hours

5. Does your child resist going to bed at bedtime?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

6. Does your child struggle at bedtime (cry, refuse to stay in bed, etc.)?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

7. Does your child typically fall asleep within 20 minutes after going to bed?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

8. Is your child restless/ does your child move a lot at night while sleeping (changes positions, throws covers off)?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

d. Unknown

9. Does your child awake once during the night?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week
d. Unknown

10. Does your child awake more than once during the night?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week
d. Unknown

11. Does your child have difficulty getting up and out of bed in the morning?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

12. Does your child take a long time to become alert in the morning?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

13. Does your child seem tired all the time?

a. Rarely – 0 to 1/week
b. Sometimes – 2 to 4/week
c. Usually – 5 to 7/week

14. How much screen time (TV, computer, game console, tablet, smart phone) does your **child** typically have each day on a **weekday**?

a. No screen time
b. Less than an hour
c. 1-2 hours

d. 3-4 hours
e. more than 4 hours

15. How much screen time (TV, computer, game console, tablet, smart phone) does your **child** typically have each day on a **weekend day**?

a. No screen time
b. Less than an hour
c. 1-2 hours
d. 3-4 hours
e. more than 4 hours

16. How much time does your **child** typically spend sitting down each day doing non-screen based activities? (i.e. reading, drawing, etc.)

a. No time
b. Less than an hour
c. 1-2 hours
d. 3-4 hours
e. more than 4 hours

17. How active would you rate your **child**?

Minimally active **Very active**

1	2	3	4	5	6	7	8	9	10

18. How active would you consider your child compared to others their age?

a. Less active
b. Same
c. More active

19. How risky would you consider each of the following activities for your child to participate in? Rate each of the activities from 1- "not risky at all" to 5- "Very risky"

	Not risky at all				**Very risky**
Swinging	1	2	3	4	5
Climbing	1	2	3	4	5

Rolling	1	2	3	4	5
Reaching	1	2	3	4	5
Sliding	1	2	3	4	5
Walking	1	2	3	4	5
Running	1	2	3	4	5
Biking	1	2	3	4	5

20. On a scale of 1 to 10, how much does risk influence what activities you allow your child to participate in?

Very Little **Very much**

1	2	3	4	5	6	7	8	9	10

21. On a scale of 1 to 10, how much does risk influence what activities your child chooses to do?

Very Little **Very much**

1	2	3	4	5	6	7	8	9	10

22. How much do you agree with each of the following statements about your child?

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I permit my child to use equipment and materials in ways other than what they were designed for.	1	2	3	4	5
I take my child to places where there are opportunities for risk-taking.	1	2	3	4	5
I limit what my child does as I worry that he/she may injure themselves	1	2	3	4	5
I feel that risk-taking is an important part to my child's development	1	2	3	4	5
I encourage my child to play outside in good weather	1	2	3	4	5
I encourage my child to play outside in rain or snow	1	2	3	4	5

Thank you for your participation!

Appendix D

Accelerometer information and log sheet

Dear Parents,
Thank you for consenting for your child to wear the accelerometer. Attached you will find a general accelerometer use guide, along with the tracking log where you can record your child's hours of wear. While the accelerometer waist band is the smallest size that is available, we recognize that it may still be a little big for your child. However, we ask that you do not cut the waist band (as they would be costly to replace in future), but instead wrap or tie the excess length around your child.
Furthermore, we suggest that you try out the accelerometer with your child this evening to see how they react to wearing it. Feel free to try whatever approach you believe will be best to help them to keep it on during waking hours. You might want to tell them it will record how fast they run or something along those lines, to make it appealing to them. If after a few tries your child still chooses not to wear the accelerometer, we ask that you return it to your child's daycare teacher/director.
If you do have any questions or concerns, please do not hesitate to contact me directly.

Thank you for your time.

Sincerely,

Michelle Stone, PhD
Co-Principal Investigator (PLEY Project)
Associate Research Scholar, Healthy Populations Institute (HPI, formerly AHPRC)
Scientific Staff, IWK
Assistant Professor, School of Health and Human Performance, Dalhousie University
6230 South Street, PO Box 15000, Halifax, NS B3H 4R2
phone: (902) 494-1167
fax: (902) 494-5120
email: michelle.stone@dal.ca

9-Day Accelerometer Wear Time Log

Please *write out* the date and times, and *circle* the 'NO' or 'YES' options for <u>each</u> day:

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
Date (M/D/Y):									
Device put **ON** at what time? (AM)	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___
Device taken **OFF** at what time? (PM)	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___	___:___
Were the devices **removed** during **wear** time? *(please circle one)*	No Yes	No Yes	No Yes	No Yes	No Yes	No Yes	No Yes	No Yes	No Yes
If **yes**, during which times:	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___
Did you take them off a second time? During which times?	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___	___:___ to ___:___
Any problems? Please explain:									

[redacted]

<u>Physical Literacy in the Early Years (PLEY) Project</u>
Accelerometer Wear Instructions

The following outlines instructions for wearing and caring for your child's accelerometer during the PLEY Project. **Your child will be asked to wear the accelerometer at the start of the study (baseline) for nine (9) consecutive days, and again 3 months and 6 months later.** If you have any questions at all, please do not hesitate to contact the PLEY Project Team (Primary Contact = Dr. Michelle Stone at michelle.stone@dal.ca).

[redacted]

This activity monitor is a more sophisticated version of a Fitbit, one that is typically used in physical activity and health-related research. Like a Fitbit, it records general movement, and will allow us to get a better idea of your child's overall activity level. We will not be able to tell what kind of specific activity is happening. At first, the belt may feel slightly awkward, but after a few hours, your child will probably get used to it and not notice it as much. It is extremely important for our study that your child wears the accelerometer properly. If it is not worn properly, we won't be able to determine how active your child is. **These instructions are provided to assist you.**

STEP 1: Please put the accelerometer on your child FIRST THING IN THE MORNING – ideally just after they get out of bed.

STEP 2: Make sure that your child wears the accelerometer attached to the belt around their waist, just above their right hipbone. They can wear it underneath or on top of their clothing. Make sure that your child wears the accelerometer snug against their body. If you have to, you can adjust the belt by pulling the end of the strap to make it tighter. Or, to loosen the belt, push more of the strap through the loop. The belt should be tight enough so that the accelerometer does not move when your child is active.

STEP 3: Next, make sure that your child is wearing the accelerometer the right way up – you'll know if it is the right way up if you look at your child and you can read the Actigraph name. Wearing it the wrong way will distort your child's data.

STEP 4: Your child should keep the accelerometer on all day (unless swimming or in the water). The accelerometer is not waterproof, therefore **<u>DO NOT SUBMERGE THE ACCELEROMETER IN WATER!</u>** Doing so will permanently damage it.

STEP 5: At night, take the accelerometer off RIGHT BEFORE YOUR CHILD GOES TO BED. **Your child should be wearing the accelerometer for at least 10 HOURS EACH DAY.**

Repeat Steps 1 to 5 daily for the entire wear time. Do not let anyone else wear your child's accelerometer.

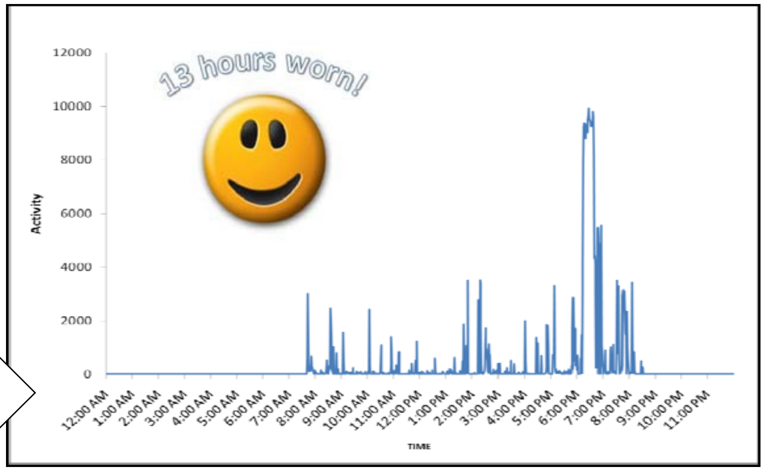
NOTE: There is no "ON" or "OFF" switch that you need to worry about turning the accelerometer on or off every day. It runs on a watch battery and is programmed to run continuously without you needing to turn it on. Please do not try to open the accelerometer; doing so will permanently damage it.

How long should your child wear the accelerometer?

