Health benefits, variability, and correlates of outdoor play in preschool-aged children

by

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Abstract

Children's outdoor play (OP) has been consistently declining over recent decades. As such, OP research has increased; however, important gaps remain in the literature, especially for preschool-aged children (3-5 years). Specifically, there is a need to better understand the health benefits of OP, the barriers and facilitators that impact OP opportunities, and the best method to measure OP. The overall objective of this thesis was to address gaps and limitations in the current evidence base regarding OP in preschool-aged children.

Two manuscripts were written to address the overall objective. Data for this thesis was from the cross-sectional Parent-Child Movement Behaviours and Pre-School Children's Development project. In total, 107 preschool-aged children and parents from Edmonton, Canada, and surrounding areas participated in the study and had data for the variables of interest. All participants were recruited through a local division of Sportball. Children's OP was measured using a parental questionnaire and the lux feature of ActiGraph WGT3X-BT accelerometers. Correlates from various levels (i.e., individual, parental, microsystem, institutional, and physical ecology level) of the socioecological framework were measured via parental questionnaire and weather data obtained from the Edmonton International Airport. Health indicators of physical, cognitive, and social-emotional development were assessed.

The objective of the first manuscript was to examine the variability of parental-reported OP, the convergent validity of the parental-reported and device-based measure of OP, and the correlates of parental-reported and device-based measured OP. To examine the variability of parental-reported OP between summer/fall and winter months and between weekday and weekend days, paired sample t-tests were conducted. To examine the convergent validity of parental-reported and device-based measures of OP in the summer/fall months, a Spearman rank

correlation coefficient was calculated to explore the relative convergent validity and a Wilcoxon signed-rank test was conducted to explore the absolute convergent validity. Linear and logistic regression models were run to examine associations between potential correlates at various levels of the socioecological framework and parental-reported and device-based measured OP. Findings demonstrated that children's OP was significantly higher in summer/fall months compared to winter months and on weekend days compared to weekdays. The device-based measure was significantly correlated with the parental-reported measure; however, the parental-reported measure had significantly higher estimates of OP compared to the device-based measure. Additionally, temperature was positively associated with parental-reported (summer/fall months) and device-based measures of OP. Parental age was positively associated with parental-reported OP on weekend days.

The objective of the second manuscript was to examine the associations between parental-reported and device-based measured OP and health indicators of physical, cognitive, and social-emotional development and determine if these associations were independent of outdoor moderate- to vigorous-intensity physical activity (MVPA). To address this objective, linear and logistic regression models were conducted, with all models adjusting for relevant covariates and additional models adjusting for accelerometer-derived outdoor MVPA. Several parental-reported OP variables (i.e., total OP, OP in summer/fall months, OP on weekdays) were negatively associated with response inhibition and working memory. However, these associations were no longer statistically significant after adjusting for outdoor MVPA. Also, after adjusting for outdoor MVPA, OP on weekdays was negatively associated with externalizing.

The findings from this thesis add to the limited evidence on the variability, correlates, and health associations of OP in preschoolers. Overall, findings suggest that OP initiatives and interventions should target all weather/seasons and be available to children on weekdays and weekend days. Enabling OP opportunities may be an effective way to help promote healthy development in preschool-aged children. Gaining a better understanding of when, where, and with who children engage in OP may be an important consideration when designing interventions for this age group. Findings from this study provide several directions for future research. Future research is needed to determine the best approach and method to measure OP for preschool-aged children, as findings were not consistent across measurement types. Given the limited evidence of OP correlates in this age group, further studies are needed to confirm our findings and explore OP correlates across various levels of the socioecological framework while considering day-of-the-week differences in children's OP engagement. Additionally, future research should build on this preliminary work to better understand the developmental benefits of OP in this age group and consider the impact MVPA may have on these associations.

Preface

The University of Alberta Research Ethics Board granted ethics approval (Study ID: Pro00115737) for this study to conduct secondary analyses for two manuscripts from an existing dataset (Study ID: Pro00081175). For both manuscripts, I analyzed and interpreted the data, and led the writing of the manuscripts.

The manuscript within Chapter 3, "The variability and correlates of outdoor play in preschool-aged children," is formatted accordingly to the Canadian Journal of Public Health (CJPH), where it will be submitted for publication. This manuscript is the work of Cody Davenport in collaboration with Dr. Valerie Carson, Dr. Nicholas Kuzik, and Dr. Richard Larouche. Specifically, Cody Davenport and Dr. Valerie Carson conceived and designed the study. Dr. Nicholas Kuzik led recruitment and data collection. Cody Davenport led the data analysis, interpretation of findings, and drafted the manuscript. Dr. Valerie Carson assisted with data analysis, interpretation of findings, and writing of the manuscript. Dr. Nicholas Kuzik and Dr. Richard Larouche revised the manuscript for important content. All authors read and approved the final version of the manuscript that was submitted for publication.

The manuscript within Chapter 4, "The associations between parental-reported and device-based measured outdoor play and health indicators of physical, cognitive, and social-emotional development in preschool-aged children.", is formatted accordingly to Pediatric Exercise Science (PES), where it will be submitted for publication. This manuscript is the work of Cody Davenport in collaboration with Dr. Valerie Carson, Dr. Nicholas Kuzik, and Dr. Richard Larouche. Specifically, Cody Davenport and Dr. Valerie Carson conceived and designed the study. Cody Davenport led the data analysis, interpretation of findings, and drafted the manuscript. Dr. Nicholas Kuzik led recruitment and data collection. Dr. Valerie Carson assisted with data analysis, interpretation of findings, and writing of the manuscript. Dr. Nicholas Kuzik and Dr. Richard Larouche revised the manuscript for important content. All authors read and approved the final version of the manuscript that was submitted for publication.

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Chapter 1: Introduction

1.1 General Introduction

Public health guidelines emphasize the importance of childhood physical activity (Tremblay et al., 2016). Performing regular physical activity is recognized as an essential component of healthy growth and development in early childhood (Mazzucca et al., 2018). Sufficient levels of physical activity in early childhood supports healthy skeletal and cognitive development (Barr-Anderson et al., 2017; Carson et al., 2017; Kuzik et al., 2017), improves psychosocial and cardiometabolic health (Carson et al., 2017; Poitras et al., 2016), and reduces the risk of current and future diseases (Barr-Anderson et al., 2017).

Despite the well-documented benefits of obtaining regular physical activity, around 38% of Canadian preschool-aged children (aged 3-4 years) fail to meet national physical activity recommendations, and over 87% of Canadian preschool-aged children fail to meet the overall 24-Hour Movement Guidelines (Chaput et al., 2017), which include recommendations for physical activity, sedentary behaviour, and sleep. Consequently, a large portion of children are at risk for sub-optimal development.

Outdoor play provides children with greater opportunities to experience various types of physical movement (Davies, 1996), and children are more physically active when outdoors compared to indoors (Tandon et al., 2018; Tremblay et al., 2015; Vanderloo et al., 2013). Outdoor play may aid in combatting the increasing obesity rates in children as it has been associated with decreases in children’s body mass index (BMI; Ansari et al., 2015). Outdoor play may also provide benefits beyond physical activity. For instance, some evidence suggests outdoor play provides children with a greater sense of freedom, connection to nature, and many sounds, sights, smells, and textures that children cannot experience indoors (Davies, 1996).

Additionally, increasing outdoor play opportunities has been shown to help protect children from the onset of myopia; promote stress reduction, attention restoration, and social integration (Abraham et al., 2010; Yang et al., 2018); and have positive effects on children's vitamin D levels (Absoud et al., 2011; Jazar et al., 2012).

Increasing exposure to outdoor environments and landscapes may be a cheap and feasible way to promote mental, physical, and social-emotional well-being (Abraham et al., 2010; Ulset et al., 2017). It is recommended within the 24-Hour Movement Guidelines for the Early Years (0-4 years) that indoor time be replaced with outdoor time, but there are no specific recommendations for the total amount of time children should engage in outdoor play (Tremblay et al., 2017). The ParticipACTION report card on physical activity for children and youth includes a benchmark of 2 hours per day of active outdoor play; however, this benchmark is based on expert opinion (ParticipACTION, 2022). Additionally, few provinces or territories in Canada have a policy on how much time children should engage in outdoor play while attending childcare. Specifically, in Alberta, Canada, there are no recommendations (Vercammen et al., 2020). Therefore, minimal guidance exists in the home and childcare settings in regard to outdoor play.

There is increasing concern regarding the lack of outdoor play among children, with evidence suggesting that children's outdoor play has declined over time (Tremblay et al., 2015). Though Canadian evidence on the decline of outdoor play in early childhood is unknown, in school-aged children, the proportion of Canadian children who play outdoors after school has declined by approximately 14% from 2002 to 2012 (Active Healthy Kids Canada, 2012). While outdoor play is beginning to receive more attention, gaps remain in the literature. More specifically, Tremblay et al. (2015) have highlighted the need for future research to better understand the risks and benefits of outdoor play and identify barriers and facilitators that promote and enable outdoor play.

Though it is well documented that outdoor play is positively associated with physical activity, its unique benefits to health indicators of physical, social-emotional, and cognitive development remain unclear, especially in preschool-aged children (Barnett et al., 2019; Gray et al., 2015; McCormick, 2017; Taylor & Kuo, 2006; Ulset et al., 2017). For instance, outdoor time was found to be unrelated to physical development (i.e., motor development; Sääkslahti et al., 1999) in a recent systematic review (Gray et al., 2015). Of note, Gray and colleagues' (2015) review only included one study that examined the association of outdoor time with indicators of physical development, and this study happened to focus on preschool-aged children. Another systematic review found that access to green space was associated with improved social-emotional and cognitive development, but the included studies did not explicitly look at outdoor play. Additionally, only two studies included in this review focused on children five years of age and younger (Aggio et al., 2015; Schutte et al., 2017). In general, it seems that outdoor play and being in nature can promote healthy child development (Davies, 1996), but limited evidence exists in preschool-aged children. Thus, in order to more confidently associate outdoor play with healthy development, further studies are needed in this age group (Taylor & Kuo, 2006).

Another limitation regarding children's outdoor play is the lack of reliable and valid tools used to measure outdoor play (Lee et al., 2021). Most studies on outdoor play use subjective (i.e., self-report, parental-report) measures with unknown psychometric properties (Lee et al., 2021). The use of device-based measures of outdoor playtime, for instance, via a light sensor (i.e., lux) feature of an accelerometer, is increasing, but there is still variation in how devices are used, including the lux thresholds used to distinguish between children's indoor and outdoor play

(Flynn et al., 2014; Kwon et al., 2022; Tandon et al., 2013). Using a device to distinguish between children's indoor and outdoor play also has limitations when clothing is worn over the accelerometer. More specifically, wearing different articles of clothing (i.e., T-shirt, sweatshirt, jacket) over the device can decrease lux readings anywhere between 40%-100% (Flynn et al., 2014). Also, certain activities, such as riding in a vehicle to preschool or transitioning between indoors and outdoors, may be misclassified by the light sensor (Flynn et al., 2014). Therefore, measuring outdoor play with both subjective and device-based tools can provide a balanced assessment of outdoor exposure.

In terms of correlates, or barriers and facilitators, of outdoor play, recent systematic reviews examined correlates of outdoor play in 3–12-year-old children (Lee et al., 2021), and determinants of outdoor time in 0-17-year-old children (Larouche et al., 2023). These reviews considered various levels of the socioecological framework and highlighted a number of important correlates with outdoor play/time. Specifically, at the individual (e.g., sex/gender, race/ethnicity), parental (e.g., parental support), microsystem (e.g., residence type), macrosystem/community (e.g., outdoor play spaces), and physical ecology (e.g., seasonality) levels (Lee et al., 2021; Larouche et al., 2023). However, no correlates were found at the institutional level (e.g., weekdays versus weekend days). Overall, limited evidence exists for outdoor play correlates exclusively for 3-5-year-old children, as approximately 75% and 87% of the studies included in the reviews by Lee et al. (2021) and Larouche et al. (2023), respectively, examined ages outside of this range.

The Behavioural Epidemiology Framework can be used to guide research focusing on preschool children's outdoor play. This framework outlines a systematic sequence of five progressive phases applicable to health-related behaviour research (Sallis et al., 2000). The phases include: 1) establish links between behaviours of interest and health outcomes; 2) develop measures of a specific behaviour; 3) identify potential influences of a behaviour; 4) evaluate intervention methods and programs targeted to change a behaviour; 5) translate research into practice (i.e., knowledge translation; Sallis et al., 2000). The objective of this framework, and following the subsequent steps, is to provide evidence-based interventions aimed at changing a specific behaviour at the population level (Sallis et al., 2000).

1.2 Objectives

The overall objective of this thesis was to address gaps and limitations in the current evidence base regarding outdoor play in preschool-aged children. This thesis targets phases 1-3 of the Behavioural Epidemiology Framework (Sallis et al., 2000). Specifically, this thesis establishes links or associations between outdoor play and development (Phase 1); provides further research on methods for measuring outdoor play (Phase 2); and identifies correlates associated with outdoor play (Phase 3; Sallis et al., 2000).

The specific objectives of this thesis were to examine in a sample of preschool-aged children:

(1) the variability of parental-reported outdoor play when comparing summer/fall with winter months and weekday with weekend days,

(2) the convergent validity of the parental-reported and device-based measure of outdoor play,

(3) the correlates of parental-reported outdoor play in summer/fall months, winter months, weekdays, and weekend days,

(4) the correlates of device-based measured outdoor play,

(5) the associations between parental-reported and device-based measured outdoor play and health indicators of physical, cognitive, and social-emotional development, and

(6) if associations in objective 5 were independent of outdoor moderate- to vigorous-intensity physical activity.

1.3 Hypotheses

1) Children will spend more time outdoors in non-winter months, and there will be no significant difference between weekdays and weekend days. 2) There will be more significant correlates at the individual level compared to other socioecological framework levels.
3) Outdoor play will be favourably associated with health indicators of physical, cognitive, and social-emotional development.

1.4 Definition of Key Terms

Preschool-aged children (i.e., Preschoolers): According to the Government of Alberta's Education Act and Early Learning and Child Care Regulation, preschoolers are children between 19 and 71 months of age or 1.6 to 5.9 years of age (Government of Alberta, 2021a, 2021b). However, the Canadian 24-hour movement guidelines consider the preschool age to start at 3 years and end at 4.9 years (Tremblay et al., 2017). The proposed thesis will combine these definitions and consider preschool-aged children and the preschool years to be those aged 3-5 years.

Physical activity (PA): Caspersen et al. (1985) define physical activity as "any bodily movement produced by skeletal muscles that results in energy expenditure" (p. 126). Physical activities are commonly categorized in light, moderate, and vigorous intensities. These intensities are frequently established using metabolic equivalents (METs), which indicate the energetic cost of physical activities in relation to one's resting metabolic rate (RMR; Byrne et al., 2005). For children, light physical activities (LPA) range between ≥1.5 and <4 METs; these activities may include walking comfortably or playing a game of catch (Trost et al., 2011). Moderate physical activities (MPA) range between ≥ 4 and < 6 METs, which could include a brisk walk (Trost et al., 2011). Vigorous physical activities (VPA) are considered any activity ≥ 6 METs, including running or playing sports (Trost et al., 2011). MPA and VPA are often not differentiated; they are combined to form moderate- to vigorous-intensity physical activity (MVPA).

Outdoor play: A common gap noted in the outdoor play literature is the terminology, where there are discrepancies and confusion in differentiating between outdoor physical activity, active free play, outdoor play, outdoor time, and outdoor activity (Lee et al., 2021). However, a recent study has reported terminology, taxonomy, and ontology of outdoor play, learning, and teaching (Lee et al., 2022). As such, spending time outdoors is referred to as “outdoor time,” and play that takes place outdoors is referred to as “outdoor play” (Lee et al., 2022). This thesis is focused on children’s outdoor play and time spent outdoors; however, ‘outdoor play’ will be the term used hereafter.

Development: This thesis focuses on three domains of development: physical development (e.g., motor skills, growth), cognitive development (e.g., language development, memory), and social-emotional development (e.g., self-regulation, behavioural problems; Berk, 2013; Kuzik et al., 2020).

Correlate: This thesis will use the term “correlate” to refer to statistical associations between measured variables and outdoor play (Bauman et al., 2002). With cross-sectional analyses, it is recommended that statistical associations be referred to as “correlates” instead of “determinants” (Bauman et al., 2002).

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Chapter 2: Review of Literature

2.1 Early Childhood

The first five or six years of life, often referred to as "early childhood," are a crucial time for children's growth and development (Royal College of Physicians and Surgeons of Canada, 2014). These years are characterized by rapid growth and advancements in numerous domains, specifically in physical, social-emotional, and cognitive domains (Royal College of Physicians and Surgeons of Canada, 2014). Many healthy and unhealthy behaviours established within a child's first six years of life will carry over into adulthood, having a lasting effect and influence on future health outcomes (Royal College of Physicians and Surgeons of Canada, 2014). Thus, early childhood, when children are especially sensitive to health indicator trajectories and influences from their environments (Berk, 2013), is a critical time to intervene and enhance behaviours that promote healthy development and have the potential to change development trajectories for the rest of their lives (Royal College of Physicians and Surgeons of Canada, 2014).

2.2 Settings

Given that preschoolers' outdoor play opportunities are dependent on their parents and educators for permission, supervision, and transportation, their outdoor play opportunities primarily take place in three main settings: home, neighbourhood, and childcare centres/programs (Armstrong et al., 2019; Loebach & Gilliland, 2016; Predy et al., 2020).

The majority of children spend a large portion of their time close to home or in their neighbourhood activity spaces (Loebach & Gilliland, 2016). Therefore, a common setting for children's outdoor play is in the home/backyard (Armstrong et al., 2019). This is likely due to children being able to easily access their backyard and does not require any form of transportation, and potentially less supervision from their parents. Similarly, the neighbourhood is a promising setting to provide outdoor play. Neighbourhood characteristics and landscapes, such as walkable landscapes, safe neighbourhoods, and access to parks and sports fields, may increase children's outdoor play opportunities and promote physical, mental, and social well-being (Abraham et al., 2010). Despite the potential these settings have for providing outdoor play opportunities, there is limited research on the relationships between backyard and neighbourhood environments and children's outdoor play, especially for preschool-aged children (Lambert et al., 2019). Of the currently available literature on the topic in children aged 3-5 years, there are limited 'good quality' studies and an evident need for additional research (Lambert et al., 2019).

In addition to the home and neighbourhood settings, the childcare setting may be a key environment for promoting and enabling outdoor play in many children. In 2011, over half of parents (54%) reported using some type of childcare for their children between the ages of 2-4 years (Government of Canada, 2014). Most provinces and territories in Canada require outdoor play in this setting, but few have designated a time requirement (Vercammen et al., 2020). This thesis will focus on the home (i.e., backyard) and neighbourhood settings because these settings are expected to be the primary locations for preschool-aged children's outdoor play (Armstrong et al., 2019; Loebach & Gilliland, 2016), and the locations where parents will be able to better recall their child's time outdoors.

2.3 Development

Play is recognized as a critical component of healthy child development (Sawyers, 1994; Thies et al., 2009). For this thesis, development will include three main domains: physical, cognitive, and social-emotional development.

2.3.1 Physical Development

Children's physical development plays an important role in their life-long health and well-being. Children have a rapid rate of growth in their first two years, and around the age of three, their rate of growth becomes slower (Thies et al., 2009). Each year preschool-aged children, on average, grow two to three inches in height and gain five pounds in weight (Berk, 2013). Children's expected adult height is often calculated to be used for growth-promoting initiatives in a clinical setting (Luo et al., 1998). As a result of children's continued growth, they become less top-heavy, and there is a downward shift in their center of gravity (Berk, 2013). This leads to improvements in their balance, and they begin to perform new skills such as running, skipping, and throwing (Berk, 2013). By the age of five, children have noticeable improvements in gross and fine motor tasks and begin to perform more complex tasks, including riding a bicycle, zippering their jacket, and drawing/colouring (Berk, 2013). Hereditary, dietary, and environmental influences are recognized as key contributors to children's physical development, as well as their opportunities for physical play (Berk, 2013).

2.3.2 Cognitive Development

Piaget (1952) recognizes language development as an important indicator of cognitive development. During preschool years, children's ability to form longer sentences, speak words more clearly and in proper contexts, and establish a stronger connection between words and their meanings improves (Berk, 2013). Additionally, language development, along with working memory and attention control, have positive influences on school-related success (e.g., numeracy/math skills, reading skills) and overall executive function (Kuhn et al., 2014; Welsh et al., 2010). Executive function refers to one's cognitive control abilities involved in self-regulated and goal-oriented actions (e.g., inhibitory control, control, and coordination of information;

Kuhn et al., 2014; Welsh et al., 2010). By the time children are three years old, they can remember the tasks asked of them, and paired with their language development, they can verbally recall things that they remember (Berk, 2013). Also, as preschoolers' attention improves, they have enhanced response inhibition (Thies et al., 2009). This highlights their improved capability to continue a single task at hand and re-consider switching back and forth between multiple tasks (Berk, 2013).

2.3.3 Social-Emotional Development

Preschoolers' play shifts from onlooking at others' play to collaboratively playing together to achieve a common goal (Berk, 2013). This represents a change in children's social behaviours. Parents are highly influential in preschoolers' social behaviours by modelling how they interact with their peers, often other family members, and arranging and providing opportunities for their children to engage in play activities with other children (Berk, 2013). With a better understanding and awareness of their emotions, preschoolers begin to further develop their sense of self-regulation and learn how to cope with negative emotions (Berk, 2013). Children's improvements in language development also plays a role in their emotional self-regulation as they are able to verbalize what they are experiencing and feeling (Cole et al., 2010). During the preschool years, problematic behaviours can hinder a child's ability to function with their peers in a childcare and education setting as well as with their families (Campbell, 1998). Two categories of problematic behaviours include internalizing (e.g., sadness, social withdrawal, anxiety) and externalizing (e.g., disruptiveness, defiance, aggression) behaviours (Halle & Darling-Churchill, 2016).

2.4 Outdoor Play

2.4.1 Prevalence

Over the past 40 years, there have been declines in children's outdoor play (Bassett et al., 2015). This decline may be due to increased parental concern for children's safety and injury prevention while outdoors (Karsten, 2005; Veitch et al., 2006), increased parental supervision and constraints on the spaces where children can play (Karsten, 2005; Tandy, 1999), and less neighbourhood connections and social and spatial freedom (Witten et al., 2013). An increase in children's screen time use may also hinder their time spent playing outdoors. Overall, the use of technology is increasingly prevalent in families (Reus & Mosley, 2018).

A recent systematic review found that children (3-12 years) today spend between 60 and 165 minutes each day in outdoor play (Lee et al., 2021). Among the articles included in the systematic review, which exclusively examined preschool-aged children, children's daily amount of outdoor play ranged between 45-191 minutes per day (Armstrong et al., 2019; Berglind & Tynelius, 2018; Burdette & Whitaker, 2005; Carsley et al., 2016; Grigsby-Toussaint et al., 2011; Kimbro et al., 2011; Kos & Jerman, 2013; Mota et al., 2017; Predy et al., 2020; Remmers, Broeren, et al., 2014; Remmers, Van Kann, et al., 2014; Wiseman et al., 2019). Other articles in the review found that over 65% of preschool-aged children accumulate 60 minutes or more of outdoor play each day (Matarma et al., 2020), over 68% have 120 minutes or more (Xu et al., 2017), and over 8% have 180 minutes or more (van Rossem et al., 2012). Also, children usually have more outdoor play on weekend days compared to weekdays (Berglind & Tynelius, 2018; Burdette & Whitaker, 2005; Caroli et al., 2011).

Though activities in nature and outdoors have been associated with improved overall health (Tremblay et al., 2015), it is still unclear how much outdoor play preschool-aged children need for healthy development. Currently, it is recommended to replace indoor with outdoor time (Tremblay et al., 2017), yet still, there are no clear amounts of time given in order to reach the potential health benefits of outdoor play.

2.4.2 Health Benefits

Parents may believe that outdoor play is dangerous and poses a greater risk to their child(ren) compared to playing indoors; however, Tremblay et al. (2015) note that most injuries from outdoor play are minor and pose minimal threat to children's wellbeing. Outdoor play is safer than parents think (ParticipACTION, 2015), and has been found to support children's overall health, though less evidence exists in preschool-aged children (Brussoni et al., 2015). The potential benefits of outdoor play in preschool-aged children can be examined across different domains of development – including physical, social-emotional, and cognitive development.

A systematic review of physical activity that included outdoor play noted that outdoor play may contribute to physical health indicators that are associated with physical activity (e.g., bone and skeletal health; Carson et al., 2017) in children of the early years (0-4 years). Three studies in this review found positive associations between outdoor activity and bone and skeletal health; however, each of these studies only assessed outdoor physical activity during non-winter months and included children outside of the preschool-age range (Jazar et al., 2012; Kensarah et al., 2015; Xu et al., 2013). In another systematic review that specifically focused on outdoor time in 3-12-year-olds, only one study was included that examined the association of outdoor time with indicators of physical development (Gray et al., 2015). Specifically, outdoor time was found to be unrelated to motor development in preschool-aged children (Sääkslahti et al., 1999). Outdoor play may have positive effects on Vitamin D levels, where children who have more outdoor play and outdoor physical activity also have higher Vitamin D levels (Absoud et al., 2011; Jazar et al., 2012). However, these studies only used subjective measures to capture children's outdoor activity (i.e., participant diary and questionnaire), and seemed to focus more on the physicality of their outdoor play. Specifically, outdoor exercise and active play were used as a combined measure in one study (Absoud et al., 2011), and another study only measured children's outdoor physical activity (Jazar et al., 2012). The association between preschool-aged children's outdoor play and BMI remains uncertain. Ansari et al. (2015) found that outdoor play is related to decreases in preschoolers' BMI scores; however, outdoor play was only measured in 5-minute intervals while children attended childcare.

There is a major gap in the evidence for associations between children's outdoor play and cognitive and social-emotional development (de Lannoy et al., 2023). A recent systematic review found that nature play has a positive impact on cognitive development (Dankiw et al., 2020). It is important to note that this review included a broad range of ages (i.e., 2-12 years old), and only examined outdoor play that included natural elements (i.e., forest, water, vegetation). Hence, the associations between outdoor play in non-natural environments (i.e., fabricated playgrounds, yards) and cognitive development remain unclear. Ulset and colleagues (2017) noted a positive association between outdoor time and preschoolers' attention/working memory skills; however, outdoor time was only measured while children attended childcare. Preschool-aged children have also been reported to have significantly less inattention when playing in green outdoor environments (i.e., hilly terrain and a lot of vegetation; Mårtensson et al., 2009). Similarly, engaging in activities in green outdoor settings has been found to decrease symptoms of ADHD (Kuo & Taylor, 2004). Outdoor play was not specifically examined by Kuo and Taylor (2004), and their study only included 5 to 18-year-old children who have been diagnosed with ADHD.

Ansari and colleagues (2015) reported null associations between outdoor play, at childcare, and indicators of children's academic learning (i.e., math and literacy skills).

Outdoor play may enhance children's social-emotional learning by providing opportunities for social interactions (Rosiek, 2020); however, this was observed in only a small sample of preschool-aged children (n=26). Outdoor play can also provide opportunities for children to experience different environments and terrains, where they can explore, develop confidence when facing new obstacles, and have social engagement and support with their peers (McClain & Vandermaas-Peeler, 2016). It is important to note that McClain and Vandermaas-Peeler (2016) only examined children's outdoor play at a river and a creek, and these environments may not be accessible to a lot of children – especially those living in an urban area. Another study noted positive aspects of children's outdoor risky play (i.e., developing courage and facing challenges); however, these aspects were only reported by early childhood educators (n=7), and were not assessed on the children themselves (Sandseter, 2012). Despite the noted potential benefits of outdoor play, further research is needed to examine benefits for children exclusively between 3-5 years of age in various settings using valid measures of outdoor play.

2.4.3 Measurement

A recent systematic review noted four different methods used to measure preschool-aged children's outdoor play: proxy-report (13 studies), self-report (five studies), device-based (two studies), and direct observation (one study; Lee et al., 2021). Another review examining the determinants of children's outdoor time (Larouche et al., 2023), noted two different methods that were used to capture preschool-aged children's outdoor time: proxy-report (six studies) and direct observation (one study). Subjective measures (i.e., proxy-report and self-report) are commonly used to capture children's outdoor play (Lee et al., 2021). Since preschool-aged children do not have the cognitive capacity to self-report their outdoor play (Baranowski, 1988), proxy-report measures are used in this age group. Key advantages of these subjective measures are that they are cost and time efficient and, depending on the measure, can capture a wealth of contextual information (Oliver et al., 2007). However, response bias and social desirability bias are inherent limitations of proxy-report measures (Koning et al., 2018). More specifically, parents may not be able to accurately recall their child's outdoor play, especially during childcare hours, or they report in a manner that they feel will be viewed more favourably (i.e., overreport their outdoor play). Overall, there is a lack of proxy-report outdoor play measures with established psychometric properties. The 'outdoor playtime checklist' and 'outdoor playtime recall' are two measures that have commonly been used in the literature for preschool-aged children (Burdette et al., 2004). These measures each consist of two questions which allow parents to report the duration of children's outdoor playtime in numerous settings (i.e., yard, park, playground) while at home and in childcare, and their outdoor playtime duration on weekdays and weekend days. Both the checklist (r=0.33) and recall (r=0.20) measures were significantly correlated with accelerometer-derived physical activity (Burdette et al., 2004). While the checklist captures outdoor playtime in various settings, it only allows respondents to select a 15-minute interval for duration, and does not precisely capture durations that are over 60 minutes. The 'outdoor playtime recall' will be used in this thesis to capture precise estimates (hours and minutes) of children's outdoor play durations, and will differentiate between weekdays and weekend days.

The use of accelerometers, with a built-in ambient light sensor reported as lux, enables the measurement of outdoor activity in children. A lux is a unit of illuminance (International System of units), which is equivalent to one lumen per square metre (lm/m^2; Flynn et al., 2014).

Device-based measures can capture less biased assessments of children's outdoor play as they do not rely on recall. Some devices (i.e., accelerometers) can also capture children's physical activity and stationary time while playing outdoors. One main disadvantage of device-based measures, such as accelerometers, is that there is limited evidence on the most accurate lux thresholds to differentiate between indoor and outdoor activity (Flynn et al., 2014). Two studies that used accelerometers to measure preschool-aged children's outdoor activity varied in their lux threshold to detect outdoor activity (i.e., >110 lux, Tandon et al., 2013; ≥240 lux, Kwon et al., 2022). For preschool-aged and school-aged children (i.e., 3-12 years old), three studies also used varying lux thresholds (i.e., ≥240 lux, Flynn et al., 2014; >1000 lux, Verkicharla et al., 2017; ≥1000 lux, Wen et al., 2020). Of these studies, Flynn and colleagues (2014) reported the most accurate (88.9% in detecting outdoor activity) lux threshold (i.e., ≥240 lux). Children aged 3-11 years were included in the study; however, only children aged 3-5 years were included to test the accuracy of this threshold – suggesting that this is an appropriate threshold to use with preschool-aged children. GPS devices have been used in combination with accelerometers to capture preschoolers' outdoor time (Tandon et al., 2013); however, a systematic review has noted the lack of a standardized operating protocol for GPS devices, and further protocols are needed to work in conjunction with accelerometers (Zougheibe et al., 2021). Additionally, direct observation is not a practical measure for children's outdoor play in large samples, and in numerous settings, due to the high experimenter burden associated with this type of measurement (Sirard & Pate, 2001). Overall, measuring children's outdoor play lacks consistency in the literature, and there is a need for a standardized measure of children's outdoor play. This thesis used both objective (device-based) and subjective (parental-reported) tools to measure outdoor play to minimize the risk of missing or misclassifying outdoor play, and examine the convergent validity of the parental-reported and device-based measure of outdoor play. A lux value of ≥240 will be used to differentiate from indoor and outdoor time (Flynn et al., 2014).