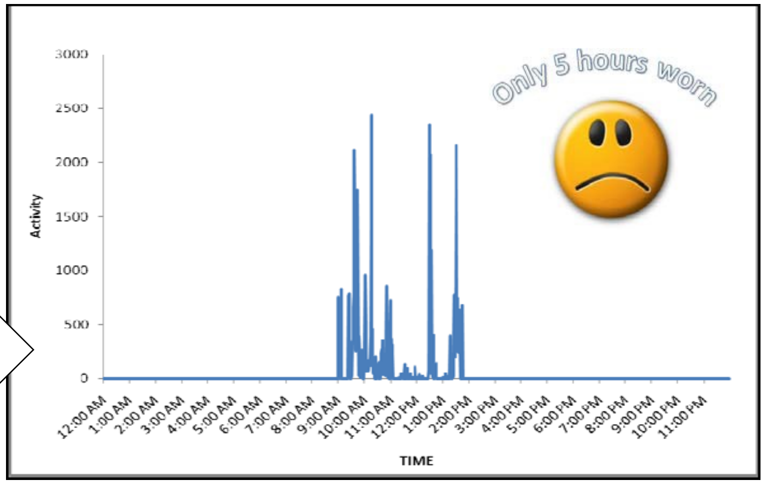
Below are some graphs that demonstrate how important it is for your child to wear the accelerometer correctly and for the right amount of time. Notice how the longer your child wears the accelerometer, the more activity information we will have access to. It really makes a difference if your child stops wearing the accelerometer, or if they do not wear it for long enough!

The accelerometer should be worn for 9 days straight, for at least <u>10 hours</u> a day. If it is worn for less than 10 hours/day, there will not be enough data to analyze.

This child did a great job of wearing his or her accelerometer! As you can see on the graph, the accelerometer was put on when he/she woke up at about 7:30 in the morning, and it was kept on until about 8:30 at night.



This child would not have enough data to analyze. It was put on when he/she woke up at about 9:00 in the morning, but it was taken off at about 2:00 in the afternoon.



NOTE: All activity data captured by your child's accelerometer are confidential. This means that any activity information captured will be accessible only to you and the research team. Your child's anonymity is ensured. Every researcher abides by an ethical code of conduct and your child's data will be protected by a unique study code.

Appendix E

Sleep Diary

Please answer the following questions to the best of your ability for each day.

DAY 1:
- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up the following the morning?: _______

DAY 2:
- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 3:
- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 4:
- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 5:
- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 6:

- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 7:

- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 8:

- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

DAY 9:

- Today's date (mm/dd/yy): ____________________________
- What time did your child put on the actigraph?: _______
- What time did your child get into bed?: _______
- What time was "lights out"?: _______
- What time did your child fall asleep?: _______
- What time did your child wake up in the morning?: _______

Once the study is complete, would you like us to share the results of the study with you (by email)? NOTE: We are not able to provide you with your own child's results, rather overall results of the study will be provided.

Yes: _____ No:_____ If Yes, please provide your preferred email

____

Appendix F

Sleep Actigraph Wear Instructions

The following outlines instructions for wearing and caring for your child's accelerometer during the study. **Your child will be asked to wear the actigraph for nine consecutive nights**. If you have any questions at all, please do not hesitate to contact the PLEY Project Team (Primary contact for sleep study = Laura Miller at laura.miller@dal.ca)

HOW TO WEAR THE DEVICE

This device resembles a wristwatch is a more sophisticated version of a Fitbit, and is frequently used in sleep research involving children. Similarly to a Fitbit, it records general movement, and will allow us to get a better idea of your child's overall sleep. We will not be able to tell what kind of sleep activity is happening. At first, the device may feel slightly awkward, but after a few minutes, your child will probably get used to it and not notice it as much. It is extremely important for the study that your child wears the device properly. If it is not worn properly, we won't be able to determine your child's sleep. **These instructions are provided to assist you.**

STEP 1: Please put the actigraph on your child's wrist **1 hour before bedtime** upon beginning your child's first night of the nine-day measurement period.

STEP 2: Make sure that your child wears the actigraph is on his/her non-dominant wrist. Make sure that the actigraph is snug against the wrist. You can adjust the band around the wrist accordingly to fit your child. The band should be tight enough so that the actigraph does not move when your child is active.

STEP 3: Your child should keep the actigraph on all night and should be removed**.** The actigraph is not waterproof, therefore **DO NOT SUBMIT THE ACCELEROMETER IN WATER!** Doing so will permanently damage it. Please remove the actigraph in the morning **1 hour after** your child's final wake up time. Place the actigraph on your child's wrist again **1 hour before** bedtime (while your child is getting ready for bed).

Repeat Step 1 to 3 daily for the entire wear time. Do not let anyone else wear your child's actigrpah.

NOTE: There is no "ON" or "OFF" switch that you need to worry about turning on or off every day. It runs on a watch battery and is programmed to run continuously without you needing to turn it on. Please do not try to open the actigraph. Doing so will permanently damage it.

It is important for your child to wear the actigraph correctly and at night when your child is sleeping.