2.4.4 Physical Activity Levels During Outdoor Play

According to the Canadian 24-Hour Movement Guidelines, preschoolers (3-4 years) should attain at least 180 minutes of various physical activities throughout the day, including at least 60 minutes of energetic play (Tremblay et al., 2017). Children (5 years) should attain at least 60 minutes of moderate to vigorous physical activity each day, several hours of light physical activity each day, and vigorous and muscle strengthening activities at least three days per week (Tremblay et al., 2016).

A systematic review of children aged 3-12 years found that time spent outdoors is positively associated with physical activity (Gray et al., 2015), and children are more active outdoors compared to indoors (Tandon et al., 2013). Children who spend more time outdoors engage in more physical activity than children who have less outdoor time (Hinkley et al., 2008). In 5-year-old children, moderate-to-vigorous physical activity increased by ten minutes on average for each additional hour spent outdoors (Larouche et al., 2016).

2.4.5 Individual Correlates of Outdoor Play

Similar to physical activity, outdoor play is thought to be influenced by multiple factors, including biological, environmental, and psychosocial factors. Due to the limited effectiveness of physical activity promotion intervention, a comprehensive model was established that considers intra- and extra-individual factors (Spence & Lee, 2003). A recent systematic review has used this socioecological model framework in the context of outdoor play to examine various levels, and their associated myriad of factors, ranging from the individual level to physical ecology (Lee et al., 2021). This thesis will use the socioecological framework as guidance when considering the correlates of preschoolers' outdoor play.

At the individual level, systematic review evidence in children 3-5 years has found consistent correlates that are both positively or negatively associated with outdoor play. For example, being part of a majority racial/ethnic group is strongly associated with more outdoor play (Damore, 2002; Grigsby-Toussaint et al., 2011; Gross et al., 2013). Other individual characteristics, such as child autonomy and initiation, are also positive correlates (Brown et al., 2009; Remmers, Broeren, et al., 2014). Having female sex, excess weight, and English being a second/additional language when living in an Anglophone environment are negatively associated with outdoor play (Caroli et al., 2011; Frech & Kimbro, 2011; Gottfried & Le, 2017; Honda-Barros et al., 2019; Mota et al., 2017; Remmers, Van Kann, et al., 2014; van Rossem et al., 2012). There are still some factors, such as age, that presumably may impact children's outdoor play; however, were found not to have a consistent association (Lee et al., 2021). More consistent findings with age may be observed when comparing preschool-aged children to older age groups. For example, Larouche and colleagues (2023) noted that one study in their review found that 7-year-old children spent, on average, approximately 60 more minutes in outdoor play per week compared to 5-year-old children (Remmers, Van Kann, et al., 2014). This thesis will further the understanding of individual-level correlates of outdoor play in preschool-aged children.

2.4.6 Home Environment Correlates of Outdoor Play

In the home environment, parents may have a significant influence on children's outdoor play. Grigsby-Toussaint et al. (2011) found that parental support, such as co-participation and transportation to outdoor play areas are positively associated with children's outdoor play.

Honda-Barros and colleagues (2019) also found that co-participation in physical activity with parents was associated with children being more likely to engage in 60 minutes or more of outdoor play per day. Additionally, parents with rules on outdoor play and habits of improving outdoor play are associated with more outdoor play minutes per day (Remmers, Broeren, 2014). Parents being part of the dominant racial/ethnic group and parents who engage in numerous types of physical activities are also positively associated with their child's outdoor play (Carsley et al., 2016; Spurrier et al., 2008; Tandon et al., 2012). In contrast, having a working mother and higher educated parents have been negatively associated with outdoor play (Frech & Kimbro, 2011; Kimbro et al., 2011; Mota et al., 2017; Tandon et al., 2012). This highlights the impact, both positive and negative, that parents have on children's outdoor play. However, there are still some factors, such as socioeconomic status, household income, and marital status/cohabitation, that, to date, have not been associated with outdoor play (Gottfried & Le, 2017; Grigsby-Toussaint et al., 2011; Kimbro et al., 2011; Tandon et al., 2012; Vandewater et al., 2007). Further exploration into these variables, especially in preschool-aged children, is needed.

This thesis also considers microsystem correlates, both proximal physical and social environment factors, as home environment correlates. Armstrong et al. (2019) found that children's (2-5 years) outdoor play at home is positively associated with backyard features, including yard size, natural features, play areas, lawn quality, and different types of fixed and portable play equipment. Living in a detached home is positively related to outdoor play (Xu et al., 2017), while a child's number of siblings is negatively associated with outdoor play (Gottfried & Le, 2017). There are social environment factors such as peer support, peer and sibling modelling, dog/pet ownership, and time spent with parent(s) that are also positively related to children's outdoor play; however, the literature for these factors does not include children 3-5 years of age (Lee et al., 2021).

2.4.7 Childcare Correlates of Outdoor Play

Childcare environments have been shown to influence children's physical activity and sedentary behaviour levels with a higher rated environment (i.e., more outdoor play area, natural elements, vegetation) increasing children's steps and lowering sedentary behaviour (Boldemann et al., 2006; Gubbels et al., 2018). However, evidence on the impact of the childcare settings on children's outdoor play remains limited and inconclusive (Lee et al., 2021). Predy et al. (2020) found that the number of outdoor play areas (areas which present different play opportunities) that childcare centres have are significantly positively correlated with children's outdoor play duration and frequency. Hours spent in childcare are also positively correlated with outdoor play (Gottfried & Le, 2017; Predy et al., 2020). There is limited research on childcare correlates of outdoor play for 3-5-year-olds, as Lee et al. (2021) have only identified two articles that focus on this topic in this specific age group.

2.4.8 Neighbourhood Environment Correlates of Outdoor Play

The built environment and sociocultural environment collectively make up the neighbourhood environment. Neighbourhood features, including greenness and availability of learning centers, recreational, physical activity, and sports facilities, positively influence outdoor play (Gottfried & Le, 2017; Grigsby-Toussaint et al., 2011; Remmers, Van Kann et al., 2014). Having access to play spaces and open spaces also positively impacts children's outdoor play (Brown et al., 2009). Built environments, such as intersections, path obstructions, and the density of traffic crashes, have been found to be negatively correlated with children's outdoor play in older children (Lee et al., 2021). Similarly, Lee et al. (2021) found sociocultural factors such as social norms, child friendliness, and neighbourhood relationships to play positive roles in outdoor play as well, but again, these findings did not include preschool-aged children. Further research is needed, specifically for preschoolers, to improve our understanding of built environments that may be associated with outdoor play and sociocultural factors which may influence outdoor play opportunities.

2.4.9 Physical Ecology Correlates of Outdoor Play

Australian children (5-6 years) spend significantly more time outdoors during warmer (non-winter) months compared to cooler (winter) months (Cleland et al., 2008). On both weekdays and weekend days, children spend nearly double the amount of time outdoors in warmer months than in cooler months (Cleland et al., 2008). This is consistent for children when attending childcare throughout the week. Within the childcare/preschool setting, children spend 10% more time outdoors during warmer months (23% vs. 13%; Kos & Jerman, 2013), and approximately 60 minutes more outdoors in non-winter months compared to winter months (90-119 minutes vs. 45-59 minutes; Predy et al., 2020). According to Predy et al. (2020), during non-winter months, childcare centres were more likely to meet the best practice for outdoor play duration (≥ 90 minutes/day; 55.7% vs. 14.6%) and frequency (≥ 2 times/day; 20.2% vs. 3.4%) compared to winter months. Also, during warmer months, children spent almost double the hours each week outdoors on the playground and in nature while at preschool (Kos & Jerman, 2013). These findings suggest that seasonal variation may play an important role in children's outdoor play opportunities in the childcare and home settings. With only one of the studies previously cited having taken place in Western Canada and in the childcare setting, this thesis will further our current understanding of the seasonal variation of outdoor play in the home and neighbourhood setting in this geographical area.

2.5 Summary

There are many discrepancies and inconsistencies in the tools used to measure outdoor play and the protocols used to operate those tools. Examining both parent-reported and device-based measured outdoor play will address the current limitations on children's outdoor play measurements by minimizing the risk of missing or misclassifying outdoor play that may otherwise occur if only one measurement type is used (Lee et al., 2021). Additionally, exclusively examining preschool-aged children's outdoor play correlates will add to limited existing evidence that may help enhance outdoor play opportunities for this specific age group (Lee et al., 2021). This thesis will provide insight into outdoor play correlates across different socioecological levels, capturing multiple factors that may be associated with outdoor play compared to focusing on only one socioecological level.

While most of the literature on development in preschool-aged children examine associations with movement behaviours (i.e., physical activity, sedentary behaviour, sleep), outdoor play is gaining attention regarding healthy development (de Lannoy et al., 2023). Despite outdoor play being increasingly studied, there are important gaps in the literature that exists in relation to preschoolers' development. Specifically, further research is warranted to examine the associations between outdoor play and physical, cognitive, and social-emotional health indicators of developmental for preschool-aged children, as the known benefits for this age group remain limited and unclear (Barnett et al., 2019; Taylor & Kuo, 2006; Ulset et al., 2017).

Chapter 3: Manuscript 1

3.1 Abstract

Objectives

Examine the: (1) variability of parental-reported outdoor play (OP), (2) convergent validity of the parental-reported and device-based measure of OP, (3) correlates of parental-reported, and (4) device-based measured OP in preschoolers.

Methods

Data from the cross-sectional Parent-Child Movement Behaviours and Pre-School Children's Development project was used. Participants were 107 preschool-aged children (3-5 years) and parents from Edmonton, Canada, and surrounding areas. Children's OP was measured via parental questionnaire and the lux feature of ActiGraph accelerometers (n=98). Correlates from individual, parental, microsystem, institutional, and physical ecology levels of the socioecological model were measured. Paired sample t-tests (parent-report), Wilcoxon signed-rank test (device-based), and linear (parent-report) and logistic (device-based) regression analyses were conducted.

Results

Children had significantly higher mean OP times in summer/fall months (136.4±85.0 minutes/day) compared to winter months (51.4±32.1 minutes/day) and on weekend days (108.1 ±65.8 minutes/day) compared to weekdays (86.5±48.6 minutes/day). There was a significant difference in children's median parental-reported OP (120.0±109.3 minutes/day) compared to device-measured OP (5.77±30.0 minutes/day). In the final linear regression models, parental age (B=2.56;95%CI:0.24,4.89) was positively associated with children's parental-reported OP on weekend days and temperature (B=6.49;95%CI:4.44,8.55) was positively associated with

children's parental-reported OP in summer/fall months. In the final logistic regression model, higher temperature (OR=1.90;95%CI:1.27,2.82) was associated with a higher likelihood of children participating in ≥30 minutes/day of device-based measured OP, compared to <30 minutes/day.

Conclusions

Temperature was the most consistent correlate of OP in preschool-aged children. Implementing interventions to promote OP in all weather may help reverse the declining trend of children's OP.

3.2 Introduction

Outdoor play (OP) is thought to enhance overall development in children (Dankiw et al., 2020; Kuo & Taylor, 2004; Ulset et al., 2017). Given the numerous potential benefits of OP, it is concerning that over recent decades a decline in children's OP has been reported (Bassett et al., 2015). Identifying important correlates of OP can help inform interventions and public health initiatives to reverse this declining trend. Consequently, a position statement on active OP published in 2015 highlighted that future research is needed to better understand the barriers and facilitators that promote and enable children's OP opportunities (Tremblay et al., 2015). Since this position statement, two systematic reviews were conducted on the correlates of OP in children aged 3-12 years (Lee et al., 2021), and the determinants of outdoor time in children aged 0-17 years (Larouche et al., 2023). These reviews considered various levels of the socioecological framework (Bronfenbrenner, 1992), and highlighted several consistent correlates and determinants of OP and time at the individual (e.g., sex/gender, race/ethnicity), parental (e.g., parental support), microsystem (e.g., residence type), macrosystem (e.g., outdoor play spaces), and physical ecology (e.g., seasonality) levels (Lee et al., 2021; Larouche et al., 2023).

Despite the growing research on the correlates of OP in children, numerous gaps exist in the literature. For instance, there is limited evidence for OP correlates in preschool-aged children (3-5 years of age), with approximately 75% and 87% of the studies included in the reviews by Lee et al. (2021) and Larouche et al. (2023), respectively, including ages outside of this age range. Due to the rapid growth and developmental advancements from 3-5 years of age (Royal College of Physicians and Surgeons of Canada, 2014), preschool-aged children are an important group to target with health initiatives. Therefore, more evidence is needed to enhance OP opportunities for this specific age group. Additionally, further research is needed to examine multiple correlates, either at the same or different levels of the socioecological framework, to determine how to enhance opportunities for children's OP (Lee et al., 2021). For example, considering seasonality is a consistent correlate of OP in a northern climate, such as Canada, it is possible that the correlates of OP may differ in the summer and winter months (Lee et al., 2021). OP correlates may also differ by weekdays and weekend days, particularly if children receive care outside of their homes.

Another limitation regarding the correlates of children's OP is the lack of reliable and valid tools used to measure OP (Bates & Stones, 2015; Lee et al., 2021). Various methods and techniques are used to capture children's OP, including both subjective and device-based measures, with few studies comparing methodologies and no apparent standardized approach (Bates & Stone, 2015). Most studies use subjective measures (i.e., self-report, parental-report) with unknown psychometric properties (Lee et al., 2021). The use of device-based measures of OP, for example, via a light sensor (i.e., lux) feature of an accelerometer, is increasing, but it has unique limitations, including inaccurate readings due to clothing covering the sensor and misclassifying activities that cannot be easily identified (e.g., riding in a vehicle; Flynn et al., 2014). Therefore, measuring OP with both subjective and device-based measures may give a more balanced assessment of outdoor exposure. However, there is limited evidence of the correlates of device-based measured OP in preschoolers; 86% of studies with a preschool-aged sample (3-5 years of age) in the Lee et al. (2021) and Larouche et al. (2023) reviews, respectively, using subjective measures of OP.

This study addressed the noted gaps in the literature regarding correlates of OP in preschool-aged children. Specifically, the objectives were to determine (1) the variability of parental-reported OP when comparing summer/fall with winter months and weekday with weekend days, (2) the convergent validity of the questionnaire and device-based measure of OP, (3) the correlates of parental-reported OP in summer/fall months, winter months, weekdays, and weekend days, and (4) the correlates of device-based measured OP.

3.3 Methods

3.3.1 Participants and Procedures

Participants are preschool-aged children (3-5 years) and parents or guardians (parents hereafter) who were recruited from Edmonton, Alberta and surrounding areas as part of the Parent-Child Movement Behaviours and Pre-School Children's Development project. See Appendix 1 for further details on this original project. Participants were recruited through a local division of Sportball, a program designed to enhance children's sport, motor, and pro-social skills through play (Sportball, 2018). Ethics approval was obtained for the original project (Project #00081175) and the secondary data analysis of the present study (Project #00115737). In total, 131 parents agreed to participate and provided written informed consent.

Data collection for this cross-sectional study occurred from July to November, 2018. Children were provided with ActiGraph wGT3X-BT accelerometers (ActiGraph, Pensacola, FL) and were instructed to wear the device on their right hip for seven days and only to remove the device when engaged in water-based activities (e.g., bathing, swimming). Children were also given study protocol instructions and a log sheet for parents to track accelerometer wear time. After the 7-day wear period, the lead investigator visited the participants in their homes or at an alternative location to collect the accelerometers and administer the parental questionnaire. The questionnaire included OP time measures and child, parental, and household demographic measures. Further details have previously been described (Kuzik et al., 2020).

3.3.2 Measures

3.3.2.1 Outdoor Play

Children's OP and time spent outdoors were measured in this study; however, for consistency, 'outdoor play' will be the term used throughout the paper. OP was measured using a parental questionnaire and the lux feature of accelerometers. The questionnaire asked parents how much time (hours and minutes) their child would spend playing outdoors on a typical weekday and weekend day within the past month (summer/fall months) and during last January (winter months). These questions were adopted from previous research (Burdette et al., 2004), where they were found to be significantly correlated with another parental-reported measure of OP ($r=0.57$, $P<.001$) as well as accelerometer-measured physical activity ($r=0.20$, $P=.003$; Burdette et al., 2004). Minutes per day for total, summer/fall, winter, weekday, and weekday OP were calculated.

The ActiGraph wGT3X-BT accelerometer has a built-in ambient light sensor that quantifies light intensity, reported as lux, that has been used to distinguish between when the device is indoors and outdoors (Flynn et al., 2014). Participants were included if they had ≥10 hours/day of waking day wear time for ≥3 days. OP was defined as a lux value ≥240 (Flynn et al., 2014). Previous research using this threshold with preschool-aged children has demonstrated an accuracy of 88.9% in detecting outdoor activity (Flynn et al., 2014). Additionally, a series of reliability tests have found this sensor to have high inter-instrument reliability; specifically, a Cronbach's α of 1.00 was reported across different devices between outdoor conditions (Flynn et al., 2014). Children's average OP time across the week was reported as minutes per day. Since not all participants had a weekend accelerometer day (n=94), device-based weekday and weekend OP were not calculated separately.

3.3.2.2 Correlates

At the individual level, child's age was calculated based on the date they received the accelerometer and the date of birth reported in the questionnaire. Parents were asked to select their child's sex (male or female) and race/ethnicity. Thirteen response options were listed for race/ethnicity; however, because of the high prevalence of "Caucasian" responses and heterogeneity across the other response options, race/ethnicity was categorized as "Caucasian" or "other."

At the parental level, parent's age was calculated based on the date the child received the accelerometer and the date of birth listed on the consent form. Two parents had missing data for their age, so their age was imputed with the sample median. For parental education, parents chose between seven response options, ranging from "Less than high school diploma or its equivalent" to "University certificate, diploma, or degree above the bachelor's level ." Parents also reported their household income with ten response options ranging between "Less than $25,000" to "More than $200,000", including a "Do not know" option. All "Do not know" responses (n=3) were imputed with the sample median. Parents selected their marital status from six possible response options, but were then categorized as "Married" or "Not married" due to the high prevalence of "Married" responses and heterogeneity across the other response options. Parental marital status was included for descriptive information only due to low cell counts in some analyses.

At the microsystem level, number of siblings, house type, and yard size were considered. Parents indicated how many younger ("0" to "≥3") and older ("0" to "≥3") siblings their child has. Number of siblings was categorized as "0" and "≥1" total siblings. Parents also indicated what type of home they live in by choosing between ten response options, which were then classified as “one level” or “two levels.” To describe how big their yard is, parents were given five response options ranging between “No yard at all” to “A large yard (e.g., ¼ acre block or larger).”

At the institutional level, parents were asked how many hours per week their child typically spends in care other than their own.

At the physical ecology level, the mean daily temperature (i.e., the average of the maximum and minimum temperature during a day) was used as a surrogate for weather using data observed at the Edmonton International Airport (Government of Canada, 2022). An average mean daily temperature (°C) for parental-reported OP (summer/fall months) was calculated based on the past calendar month from the first day children wore the accelerometer. For device-based OP, mean temperature (°C) was calculated for the seven days children were asked to wear the accelerometers.

3.3.3 Statistical Analysis

The data were analyzed using STATA 17 software. Descriptive statistics were calculated to determine the duration and frequency of OP time and for demographic variables. Statistical assumptions for all tests were checked. Device-based OP was not normally distributed, and transformations did not improve the distribution. Therefore, nonparametric tests or logistic regression were used to address objectives that included this variable. Outliers were detected using the Median Absolute Deviation (MAD) method (Leys et al., 2013), and were handled using a Winsorization approach where outliers were transformed to the highest percentile (i.e., 90^{th}, 95^{th}, or 99^{th} percentile) that was below the determined outlier cut-off point (Leys et al., 2019). For objective 1, paired sample t-tests were used to examine the variability between the parental-reported OP in summer/fall vs. winter months and weekday vs. weekend days. For objective 2, Spearman's rank correlation coefficient was used to determine the relative convergent validity between the parental-reported and device-based measures of OP in the summer/fall months. As per Cohen (1992), effect sizes for the correlation coefficient were defined as small ($r \leq 0.29$), medium ($r=0.30-0.49$), and large ($r \geq 0.50$). In addition, a Wilcoxon signed-rank test was used to examine the absolute convergent validity between the parental-reported and device-based measured OP in the summer/fall months.

To address objective 3, simple and multiple linear regression models were conducted to examine associations between correlates and parental-reported OP. First, simple linear regression models were run separately between correlates at the individual, parental, microsystem, institutional, and physical ecology level, and parental-reported OP for season (summer/fall and winter months) and days of the week (weekdays and weekend days). A multiple linear regression model was run for variables that met a p-value <0.10 cut-off in the simple linear regression models.

To address objective 4, a series of simple and multiple logistic regression models were conducted to examine associations between correlates at the various levels of the socioecological framework and device-based measured OP. Device-based outdoor play was dichotomized as <30 minutes per day and ≥30 minutes per day based on frequency distributions. The 30-minute cut-off represented the 75^{th} percentile, denoting high OP time. A multiple logistic regression model was run with variables that met a p-value <0.10 cut-off in the simple logistic regression models. Statistical significance was set at $p < 0.05$ for all tests.

3.4 Results

A total of 107 participants had complete subjective-measured (parental-reported) data and were included in the analysis. Children were an average age of 4.5 years (±0.7 years), and were predominantly males (68.2%) and Caucasian (71.0%; see Table 1.1 for participant characteristics). Of 107 participants, 98 participants had complete device-based (accelerometer-measured) data. The average accelerometer wear time was 12.8 hours (±0.7 hours) per day for an average of 5.6 days (±2.0 days). The average daily temperature in summer/fall months was 7.0°C (±8.3°C) and -11°C (±7.8°C) in winter months (i.e., January).

Table 1.1 Participant Characterisitcs (n=107)

Variables:		Mean ± SD or n (%)
Child age (years)		4.5 ± 0.7
Sex	Male:	73 (68.2%)
	Female:	34 (31.8%)
Race/Ethnicity	Caucasian:	76 (71.0%)
	Other:	31 (29.0%)
Siblings	0	20 (18.7%)
	≥1:	87 (81.3%)
Parent age (years)		37.6 ± 5.4
Childcare (hours/week)		20.9 ± 17.2
Parent education	Below bachelor's degree:	23 (21.5%)
	Bachelor's degree (e.g., B.A., B.Sc., LL.B.):	50 (46.7%)
	Above bachelor's degree:	34 (31.8%)
Marital status	Married:	97 (90.7%)
	Not married:	10 (9.3%)
Household income	≤ $100,000:	11 (10.3%)
	$100,001 to $200,000:	69 (64.5%)
	> $200,000:	27 (25.2%)
House type	One level:	41 (38.3%)
	Two levels:	66 (61.7%)
Yard size	No yard at all, no private yard, or a small yard (e.g., unit or courtyard):	12 (11.2%)
	A medium yard (e.g., standard block of land):	73 (68.2%)
	A large yard (e.g., ¼ acre block or larger):	22 (20.6%)

Parental-reported OP durations for all time periods are presented in Figure 1.1. For parental-reported total OP (across summer/fall and winter months and weekdays and weekend days), children spent an average of 94.7 minutes (±54.7 minutes) per day. Children had significantly higher OP times in summer/fall months (136.4±85.0 minutes) compared to winter months (51.4±32.1 minutes) and on weekend days (108.1±65.8) compared to weekdays (86.5±48.6 minutes).

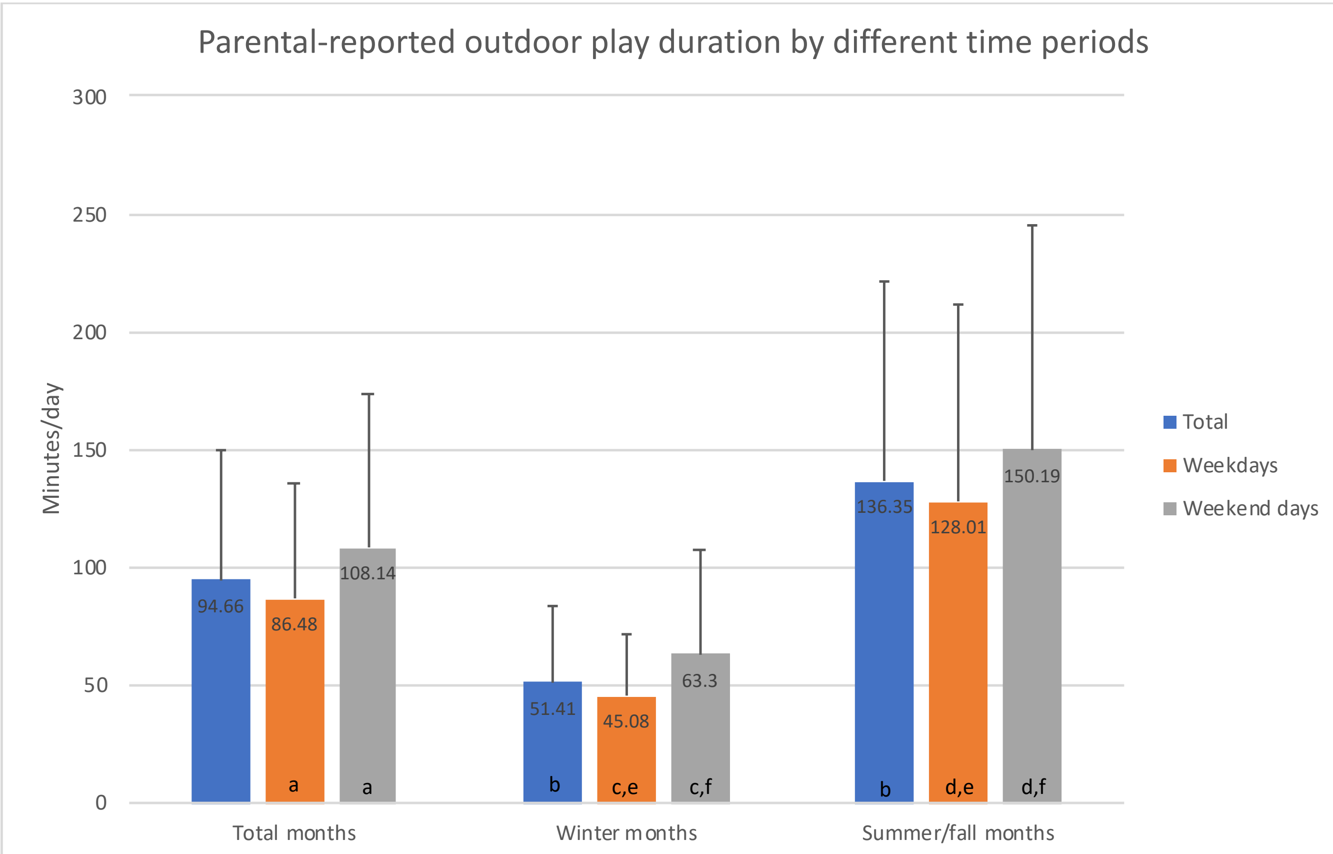

Figure 1.1 Parental-reported outdoor play duration by different time periods (n=107)

Footnote: [a, b, c, d, e, f] represent statistically significant differences (p-value <0.05) when performing paired t-test.

Convergent validity of the parental-reported and device-based measures of OP are presented in Table 2.1. For relative convergent validity, the device-based measure (r=0.44) was significantly correlated with the parental-reported measure, with a medium effect size (Cohen, 1992). For absolute convergent validity, there was a significant difference in children's parental-reported (120.0±109.3 minutes) and device-based (5.8±30.0 minutes) measured OP for total summer/fall months (including weekdays and weekend days).

Table 2.1 Correlation and differences between the parental-reported and device-based measures in summer/fall months (n=98)

Measures	Outdoor play duration (mins/day) Median (IQR)	Spearman rank correlation		Wilcoxon signed-rank test
		r	p-value	p-value
Parental-reported	**120.0 (109.29)***	-	-	-
Device-based	**5.77 (29.96)***	0.441	**<0.01***	**<0.01***

Footnote: **Bold font*** represents p-value <0.05.
IQR= Interquartile range

Simple linear regression models for correlates of parental-reported OP are presented in Table 3.1. Temperature (B=6.63; 95%CI:4.62,8.64) and hours spent in childcare (B=-0.81; 95%CI:-1.75,0.13) met the p<0.10 cut-off for OP in the summer/fall months. Parental age (B=2.56;95%CI:0.24,4.89) was significantly associated with OP on weekend days. Consequently, a multiple linear regression model was only run for OP in summer/fall months. Higher temperature (B=6.49;95%CI:4.44,8.55) remained significantly associated with more OP in the summer/fall months (Table 4.1).

Table 3.1 Simple linear regression models for correlates of parental-reported outdoor play by different time periods

Potential correlates		Total (min/day)	Seasonality		Time of week	
			Winter months (min/day)	Summer/fall months (min/day)	Weekdays (min/day)	Weekend days (min/day)
Individual level		B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)
Child age (years)		-8.82 (-24.15, 6.51)	-4.37 (-13.39, 4.65)	-11.69 (-35.57, 12.19)	-8.72 (-22.33, 4.89)	-3.60 (-22.16, 14.95)
Sex	Male:	Reference				
	Female:	11.54 (-10.97, 34.05)	9.67 (-3.48, 22.83)	14.59 (-20.47, 49.64)	15.08 (-4.82, 34.98)	5.63 (-21.58, 32.84)
Race/ethnicity	Caucasian:	Reference				
	Other:	-3.83 (-27.04, 19.37)	-2.56 (-16.19, 11.07)	-4.08 (-40.17, 32.01)	-4.05 (-24.68, 16.57)	-4.02 (-31.96, 23.92)
Parental level						
Parent age (years)		1.35 (-0.61, 3.30)	0.87 (-0.28, 2.01)	1.92 (-1.12, 4.97)	0.98 (-0.76, 2.72)	**2.56 (0.24, 4.89)****
Education[a]		-5.30 (-12.89, 2.28)	-3.87 (-8.30, 0.56)	-6.01 (-17.85, 5.83)	-3.63 (-10.40, 3.14)	-6.97 (-16.09, 2.14)
Household income[b]		-3.08 (-8.82, 2.65)	-1.49 (-4.87, 1.88)	-3.92 (-12.86, 5.01)	-2.24 (-7.35, 2.87)	-2.89 (-9.81, 4.03)
Microsystem level						
Siblings	0	-9.81 (-36.76, 17.14)	-8.90 (-24.68, 6.87)	-12.49 (-54.43, 29.45)	-5.57 (-29.56, 18.43)	-20.15 (-52.44, 12.14)
	≥1	Reference				
House type	One level:	1.57 (-20.09, 23.23)	-0.94 (-13.66, 11.79)	5.60 (-28.06, 39.27)	-0.60 (-19.86, 18.65)	8.69 (-17.33, 34.72)
	Two levels:	Reference				
Yard size[c]		0.96 (-12.99, 14.92)	-2.01 (-10.20, 6.18)	3.73 (-17.96, 25.42)	-1.38 (-13.79, 11.02)	3.72 (-13.06, 20.51)
Institutional level						
Hours spent in child care		-0.44 (-1.05, 0.17)	-0.04 (-0.40, 0.32)	**-0.81 (-1.75, 0.13)***	-0.48 (-1.02, 0.06)	-0.42 (-1.15, 0.31)
Physical ecology						
Temperature				**6.63 (4.62, 8.64)****		

Footnote: ****p-value <0.05; *p<0.10**
B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day
[a]Parental education is ordinal with values from 1 to 7 representing less than a high school diploma or its equivalent to university certificate, diploma, or degree above the bachelor's level.
[b]Household income is ordinal with values from 1 to 9 representing <$25,000 to >$200,000.
[c]Yard size is ordinal with values from 1 to 5 representing no yard to large yard.

Table 4.1 Multiple linear regression model for correlates of parental-reported outdoor play in summer/fall months

Potential correlates	Summer/fall months (min/day)
Institutional level	B (95% CI)
Hours spent in child care	-0.28 (-1.07, 0.51)
Physical ecology	
Temperature	**6.49 (4.44, 8.55)***
Footnote: ***p-value <0.05** B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day	

Correlates of device-based measured OP are presented in Table 5.1. Temperature (OR=1.90;95%CI:1.27,2.82) and parental age (OR=1.13;95%CI:1.02,1.24) both met the p<0.10 cut-off. In the multiple regression model, only temperature remained significantly associated with children's OP. Specifically, higher temperature (OR=1.90;95%CI:1.27,2.82) was associated with a higher likelihood of children participating in ≥30 minutes of OP compared to <30 minutes.

Table 5.1 Simple and multiple logistic regression models for correlates of device-based measured outdoor play

Potential correlates		Outdoor play duration (≥ 30 min/day)	
		OR (95% CI)	Final OR (95% CI)
Individual level			
Child age (years)		1.62 (0.82, 3.19)	-
Sex	Male	Reference	-
	Female	1.77 (0.68, 4.57)	-
Race/Ethnicity	Caucasian:	Reference	-
	Other:	1.60 (0.61, 4.22)	-
Parental level			
Parent age (years)		**1.13 (1.02, 1.24)****	1.05 (0.91, 1.22)
Education[a]		0.88 (0.64, 1.22)	-
Household income[b]		1.05 (0.82, 1.35)	-
Microsystem level			
Siblings	0	0.34 (0.07, 1.59)	-
	≥1	Reference	-

House type	One level:	1.01 (0.40, 2.56)	-
	Two levels:	Reference	-
Yard size[c]		1.00 (0.55, 1.80)	-
Institutional level			
Hours per week spent in childcare		0.99 (0.96, 1.01)	-
Physical ecology			
Temperature		**1.89 (1.28, 2.78)****	**1.90 (1.27, 2.82)****

Footnote: ****p-value <0.05** and ***p-value <0.10**
OR= odds ratio; 95% CI= 95% confidence interval; min/day= minutes per day
[a]Parental education is ordinal with values from 1 to 7 representing less than a high school diploma or its equivalent to university certificate, diploma, or degree above the bachelor's level.
[b]Household income is ordinal with values from 1 to 9 representing <$25,000 to >$200,000.
[c]Yard size is ordinal with values from 1 to 5 representing no yard to large yard.

3.5 Discussion

This study examined the variability of parental-reported OP during different time periods (i.e., summer/fall and winter months and weekday and weekend days), the convergent validity of parental-reported and device-based measures of OP, and the correlates of OP. Overall, parental-reported OP was higher in summer/fall months compared to winter months and weekend days compared to weekdays. The device-based measure of OP was significantly correlated with the parental-reported measure. However, the parental-reported estimates of OP were significantly higher than the device-based estimates. In terms of correlates, parental age was associated with more parental-reported OP on weekend days, while a higher temperature was significantly associated with more OP for both parental-reported and device-based measured outdoor play. All other variables across various levels of the socioecological framework were not significantly associated with OP.

Findings from this study regarding variability in OP are consistent with a previous study in 5-6-year-old children. Specifically, Cleland et al. (2008) found that Australian children spend significantly more time outdoors during warmer (non-winter) months compared to cooler (winter) months on both weekdays and weekend days. Interestingly, these patterns were consistent despite the differences in climate between Australia and Canada. Within the childcare/preschool setting, children have been found to spend 10% more time outdoors during warmer months in Slovenia (Kos & Jerman, 2013), and approximately 60 minutes more outdoors in non-winter months compared to winter months (90-119 minutes vs. 45-59 minutes) in Alberta, Canada (Predy et al., 2020). In Edmonton, Canada, the average January temperature is approximately -10.5°C but can reach extremes as low as -42°C (Government of Canada, 2022); therefore, sometimes time spent outside needs to be limited due to safety reasons. Additionally, unfavourable weather conditions and shorter days during colder months likely contribute to lower outdoor activity levels and engagement (Tucker & Gilliland, 2007).

This was the first Canadian study to examine day-of-the-week differences in OP in preschool-aged children. In other countries, previous studies support the findings of the present study that preschoolers tend to have more OP per day on weekend days compared to weekdays (Berglind & Tynelius, 2018; Wiseman et al., 2019). It could be that OP is higher on weekend days due to parents having more free time and being able to engage in OP with their child compared to throughout the week. Additionally, OP that occurs during the week while at childcare could be difficult for parents to accurately report on, which could result in the underreporting of weekday OP.

To our knowledge, this is the first study examining the convergent validity between parental-reported (i.e., subjective measure) and device-based (i.e., objective measure) measures of preschool-aged children's OP. Findings suggest that parents may be able to identify if their child had a lot or little amount of OP, but meaningful differences were observed between parental-reported and device-based estimates. It is important to note that the device-based estimates of OP may also be underestimated, particularly for children who participated in the fall months when heavier jackets are typically worn. Flynn et al. (2014) note that if an ActiGraph GT3X accelerometer is worn outdoors under a winter jacket, the lux readings are decreased by 100%. Lux readings were also found to be reduced under t-shirts (white:40%, black:61%) and sweatshirts (dark:90%; Flynn et al., 2014). The instructions in the logbook given to parents indicated that accelerometers were to be worn over clothing; however, given OP was not the main focus of the original study, this was not explained further unless asked by the parents. Future studies using a similar approach to capture OP time via accelerometers should outline clear guidelines to their participants so the device is not covered by clothes and jackets in order to accurately capture their time spent outdoors.

In terms of correlates, the results from the present study show temperature and parental age to be significant correlates for preschoolers' OP. Temperature, or seasonal variation, was also noted as a correlate for preschool-aged children's OP in a recent systematic review (Lee et al., 2021). Lee and colleagues (2021) highlighted that temperature was positively associated with more OP in this age group (Carsley et al., 2016; Kimbro et al., 2011; Kos & Jerman, 2013; Predy et al., 2020). No studies in preschool-aged children were included in the Larouche et al. (2023) review that examined the correlate temperature. However, one study from Larouche et al.'s (2023) review noted that over time children 1-5 years old from older fathers had an increase in outdoor time (Li et al., 2022). Parental age was not found to have any association with preschoolers' OP in Lee et al.'s (2021) review, where only one study examined the association between parental age and OP in preschool-aged children (Wiseman et al., 2019). Hence, further studies are needed to confirm our findings. There were several non-significant associations observed in the present study that were previously found to have a positive (i.e., children being part of a dominant racial/ethnic group; more educated parents; living in a detached home; hours spent in childcare) or negative (i.e., having female sex; higher educated parents; number of siblings) association with preschoolers' OP in one of the previous reviews (Lee et al., 2021; Lorouche et al., 2023). The small sample used in the present study, which included predominantly Caucasian and male children, may be one explanation for why associations were not observed.

A strength of this study is the inclusion of correlates across various levels of the socioecological framework. While only correlates at the parental and physical ecology levels were found to have significant associations with OP, it is important to examine correlates across socioecological framework levels to consider the myriad of factors which may influence OP. Another strength of the present study is the inclusion of both subjective and objective measures of outdoor play/time. While each measurement type may have inherent limitations, this study provides valuable information where limited studies have looked at correlates in children's OP using both measurement types. A limitation of this study is the use of convenience sampling through the Sportball program. The small sample used in this study may not be representative of preschool-aged children in Alberta. For instance, based on household income, the sample was predominantly of higher socioeconomic status. Additionally, due to the distribution of device-based outdoor time, the variable was dichotomized, resulting in a loss of statistical power. Finally, the cross-sectional design limits our ability to determine causation between the correlates examined and preschoolers' OP.

3.6 Conclusion

Overall, the findings from this study suggest that OP is higher during warmer temperatures (i.e., weather) and warmer seasons. Therefore, interventions to promote OP in preschool-aged children should consider all weather conditions and target colder seasons. Additionally, a better understanding of modifiable factors that influence preschoolers' OP will help guide future interventions to enhance outdoor play opportunities. Given the limited evidence in this age group, it would be beneficial for further studies to explore OP correlates exclusively for preschool-aged children. In particular, more research is needed on the role of parental age. Further research is also needed to determine the best method to measure preschool-aged children's OP, whether it be subjectively, objectively, or a combination of the two.

3.7 References

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Chapter 4: Manuscript 2

4.1 Abstract

Purpose: Examine: (1) the associations between parental-reported and device-measured outdoor play (OP) and health indicators of physical, cognitive, and social-emotional development, and (2) if associations were independent of outdoor moderate- to vigorous-intensity physical activity (MVPA).

Methods: This cross-sectional study includes 107 participants. Children's OP was measured via a parental questionnaire and the lux feature of ActiGraph wGT3X-BT accelerometers. Children's growth, adiposity, and motor skills were assessed as physical development indicators. Visual-spatial working memory, response inhibition, and expressive language were assessed as cognitive development indicators. Sociability, prosocial behaviour, internalizing, externalizing, and self-regulation were assessed as social-emotional development indicators. Linear and logistic regressions were conducted that adjusted for relevant covariates. Additional models further adjusted for accelerometer-derived outdoor MVPA.

Results: Parental-reported total OP, OP in summer/fall months, and OP on weekdays were negatively associated (small effect sizes) with response inhibition and working memory. However, after adjusting for outdoor MVPA, these associations were no longer statistically significant. Additionally, OP on weekdays was negatively associated with externalizing (B=-0.04;95%CI:-0.08,-0.00) after adjusting for outdoor MVPA. A similar pattern was observed for device-based measured total OP (B=-0.49;95%CI:-1.05,0.07; p=0.09).

Conclusions: Future research should take into account MVPA and contextual factors when examining the association between OP and health-related indicators.

4.2 Introduction

Outdoor play (OP), which can be defined as "a form of play that takes place outdoors" (Lee et al., 2022), provides children with ample opportunities to experience various types of physical movement (Davies, 1996). Oftentimes children are more physically active when outdoors compared to indoors (Tremblay et al., 2015). In early childhood (≤ 5 years), a key period of development, sufficient levels of physical activity supports healthy overall development (Carson, Lee et al., 2017; Kuzik et al., 2017). Though it is well documented that OP is positively associated with physical activity, the benefits of OP independent of physical activity remain unclear (Barnett et al., 2019; Gray et al., 2015; de Lannoy et al., 2023). This is particularly true for moderate-to-vigorous physical activity (MVPA), which is the intensity of physical activity associated with the largest health benefits (Carson, Lee et al., 2017). Evidence regarding the unique development benefits of OP is particularly lacking in early childhood, including preschool-aged children (3-5 years; Barnett et al., 2019; Gray et al., 2015; de Lannoy et al., 2023). For instance, in a systematic review, only one study was included that examined the association between outdoor time and indicators of physical development (Gray et al., 2015). No association was observed between outdoor time and motor development among preschool-aged children in this study (Sääkslahti et al., 1999).

There is currently a wide variety of measures being used to assess children's OP, and a consensus on measurement and standardization of measurement tools has been called for (de Lannoy et al., 2023). Using both objective and subjective measures of children's OP when examining the associations with health indicators can provide a more comprehensive assessment. Therefore, the primary objective of this study was to examine the associations between parental-reported and device-based measured OP and health indicators of physical, cognitive, and social-emotional development. The secondary objective was to examine if associations were independent of outdoor MVPA.

4.3 Methods

4.3.1 Participants and Procedures

Data from the Parent-Child Movement Behaviours and Pre-School Children's Development project were used for this study. See Appendix 1 for further details on the original project. Participants were 3-5-year-old children, and their parents or guardians (parents hereafter) who were recruited from Edmonton, Alberta, and surrounding areas through a local division of Sportball (Sportball, 2018). English was the primary language spoken at home for eligible families. In total, 131 parents agreed to participate and provided written informed consent. Data collection for this cross-sectional study occurred from July to November, 2018. Children had a gross motor development assessment at the University of Alberta; thereafter, children were provided with ActiGraph wGT3X-BT accelerometers (ActiGraph, Pensacola, FL), study protocol instructions, and a log sheet for parents to track accelerometer wear time. The children were instructed to wear the accelerometers for seven days, and were told to only remove the device during water-based activities (e.g., bathing, swimming). Following the 7-day wear period, the lead investigator administered the parental questionnaire, which included demographic and social-emotional measures, and the cognitive development tasks. Further details on participants and procedures have been previously published (Kuzik et al., 2020). Ethics approval was obtained from the University of Alberta Research Ethics Board 2 for the secondary data analyses of the present study (Project # 00115737). Written informed consent was obtained from parents in the original study (Project # 00081175).

4.3.2 Measures

4.3.2.1 Outdoor Play

This study measured children's OP and time spent outdoors; however, the term 'outdoor play' will be used throughout the paper for consistency. OP was measured using a parental questionnaire and the lux feature of ActiGraph wGT3X-BT accelerometers. The questionnaire asked parents to indicate how much time (hours and minutes) their child spent playing outdoors on a typical weekday and weekend day within the past month (summer/fall months) and during last January (winter months). These questions were adopted from previous research (Burdette et al., 2004), where they were found to be significantly correlated with another parental-reported measure of OP ($r=0.57$, $P<.001$) and accelerometer-measured physical activity ($r=0.20$, $P=.003$; Burdette et al., 2004). Minutes per day of total (average across the day of week and season), weekday (average across seasons), weekend (average across seasons), summer/fall (average across days of the week), and winter (average across days of the week) OP were calculated.

The ActiGraph wGT3X-BT accelerometer features an ambient light sensor that can detect and quantify light intensity, which is reported as a lux value (Flynn et al., 2014). Participants were included if they had ≥3 valid wear days (i.e., ≥10 hours/day of waking day wear time).The present study used the lux value to distinguish when children were indoors and outdoors. OP was defined as a lux value ≥240 (Flynn et al., 2014). This threshold was previously used with preschool-aged children with a demonstrated accuracy of 88.9% in detecting outdoor activity (Flynn et al., 2014). Additionally, in terms of inter-instrument reliability, a Cronbach's α of 1.00 was observed across different devices between outdoor conditions (Flynn et al., 2014). Minutes per day of children's average OP time across the week were calculated. Some participants were missing a weekend accelerometer day (n=94 had at least one weekend day); as a result, weekday and weekend OP was not calculated separately for the device-based measure.

4.3.2.2 Physical Development

This study includes three health indicators of physical development, including adiposity, growth, and motor skills, as described by Kuzik et al. (2020). Children's measured height and weight were used to calculate BMI as a surrogate for adiposity, and body mass index (BMI) z-scores were calculated based on World Health Organization growth standards (World Health Organization Multicentre Growth Reference Study Group, 2006). For growth, sex-specific formulas were used to calculate each child's percent of expected adult height based on their height and the average of their biological mother's and father's height (Luo et al., 1998). A higher BMI z-score indicated higher adiposity, and a higher growth score indicated higher achievement of height potential. See Appendix 1 for further details on the development measures.

Motor skills were measured using the Test of Gross Motor Development—2nd Edition (Ulrich, 2000). This assessment tool includes six object motor skills (e.g., kicking, catching, throwing), six locomotor skills (e.g., running, hopping, sliding), and total motor skills (summation of object and locomotor skills). The children's object motor skill score and locomotor skill score, both out of a maximum 48 points, were calculated by summing the components across each skill. A total motor skill development score was calculated by summing the object motor and locomotor skills scores. Higher scores indicate more advanced motor skills. The TGMD-2 has established construct validity and reliability (Griffiths et al., 2018). When children had missing data (n=8), subscale averages were calculated without the missing values.

4.3.2.3 Cognitive Development

This study includes three health indicators of cognitive development, including visual-spatial working memory, response inhibition, and expressive language (Kuzik et al., 2020). These health indicators were measured using specific tasks from the iPad-based Early Years Toolbox (Case, 1985; Howard & Melhuish, 2017; Howard & Okely, 2015; Morra, 1994; Wiebe et al., 2012). Specifically, the Mr. Ant task was used to assess visual-spatial working memory, the Go/No-Go task was used to assess response inhibition, and the Expressive Vocabulary task was used to assess language development. For the Mr. Ant task, values closer to 8 indicate more advanced visual-spatial working memory; values closer to 1 in the Go/No-Go task represent more advanced response inhibition; and for the Expressive Vocabulary task, values closer to 45 indicate more advanced language development. Each iPad task has built-in instructions for administrating the task, and the trained lead researcher was present to provide further clarification or instructions if needed. Specific details for these tasks have previously been described (Kuzik et al., 2020). Validity and reliability have previously been reported for the Early Years Toolbox (Howard & Melhuish, 2017). In this sample, internal consistency for go trials (α= 0.90), no-go trials (α= 0.78), and expressive vocabulary (α= 0.90) have also been previously reported (Kuzik et al., 2020). When children had missing data (n=7), subscale averages were calculated without the missing values.

4.3.2.4 Social-Emotional Development

This study includes five health indicators of social-emotional development, including sociability and prosocial behaviour, internalizing, externalizing, and self-regulation (Kuzik et al., 2020). All social-emotional development indicators were assessed using the Early Years Toolbox Child Self-Regulation and Behaviour Questionnaire (CSBQ; Howard & Melhuish, 2017).

Parents were asked to complete the paper-based questionnaire, which included 34 items with response options ranging from 1 (not true) to 5 (certainly true). The subscales were calculated by averaging the scores across items, and reverse scoring some of the items. With the subscales ranging from 1 to 5, values closer to 1 are more favourable for internalizing and externalizing, and score values closer to 5 are more favourable for self-regulation, sociability, and prosocial behaviour. Validity and reliability have previously been reported for this questionnaire (Howard & Melhuish, 2017). In this sample, internal consistency for most subscales (α= 0.75-0.82) was >0.7, except for prosocial behaviour (α= 0.64) and internalizing (α= 0.55; Kuzik et al., 2020).

4.3.2.5 Covariates

Covariates were selected based on previous movement behaviour and development research in preschool-aged children (Carson, Hesketh, et al., 2017; Carson & Kuzik, 2017; Kuzik et al., 2020). Covariates included children's age, sex, race/ethnicity, number of siblings, and hours/week spent in childcare, as well as parental age, education and marital status, and household income, house type, and yard size. The covariates were collected via the parental questionnaire and consent forms. "Do not know" responses (n=3) for household income were imputed with the sample median. Parental age was the only covariate with missing data (n=2). Missing data for this variable was imputed with the sample median. Further details on the covariates have been previously published (Kuzik et al., 2020). To address the secondary study objective, outdoor MVPA was also considered as a covariate. Accelerometry-measured MVPA was categorized as ≥420 counts/15 seconds and, outdoor MVPA was based on a lux value ≥240 (Flynn et al., 2014; Pate et al., 2006).

4.3.3 Statistical Analysis

The data were analyzed using STATA 17 software. Descriptive statistics were calculated for all outcome variables. Statistical assumptions for all tests were checked, and device-based OP and internalizing (i.e., social-emotional development indicator) were not normally distributed. Transformations did not improve either distribution, so categorical variables were created. OP was dichotomized using the 75th percentile (i.e., ≥ 30 minutes) to differentiate high OP from lower OP. Internalizing was dichotomized at the median value (i.e., > 1.2 [60.8%]), consistent with previous research (Kuzik et al., 2022). The Median Absolute Deviation (MAD) method was used to detect outliers for continuous variables (Leys et al., 2013). Outliers were handled using a Winsorization approach (Leys et al., 2019).

To address the primary study objective, linear and logistic regressions were used to examine the associations between parental-reported and device-based measured OP and each health indicator. The models were adjusted for relevant covariates that have previously demonstrated significant associations with each health indicator (Kuzik et al., 2020). Parental-reported OP models were run by seasonality (i.e., summer/fall and winter months) and time of the week (i.e., weekdays and weekend days). To address the secondary study objective, outdoor MVPA was added into all models. Parental-reported OP was presented as 10 mins/day in all models for more meaningful interpretations of the beta coefficients. Statistical significance was set at $p < 0.05$ for all tests.

4.4 Results

A total of 107 participants had complete parental-reported OP data and were included in the analysis. Out of 107 participants, 98 had completed device-based measured OP. Participant descriptive characteristics, including OP durations for both measurement types, have been previously presented (Davenport et al., 2023 [under review]). Descriptive statistics for each development domain, and their applicable subcategories, are presented in Table 1.2.

Table 1.2 Outcome variables descriptive statistics

Domain	**Outcome variables**	**Mean ± SD or Median (IQR)***
Physical development	Locomotor Skills (n=105)	27.50 ± 9.05
	Object Motor Skills (n=104)	22.70 ± 7.10
	Total Motor Skills (n=104)	50.43 ± 13.72
	BMI z-scores (n=107)	0.22 ± 0.83
	Expected Adult Height (%) (n=107)	60.57 ± 3.80
Cognitive development	Response Inhibition (n=103)	0.63 ± 0.22
	Working Memory (n=105)	1.85 ± 0.86
	Vocabulary (n=106)	30.94 ± 6.96
Social-Emotional development	Behavioural Self-Regulation (n=107)	3.87 ± 0.66
	Cognitive Self-Regulation (n=107)	3.67 ± 0.61
	Emotional Self-Regulation (n=107)	3.43 ± 0.79
	Internalizing (n=107)*	1.20 (0.60)
	Externalizing (n=107)	2.12 ± 0.75
	Sociability (n=107)	4.00 ± 0.63
	Prosocial Behaviour (n=107)	3.97 ± 0.56
Footnote: * represents Median (IQR) reported due to non-normal distribution. IQR= interquartile range		

There were no significant associations between device-based measured OP and health indicators in the linear and logistic regression models (see Table 2.2). Similarly, no significant associations were observed when outdoor MVPA was added to the model (see Table 3.2). However, the association between OP and externalizing approached significance (B=-0.49; 95%CI: -1.05, 0.07; p=0.09).

Table 2.2 Multiple linear and logistic regression models of outcome variables and device-based measured outdoor play

Domain	**Outcome Variable**	**Outdoor play duration (≥ 30 min/day vs. <30 min/day)**

		B (95% CI)	p-value
Linear Regression			
Physical Development	Locomotor Skills	-2.11 (-5.81, 1.59)	0.26
	Object Motor Skills	1.60 (-1.45, 4.65)	0.30
	Total Motor Skills	-0.51 (-6.19, 5.17)	0.86
	BMI z-scores	0.26 (-0.11, 0.62)	0.16
	Expected Adult Height (%)	0.01 (-0.00, 0.02)	0.06
Cognitive Development	Response Inhibition	-0.00 (-0.09, 0.09)	0.97
	Working Memory	-0.27 (-0.62, 0.07)	0.12
	Vocabulary	-0.45 (-3.00, 2.09)	0.72
Social-Emotional Development	Behavioural Self-Regulation	0.60 (-0.25, 0.37)	0.70
	Cognitive Self-Regulation	-0.08 (-0.37, 0.21)	0.58
	Emotional Self-Regulation	0.09 (-0.29, 0.46)	0.64
	Externalizing	-0.11 (-0.46, 0.25)	0.56
	Sociability	0.17 (-0.10, 0.44)	0.21
	Prosocial Behaviour	0.00 (-0.25, 0.26)	0.98
Logistic Regression		OR (95% CI)	p-value
Social-Emotional Development	Internalizing	1.14 (0.44, 2.93)	0.78

Footnote: B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day; OR= odds ratio
covariates used: child's age (locomotor skills, object motor skills, total motor skills, percent of expected adult height, response inhibition, working memory, expressive vocabulary), child's sex (percent of expected adult height, response inhibition, prosocial behaviour), race/ethnicity (internalizing), parent's age (percent of expected adult height, expressive vocabulary, cognitive self-regulation), marital status (expressive vocabulary), household income (percent of expected adult height), number of siblings (emotional self-regulation, prosocial behaviour), house type (body mass index), and yard size (sociability, prosocial behaviour).

Table 3.2 Multiple linear and logistic regression models of outcome variables and device-based measured outdoor play, adjusting for outdoor MVPA

Domain	**Outcome Variable**	**Outdoor play duration (≥ 30 min/day vs. <30 min/day)**	
		B (95% CI)	p-value
Linear Regression			
Physical Development	Locomotor Skills	-3.41 (-9.30, 4.01)	0.25
	Object Motor Skills	-0.81 (-5.64, 4.01)	0.74
	Total Motor Skills	-4.23 (-13.24, 4.78)	0.35
	BMI z-scores	0.070 (-0.51, 0.65)	0.81

	Expected Adult Height (%)	0.011 (-0.00, 0.03)	0.17
Cognitive Development	Response Inhibition	0.083 (-0.06, 0.23)	0.25
	Working Memory	-0.13 (-0.68, 0.43)	0.65
	Vocabulary	-0.39 (-4.36, 3.57)	0.84
Social-Emotional Development	Behavioural Self-Regulation	0.18 (-0.31, 0.68)	0.46
	Cognitive Self-Regulation	-0.17 (-0.62, 0.28)	0.46
	Emotional Self-Regulation	0.42 (-0.17, 1.01)	0.16
	Externalizing	-0.49 (-1.05, 0.07)	0.09
	Sociability	0.038 (-0.40, 0.47)	0.86
	Prosocial Behaviour	0.16 (-0.24, 0.56)	0.43
Logistic Regression		OR (95% CI)	p-value
Social-Emotional Development	Internalizing	0.66 (0.15, 3.02)	0.59

Footnote: B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day; OR= odds ratio
covariates used: child's age (locomotor skills, object motor skills, total motor skills, percent of expected adult height, response inhibition, working memory, expressive vocabulary), child's sex (percent of expected adult height, response inhibition, prosocial behaviour), race/ethnicity (internalizing), parent's age (percent of expected adult height, expressive vocabulary, cognitive self-regulation), marital status (expressive vocabulary), household income (percent of expected adult height), number of siblings (emotional self-regulation, prosocial behaviour), house type (body mass index), and yard size (sociability, prosocial behaviour).

With linear regression models of parental-reported OP (see Table 4.2), response inhibition and working memory (i.e., cognitive development) were negatively associated with total OP (B= -0.01; 95% CI: -0.02, -0.00; B= -0.03; 95% CI: -0.06, -0.01, respectively) and OP in summer/fall month (B= -0.01; 95% CI: -0.01, -0.00; B= -0.02; 95% CI: -0.04, -0.01, respectively) and on weekdays (B= -0.01; 95% CI: -0.02, -0.00; B= -0.04; 95% CI: -0.07, -0.01, respectively). There were no significant associations between internalizing and parental-reported OP in the logistic regression models (see Table 4.2). When adjusting for outdoor MVPA (see Table 5.2), externalizing (i.e., social-emotional development) was negatively associated with OP on weekdays (B= -0.04; 95% CI: -0.08, -0.00). Additionally, significant negative associations between parental-reported OP and response inhibition and working memory were no longer observed. However, the association between summer/fall OP (B=-0.01; 95% CI:-0.01, 0.00;

p=0.09) and weekday OP (B=-0.01; 95% CI:-0.02, 0.00; p=0.07) and response inhibition approached significance.

Table 4.2 Multiple linear and logistic regression models of outcome variables and parental-reported outdoor play by different time periods

Domain	Outcome Variable	Total (10 min/day)		Seasonality				Time of week			
				Winter months (10 min/day)		Summer/fall months (10 min/day)		Weekdays (10 min/day)		Weekend days 10 min/day)	
		B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value
Linear Regression											
Physical Development	Locomotor Skills	-0.13 (-0.42, 0.16)	0.37	0.09 (-0.39, 0.58)	0.71	-0.11 (-0.30, 0.07)	0.23	-0.12 (-0.45, 0.20)	0.45	-0.08 (-0.32, 0.17)	0.54
	Object Motor Skills	0.14 (-0.10, 0.38)	0.25	0.32 (-0.08, 0.73)	0.11	0.08 (-0.07, 0.24)	0.30	0.14 (-0.13, 0.41)	0.30	0.16 (-0.04, 0.36)	0.12
	Total Motor Skills	0.00 (-0.44, 0.44)	0.99	0.49 (-0.24, 1.23)	0.19	-0.05 (-0.34, 0.24)	0.73	0.01 (-0.48, 0.50)	0.96	0.07 (-0.30, 0.44)	0.70
	BMI z-scores	0.02 (-0.01, 0.05)	0.26	0.00 (-0.05, 0.05)	0.93	0.01 (-0.01, 0.03)	0.17	0.02 (-0.01, 0.06)	0.16	0.01 (-0.01, 0.04)	0.32
	Expected Adult Height (%)	0.00 (-0.00, 0.00)	0.49	0.00 (-0.00, 0.00)	0.19	0.00 (-0.00, 0.00)	0.56	0.00 (-0.00, 0.00)	0.49	0.00 (-0.00, 0.00)	0.21
Cognitive Development	Response Inhibition	**-0.01 (-0.02, -0.00)****	**0.01****	-0.00 (-0.02, 0.01)	0.63	**-0.01 (-0.01, -0.00)****	**0.01****	**-0.01 (-0.02, -0.00)****	**0.01****	-0.01 (-0.01, 0.00)	0.08
	Working Memory	**-0.03 (-0.06, -0.01)****	**0.01****	-0.03 (-0.08, 0.01)	0.18	**-0.02 (-0.04, -0.01)****	**0.01****	**-0.04 (-0.07, -0.01)****	**0.01****	-0.02 (-0.04, 0.00)	0.07
	Vocabulary	-0.10 (-0.29, 0.09)	0.29	-0.11 (-0.44, 0.22)	0.50	-0.07 (-0.19, 0.05)	0.24	-0.09 (-0.31, 0.12)	0.39	-0.13 (-0.29, 0.03)	0.10
Social-Emotional Development	Behavioural Self-Regulation	-0.00 (-0.03, 0.02)	0.86	0.00 (-0.04, 0.04)	0.84	-0.00 (-0.02, 0.01)	0.73	0.00 (-0.03, 0.03)	0.90	-0.01 (-0.03, 0.01)	0.43
	Cognitive Self-Regulation	0.01 (-0.01, 0.03)	0.43	0.01 (-0.02, 0.05)	0.49	0.01 (-0.01, 0.02)	0.45	0.01 (-0.01, 0.04)	0.30	0.00 (-0.02, 0.02)	0.88
	Emotional Self-Regulation	0.02 (-0.01, 0.05)	0.22	0.04 (-0.01, 0.09)	0.10	0.01 (-0.01, 0.03)	0.34	0.02 (-0.01, 0.05)	0.18	0.01 (-0.01, 0.03)	0.43
	Externalizing	-0.02 (-0.05, 0.01)	0.17	-0.04 (-0.09, 0.00)	0.06	-0.01 (-0.03, 0.01)	0.33	-0.03 (-0.06, 0.00)	0.07	-0.00 (-0.03, 0.02)	0.72
	Sociability	0.01 (-0.01, 0.03)	0.29	0.01 (-0.03, 0.05)	0.52	0.01 (-0.01, 0.02)	0.24	0.01 (-0.01, 0.04)	0.32	0.01 (-0.01, 0.03)	0.19
	Prosocial Behaviour	0.00 (-0.02, 0.02)	0.64	0.01 (-0.03, 0.04)	0.69	0.00 (-0.01, 0.02)	0.70	0.01 (-0.02, 0.03)	0.60	0.00 (-0.01, 0.02)	0.74
Logistic Regression		OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value
Social-Emotional Development	Internalizing	0.99 (0.93, 1.07)	0.89	0.98 (0.87, 1.11)	0.77	1.00 (0.95, 1.04)	0.91	1.00 (0.92, 1.08)	0.92	0.98 (0.92, 1.04)	0.49

Footnote: ****p-value <0.05.** B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day; OR= odds ratio
Results represent the effect of each additional 10 mins/day of outdoor play.
Covariates used: child's age (locomotor skills, object motor skills, total motor skills, percent of expected adult height, response inhibition, working memory, expressive vocabulary), child's sex (percent of expected adult height, response inhibition, prosocial behaviour), race/ethnicity (internalizing), parent's age (percent of expected adult height, expressive vocabulary, cognitive self-regulation), marital status (expressive vocabulary), household income (percent of expected adult height), number of siblings (emotional self-regulation, prosocial behaviour), house type (body mass index), and yard size (sociability, prosocial behaviour).

Table 5.2 Multiple linear and logistic regression models of outcome variables and parental-reported outdoor play by different time periods, adjusting for outdoor MVPA

Domain	Outcome Variable	Total (10 min/day)		Seasonality				Time of week			
				Winter months (10 min/day)		Summer/fall months (10 min/day)		Weekdays (10 min/day)		Weekend days (10 min/day)	
		B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value	B (95%CI)	p-value
Linear Regression											
Physical Development	Locomotor Skills	-0.03 (-0.39, 0.33)	0.86	0.29 (-0.23, 0.82)	0.27	-0.07 (-0.32, 0.18)	0.58	-0.00 (-0.39, 0.39)	0.99	0.00 (-0.29, 0.29)	0.99
	Object Motor Skills	0.08 (-0.21, 0.37)	0.60	0.21 (-0.22, 0.64)	0.33	0.04 (-0.16, 0.24)	0.67	0.07 (-0.25, 0.39)	0.67	0.12 (-0.11, 0.36)	0.30
	Total Motor Skills	0.05 (-0.50, 0.59)	0.87	0.51 (-0.29, 1.31)	0.21	-0.03 (-0.40, 0.35)	0.89	0.07 (-0.53, 0.66)	0.82	0.12 (-0.32, 0.56)	0.58
	BMI z-scores	0.01 (-0.03, 0.04)	0.76	-0.01 (-0.06, 0.04)	0.69	0.01 (-0.02, 0.03)	0.63	0.01 (-0.03, 0.05)	0.65	0.00 (-0.03, 0.03)	0.92
	Expected Adult Height (%)	0.00 (-0.00, 0.00)	0.99	0.00 (-0.00, 0.00)	0.33	-0.00 (-0.00, 0.00)	0.82	0.00 (-0.00, 0.00)	0.94	0.00 (-0.00, 0.00)	0.58
Cognitive Development	Response Inhibition	-0.01 (-0.02, 0.00)	0.13	-0.00 (-0.02, 0.01)	0.82	-0.01 (-0.01, 0.00)	0.09	-0.01 (-0.02, 0.00)	0.07	-0.00 (-0.01, 0.00)	0.48
	Working Memory	-0.03 (-0.06, 0.01)	0.14	-0.03 (-0.07, 0.02)	0.32	-0.02 (-0.04, 0.01)	0.15	-0.03 (-0.06, 0.01)	0.13	-0.01 (-0.04, 0.02)	0.39
	Vocabulary	-0.10 (-0.34, 0.13)	0.39	-0.16 (-0.51, 0.20)	0.39	-0.07 (-0.23, 0.09)	0.38	-0.09 (-0.35, 0.17)	0.51	-0.13 (-0.32, 0.06)	0.17
Social-Emotional Development	Behavioural Self-Regulation	-0.01 (-0.04, 0.02)	0.67	-0.01 (-0.05, 0.04)	0.80	-0.00 (-0.03, 0.02)	0.62	0.00 (-0.03, 0.03)	0.93	-0.01 (-0.04, 0.01)	0.31
	Cognitive Self-Regulation	0.01 (-0.02, 0.04)	0.41	0.02 (-0.02, 0.06)	0.38	0.01 (-0.01, 0.03)	0.47	0.02 (-0.01, 0.05)	0.28	0.00 (-0.02, 0.02)	0.92
	Emotional Self-Regulation	0.02 (-0.01, 0.06)	0.23	0.04 (-0.02, 0.09)	0.19	0.01 (-0.01, 0.04)	0.30	0.03 (-0.01, 0.07)	0.17	0.01 (-0.02, 0.04)	0.43
	Externalizing	-0.03 (-0.06, 0.01)	0.11	-0.05 (-0.10, 0.00)	0.08	-0.02 (-0.04, 0.01)	0.20	**-0.04 (-0.08, -0.00)****	**0.03****	-0.01 (-0.03, 0.02)	0.61
	Sociability	0.01 (-0.02, 0.03)	0.65	0.01 (-0.03, 0.05)	0.65	0.00 (-0.01, 0.02)	0.64	0.01 (-0.02, 0.03)	0.67	0.01 (-0.01, 0.03)	0.46
	Prosocial Behaviour	0.01 (-0.02, 0.03)	0.46	0.01 (-0.03, 0.04)	0.75	0.01 (-0.01, 0.02)	0.43	0.01 (-0.02, 0.04)	0.43	0.01 (-0.01, 0.03)	0.50
Logistic Regression		OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value	OR(95%CI)	p-value
Social-Emotional Development	Internalizing	0.97 (0.89, 1.06)	0.54	0.95 (0.82, 1.09)	0.43	0.99 (0.93, 1.05)	0.64	0.98 (0.88, 1.08)	0.62	0.96 (0.90, 1.04)	0.33

Footnote: ****p-value <0.05**. B= unstandardized beta coefficient; 95% CI= 95% confidence interval; min/day= minutes per day; OR= odds ratio
Results represent the effect of each additional 10 mins/day of outdoor play.
Covariates used: child's age (locomotor skills, object motor skills, total motor skills, percent of expected adult height, response inhibition, working memory, expressive vocabulary), child's sex (percent of expected adult height, response inhibition, prosocial behaviour), race/ethnicity (internalizing), parent's age (percent of expected adult height, expressive vocabulary, cognitive self-regulation), marital status (expressive vocabulary), household income (percent of expected adult height), number of siblings (emotional self-regulation, prosocial behaviour), house type (body mass index), and yard size (sociability, prosocial behaviour).

4.5 Discussion

The associations between children's OP and development, in particular cognitive and social-emotional development, have recently been highlighted as a major evidence gap (de Lannoy et al., 2023). This study addressed this gap by examining the associations between parental-reported and device-based measured OP and a wide variety of development health indicators, before and after adjusting for outdoor MVPA. Overall, most associations between children's OP and development were not significant. However, some parental-reported OP variables (i.e., total, summer/fall months, and weekdays) were negatively associated with two cognitive development indicators (i.e., response inhibition and working memory). In other words, more parental-reported OP was associated with less advanced cognitive development, but after adjusting for outdoor MVPA, significant associations were no longer observed. In contrast, OP, independent of outdoor MVPA, may be beneficial for reducing externalizing behaviours, with a negative association being found with parental-reported weekday OP. Overall, observed associations represented small effect sizes.

In terms of physical development, the null associations observed between OP and motor skills are consistent with previous research. A systematic review noted that outdoor time was unrelated to children's motor skill development (Gray et al., 2015); however, there was only one included study that examined these associations, and it included a sample of preschool-aged children (Sääkslahti et al., 1999). While it is thought that playing outdoors provides children with opportunities to better their motor skills (Little & Wyver, 2008), the association between the two remains unclear (Barnett et al., 2019). It may be that OP experience needs to encompass activities and opportunities that can support object and locomotor skill development.

BMI is one of the more commonly examined physical development health indicators with preschoolers' OP. Unlike the present study, which found no associations between OP and BMI, a previous study in preschool-aged children found OP to be negatively associated with children's BMI (Ansari et al., 2015). It is noteworthy that these studies captured OP via subjective measures only (i.e., parental and teacher reports), and only on weekdays.

Findings from this study regarding the negative association between cognitive development and OP add to the inconsistent findings of previous literature. For instance, a previous longitudinal study, which included preschool-aged children, found outdoor time to be beneficial for children's cognitive development, specifically, their attention/working memory skills (Ulset et al., 2017). However, associations were strongest at ages 5 and 6 years (slightly older than the current sample), and outdoor time was specific to childcare. Outdoor time in fall/winter and spring/summer months were captured by Ulset and colleagues (2017) but were combined for a yearly average for analysis, limiting the ability to examine associations between OP and cognitive development by season, as done in the present study. In another sample of preschool-aged children, OP during childcare was not associated with math or literacy skills (Ansari et al., 2015). Given the small effect sizes in our study, and the inconsistency with previous studies, findings should be interpreted with caution.

After adjusting for outdoor MVPA, the associations between parental-reported OP and cognitive development were no longer significant. Evidence on the associations between MVPA and cognitive development in preschool-aged children suggests that MVPA is positively associated with multiple health indicators, including cognitive development (Carson, Lee et al., 2017). Two studies from Carson, Lee et al.'s (2017) review noted that academic MVPA lessons were positively associated with preschoolers' cognitive development (Kirk et al., 2014; S. Kirk

& E. Kirk, 2016). In school-aged children, evidence suggests the type of physical activity is important for cognitive development. Activities such as martial arts and yoga may be more beneficial for children's cognitive development (Diamond, 2012), compared to traditional aerobic activities that do not require much thought (i.e., walking and running; Diamond, 2015). In the present study, we do not know what children were doing when playing outside. Contextual factors, including outdoor environments, OP activities, and who children are playing with outdoors (i.e., peers, teachers, parents, etc.), should be considered to further our understanding of optimal OP opportunities to enable healthy development, including cognitive development, in preschool-aged children.

The current study also suggests that OP, independent of outdoor MVPA, may be beneficial for children's externalizing behaviours. This is consistent with previous research that found spending time outdoors was positively associated with behavioural development and linked to improvements in children's behaviour (Ulset et al., 2017). For instance, Ulset et al. (2007) reported that outdoor time in childcare was associated with lower inattention-hyperactivity symptoms. Similar to cognitive development, these associations were strongest at ages 5 and 6 years of age. The attention restoration theory may explain these beneficial findings (Kaplan, 1995). Specifically, Mårtensson et al. (2009) noted that green outdoor environments (e.g., large amounts of trees and shrubs, hilly terrain) correlated to preschool-aged children's attention, and when children played in these outdoor environments, they had significantly less inattention. Additionally, activities performed in green outdoor environments have been shown to significantly reduce ADHD symptoms in 5-18-year-old children who were diagnosed with ADHD (Kuo & Taylor, 2004). This theory should be further examined in preschool-aged children.

Due to the preliminary findings from this study and the lack of current evidence for preschoolers, further research is needed to better understand the developmental benefits of OP in this age group. To effectively understand OP benefits while determining OP frequency and duration, it is critical that a reliable and valid measure is being used. A novel aspect of the present study was the use of both subjective and device-based measures of OP. Few consistent findings were observed; however, previous research suggests that while these two measures are significantly correlated, they produced significant differences in median estimates (Davenport et al., 2023 [under review]). The findings of this study also suggest it is important for future research to consider MVPA as a potential mediator. Previous research in adolescents found MVPA mediated the associations between outdoor time and mental health (Bélanger et al., 2019). This mediating role of MVPA should be further examined in preschool-aged children. Finally, as previously mentioned, future research should capture contextual factors related to OP.

A strength of this study is the use of a wide variety of health indicators, which spans various domains of children's development. The use of objective and subjective measures of OP in this study is also a strength. While each individual measurement type may have its limitations, using both measurement types may provide a more accurate representation of children's OP. Another strength of this study is that it addresses a major gap noted in the literature (de Lannoy et al., 2023). A limitation of this study is the use of a small sample, which may not be representative of preschoolers in Alberta. Specifically, this study used convenience sampling from a program designed to improve children's sport, pro-social, and motor skills through play, and comprised mostly of higher socioeconomic status families. Additionally, the sample included a higher proportion of males compared to females. Another limitation of this study was the loss of statistical power due to device-based outdoor being dichotomized because of its non-normal distribution. Finally, the cross-sectional design of this study limits our ability to draw causation conclusions between children's OP and development.

4.6 Conclusion

This study filled an important gap in the literature by examining the associations between parental-reported and device-based OP with a wide variety of health indicators in a sample of preschool-aged children. While most associations between children's OP and development were not significant, findings provide insight on directions for future research to better understand the impact of OP on preschool-aged children's healthy development. Future research building on this preliminary work should take into account physical activity and contextual factors, including outdoor environments and OP activities, when examining the associations between OP and healthy development in preschool-aged children.

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Chapter 5: Conclusion

5.1 Overview

The overall objective of this thesis was to address key gaps in the literature regarding outdoor play in preschool-aged children. This thesis targeted phases 1-3 of the Behavioural Epidemiology framework by establishing associations between outdoor play and development (Phase 1); providing further evidence on the methods for measuring outdoor play (Phase 2); and examining correlates of outdoor play (Phase 3; Sallis et al., 2000). To address the overall objective of this thesis, data was used from a sample of preschool-aged children and parents from Edmonton, Canada, and surrounding areas. This chapter will outline key findings, strengths and limitations, and key implications for future directions across both manuscripts included within this thesis.

5.2 Summary of Key Findings

Understanding when children engage in less outdoor play may be an important consideration when attempting to increase their outdoor play. As such, Manuscript 1 examined the variability of children's parental-reported outdoor play in summer/fall months, winter months, weekdays, and weekend days. For parental-reported outdoor play, consistent with my thesis hypothesis number one, durations were significantly higher in summer/fall months compared to winter months by approximately 85 minutes. In contrast to my thesis hypothesis number one, parental-reported outdoor play on weekend days was higher compared to weekdays by approximately 22 minutes. It was thought that outdoor play would be relatively consistent throughout the week, in particular for children not in childcare (n=14). Additionally, it was thought that children in childcare would have outdoor play at childcare and potentially after childcare with their parents, and then outdoor play with their parents on weekend days when many families would have more free time. As discussed in manuscript number one, it is possible that parents underreported children's weekday outdoor play because they do not know how much outdoor play their child typically does at childcare. Alternatively, parents may have more time on weekend days compared to weekdays to facilitate outdoor play, in particular, in winter when daylight hours are limited after childcare on weekdays.

To my knowledge, Manuscript 1 is the first study to examine the convergent validity between subjective and objective measures of preschool-aged children's outdoor play. For the relative convergent validity, there was a significant correlation between the parental-reported and device-based measures of outdoor play. This correlation had a medium effect size (Cohen, 1992). For the absolute convergent validity, parental-reported outdoor play was significantly higher than device-based measured outdoor play in summer/fall months by approximately 114 minutes, representing a large absolute difference. This large absolute difference could be due to a combination of limitations across devices, including recall and social desirability biases of the parental-report measure (Koning et al., 2018), and clothing being worn over the accelerometer impacting the ambient light sensor (Flynn et al., 2014). Additionally, the time period was different between measurement types, with the accelerometer being worn for 3 to 7 days (Kuzik et al., 2020), and the questionnaire capturing a typical weekday in the last month (Burdette et al., 2004).

There is a gap in the literature for outdoor play correlates in preschool-aged children, where limited evidence exists exclusively in this age group (3-5 years of age). In Manuscript 1, the multiple linear regression models of parental-reported outdoor play indicated that parental age was positively associated with outdoor play on weekend days, and higher temperature was positively associated with outdoor play in summer/fall months. Specifically, for every 1-year increase in parental age, outdoor play was approximately 3 minutes higher, and for every 1°C increase in temperature, outdoor play was approximately 7 minutes per day higher. In the final logistic regression model of device-based outdoor play, only a higher temperature was associated with a higher likelihood of children engaging in ≥30 minutes of outdoor play compared to <30 minutes. Specifically, for every 1°C increase in temperature, children were approximately two times more likely to engage in ≥30 minutes of outdoor play compared to <30 minutes. These findings did not support my thesis hypothesis number 2 as there were not more significant correlates at the individual level compared to other levels of the socioecological framework. This hypothesis was formed primarily based on evidence from a systematic review, which did not exclusively focus on preschool-aged children, but rather on 3-12-year-olds (Lee et al., 2021).

MVPA has been consistently positively associated with various health indicators in children's early years (0-4 years; Carson et al., 2017). However, the benefits of outdoor play, independent of MVPA, remain unclear. In Manuscript 2, various parental-reported outdoor play variables (i.e., total outdoor play, outdoor play in summer/fall months, and outdoor play on weekdays) were negatively associated (small effect sizes) with health indicators of cognitive development (i.e., response inhibition and working memory). However, these associations were weak and no longer observed after adjusting for outdoor MVPA. Additionally, when adjusting for outdoor MVPA, parental-reported outdoor play on weekdays was negatively associated (small effect size) with externalizing (i.e., health indicator of social-emotional development). Specifically, for every 10-minute increase in outdoor play, children's externalizing scores were 0.04 units lower. No significant associations were observed between device-based measured outdoor play and health indicators of development. However, the association between outdoor play and externalizing approached significance. These findings also did not fully support my thesis hypothesis number three because favourable associations were not observed between outdoor play and health indicators of physical, cognitive, and social-emotional development. Again, this hypothesis was primarily based on review evidence that did not exclusively focus on preschool-aged children (Brussoni et al., 2015; Gray et al., 2015).

Some common themes emerged across manuscripts. First, the majority of associations examined regarding potential correlates and health indicators across manuscripts were null, resulting in thesis hypotheses number two and three not being supported. The null findings may be due to the limitations highlighted in section 5.3 below. As alluded to earlier in this section, the null findings could also reflect the unique age group of preschool-aged children, as thesis hypotheses were primarily derived from previous research in older children. In comparison to preschool-aged children, school-aged children typically have increased autonomy, independence, and independent mobility, which have all been positively associated with school-aged children's outdoor play (Moran et al., 2017; Remmers et al., 2014; Wen et al., 2009). As children age and have more freedom to choose when, where, and with whom they play outside, this may impact their time spent playing outdoors. Furthermore, there are vast developmental differences between these two age groups (Berk, 2013). This highlights the importance of studying outdoor play, specifically in preschool-aged children.

A second theme observed across manuscripts was of the significant associations that did emerge, relatively consistent findings were observed across both parental-report and device-based measures. For instance, a higher temperature was positively associated with parental-reported and device-based outdoor play in summer/fall months, and similar patterns were observed between both measures of outdoor play and externalizing – where negative associations were observed. Observing consistent findings across measurement types provides more confidence in these findings. Overall, the strengths and limitations of this work should be taken into consideration when interpreting the key findings of this thesis.

5.3 Strengths and Limitations

Specific strengths and limitations of each study are discussed in detail in Chapters 3 and 4. This section focuses on the strengths and limitations that overlap across the manuscripts. The use of subjective and device-based measures of children's outdoor play is a strength of both manuscripts. Given both measurement types have unique limitations (Flynn et al., 2014; Koning et al., 2018), this thesis provided a balanced assessment of outdoor play that enabled the comparison of findings between measures. As previously mentioned, findings that were consistent across measurement types may be more meaningful. Another major strength of this thesis is the focus on preschool-aged children. While outdoor play research has been on the rise (de Lannoy et al., 2023), limited studies exist that focus exclusively on preschool-aged children (i.e., 3-5 years of age; Larouche et al., 2023; Lee et al., 2021). As highlighted in the previous section (5.2), this is an important age group to target with health initiatives because of rapid growth and development advancements (Royal College of Physicians and Surgeons of Canada, 2014), as well as the early establishment of healthy movement behavioural patterns that may track into later childhood and even adulthood (Garcia et al., 2002).

A limitation of this thesis is the use of a small convenience sample. The sample was comprised mostly of higher socioeconomic status families, and children were predominantly males and Caucasian. As such, this sample may not be representative of preschool-aged children in Alberta. This sample was recruited from a physical activity/sports organization, primarily via their summer camps. Therefore, this demographic breakdown likely reflects those who can afford and are interested in these camps and programs. Additionally, device-based outdoor play was dichotomized in both manuscripts due to its non-normal distribution, resulting in a loss of statistical power. Lastly, causation between the examined correlates and outdoor play, and children's outdoor play and health indicators of development, cannot be determined due to the cross-sectional design. Given the limitations of this work, and the preliminary nature of the findings in these manuscripts, future research is needed to confirm and build on this work before firm conclusions can be made regarding outdoor play in preschool-aged children. Directions for future research are discussed in further detail in the next section.

5.4 Implications for Future Directions

The findings of this thesis have several implications for future research. In terms of outdoor play's association with children's health indicators of development (phase 1 of the Behavioural Epidemiology Framework), further studies are needed to build on the preliminary findings in Manuscript 2. A major gap remains in the literature on the developmental benefits of outdoor play in preschool-aged children, especially for cognitive and social-emotional development (de Lannoy et al., 2023). I will discuss three key directions for future research in this area. First, in Manuscript 2, the few associations observed between outdoor play variables and health indicators of development varied by direction and significance depending on whether outdoor moderate-to-vigorous physical activity (MVPA) was included in the models. A recent systematic review noted that MVPA was consistently positively associated with numerous health indicators in preschool-aged children (Carson et al., 2017). Therefore, physical activity may have a confounding effect on the association between children's outdoor play and health indicators of development. More specifically, physical activity has been favourably associated with health indicators of development (outcome variable; Carson et al., 2017), as well as with outdoor play (exposure variable; Lee et al., 2021). Alternatively, physical activity may have a mediating effect where it is on the causal pathway between outdoor play and health indicators, thus driving the association between the two. Bélanger and colleagues (2019) found that MVPA mediated the associations between outdoor time and mental health indicators in adolescents. Specifically, adolescents who spent more time outdoors also had higher PA levels, which was favourably associated with their mental health. Therefore, physical activity appears to be an important third variable to consider when examining the association between outdoor play and health indicators of development in future research.

This thesis examined the habitual associations of outdoor play (e.g., in the previous week or month) on children's development and did not consider the acute impacts; this is a second key direction for future research. For instance, Schutte and colleagues (2017) noted that preschoolers who had just returned from a nature walk had more stable spatial working memory compared to an urban walk. This suggests that outdoor activity, in this case within a specific environment, may have immediate impacts on children's development, and over time, the accumulation of these acute effects may lead to habitual impacts. In a longitudinal study by Ulset et al. (2017), where participants were preschoolers at baseline and followed for 4 years, associations between outdoor play and cognitive development were strongest at ages 5 and 6, potentially supporting this line of thinking.

Contextual factors, such as what activities children are doing outdoors, who they are doing those activities with, and where they engage in these activities, are a third important direction for future research when examining the association between children's outdoor play and health indicators of development. With physical activity, non-traditional forms of activity (i.e., yoga and martial arts), compared to traditional activities (i.e., running and walking), may offer more developmental benefits to children (Diamond, 2012). This could also be the case with outdoor play, where certain outdoor activities and environments may offer more developmental benefits compared to other activities and environments. For instance, a systematic review on the association between unstructured nature play and development in early childhood found consistent associations with physical activity and cognitive development outcomes (Dankiw et al., 2020). In particular, nature play appeared to have positive impacts on imaginative and dramatic play (Dankiw et al., 2020). However, optimal outdoor play activities, environments, and who these activities are done with to achieve health benefits remain understudied with preschool-aged children.

A key direction for future outdoor play research in the methods phase, or phase 2 of the Behavioural Epidemiology Framework, is that further validation research is needed to determine the best method to measure children's outdoor play. Furthermore, a consensus on measurement tools and methodologies is required (de Lannoy et al., 2023). In physical activity research, device-based measures are typically more accurate than subjective measures (Westerterp, 2009). Manuscript 1 highlighted the similarities and inconsistencies between outdoor play durations by measurement type; however, as previously mentioned in section 5.2, it is important to note that device-based measured outdoor play in this thesis may be underestimated due to clothing potentially covering the device. In order to get accurate lux values and valid estimates of children's outdoor activities, it is vital that the accelerometer is worn on top of clothing. Future research using accelerometers to capture children's outdoor activities should emphasize the importance of this to their participants.

While this research used subjective and device-based measures of outdoor play separately, a combination of methods may be important to consider in future research. For instance, in older children (10-13 years), previous studies have used a combination of subjective (i.e., activity logs, children's weekly schedule, daily diaries, surveys, and interviews) and objective (i.e., GPS monitors, and accelerometers) measures to capture children's outdoor play (Borghese & Janssen, 2018; Han et al., 2018). Similar methods may be advantageous for preschool-aged children to capture a diverse dataset on multiple components of children's outdoor play. Specifically, this combined measurements approach may capture children's physicality, context, and experiences during outdoor play. However, this method has yet to be tested in this age group, making it a key direction for future research.

A key direction for future outdoor play research, in the correlates phase of the Behavioural Epidemiology Framework (phase 3), is identifying other modifiable factors which may increase children's outdoor play. Given parents are important gatekeepers to children's outdoor play (McFarland & Laird, 2020), understanding parental correlates may be key. A study conducted on parents of preschoolers in Edmonton, Canada, identified numerous neighbourhood features which parents deemed important for children's active play, both indoors and outdoors (Hunter et al., 2022). Specifically, some of these features included parks, trails, street lighting, sidewalk maintenance, cleanliness, and natural and landscaped features. This thesis primarily examined built environment factors in the home setting and did not include sociocultural or built environment factors in other settings. Though the home setting is a key setting for outdoor play in this age group, a comprehensive assessment of correlates across home, neighbourhood and childcare settings should be considered in future research. This research is key for guiding interventions that can be implemented in various settings where children play outdoors. Furthermore, as reported in Manuscript 1, children do not engage in outdoor play similarly throughout the week or across different seasons. As such, it is important to identify factors that may increase children's outdoor play in times (i.e., days, seasons) when they engage in more or less outdoor activities.

The findings of this thesis also have several practical implications. First, data for this thesis was collected prior to COVID-19. The importance of outdoor play was amplified during COVID-19 lockdowns when restrictions were in place in many indoor play settings. Systematic review evidence on children's outdoor play (0-12 years) suggests the impact of COVID-19 varied based on setting (e.g., home, preschool/school) and restrictions (e.g., stay at home orders; Liu et al., 2022). In a large international study of preschool-aged children (3-5 years) from 14 counties, time spent outdoors on weekdays and weekend days decreased by 81 and 105 minutes/day, respectively, during the initial lockdown (Okely et al., 2021). Similarly, a Canadian study in school-aged children and youth (5-17 years) reported a decline in outdoor play, with an increase in leisure screen time (Moore et al., 2020). Therefore, future interventions and initiatives need to take into account changes that may have occurred in outdoor play as a result of COVID-19.

Given the preliminary nature of the work conducted in this thesis, caution must be taken in making recommendations for future interventions and initiatives. This thesis, along with findings from previous and future research, can help inform future interventions and initiatives. For instance, findings from this thesis, along with previous research (Predy et al., 2020), suggests that in a northern climate, preschoolers engage in more outdoor play in warmer months. Specifically, in Manuscript 1, for both the device-based and parental-reported measures of outdoor play, a higher temperature was consistently associated with more outdoor play. Furthermore, children's outdoor play was less in winter months. Implementing interventions to promote outdoor play in all weather, in particular colder seasons, may help reverse the declining trend of children's outdoor play that has been reported over recent decades.

One focus of interventions aiming to increase outdoor play during colder weather and seasons is providing education on and addressing the affordability of appropriate outdoor clothing to help make outdoor play during colder weather and colder seasons more enjoyable for families. In the childcare setting, if even a few children do not have suitable clothing for colder temperatures, this could prevent their entire cohort from being able to play outdoors (Copeland et al., 2012). Donations and winter outdoor clothing drives could be one strategy to make appropriate clothing more affordable and accessible. Also, families and educators could be informed of signs and symptoms of frostnip and frostbite, so they can monitor their children while playing outdoors in cold weather. Other educational tools outlining the potential benefits of outdoor play all year round, and how to appropriately layer clothing, may also be useful to encourage outdoor play in colder weather. This may be particularly helpful for individuals new to Canada who are not used to the winter climate.

Another focus of interventions aiming to increase outdoor play during colder weather and seasons could be on the neighbourhood environment and service facilities as well as community initiatives. For instance, the addition of deciduous trees (i.e., those that shed their leaves) in outdoor play areas will not decrease solar radiation in winter months; thus will not make the environment colder, compared to coniferous trees (e.g., evergreen trees that maintain their needle foliage in winter months; Qi et al., 2022). Service facilities could be added, such as hot drink dispensers and places (e.g., indoor buildings, fire pits) close to nearby outdoor play areas where children and their parents can warm up (Qi et al., 2022). Societal norms may lean toward winter months being a time to relax, and indoor activities being more seasonally appropriate (Ergler et al., 2013). However, children may have more tolerance for colder weather and environments compared to their parents (Qi et al., 2022), and are still eager and excited to play outdoors in winter months (Ergler et al., 2013). Therefore, communities offering fun family events, activities, and winter festivals may encourage parents to embrace the great outdoors in the winter with their children.

5.5 Conclusion

This thesis addressed key gaps noted in the literature regarding outdoor play in preschool-aged children, and findings reveal potential directions for future research, interventions, and initiatives. The use of both subjective and objective measures of outdoor play was a novel aspect of this thesis. This approach may help advance the methods for future research to accurately capture children's outdoor activities that combine both subjective and device-based measures. Overall, with few correlates being identified in this thesis, and correlates only being observed at the parental and physical ecology level, further studies are needed to gain a better understanding of factors that influence preschoolers' outdoor play to inform future interventions and initiatives. Based on the findings of this study and previous research, interventions aimed at increasing outdoor play in periods with cold temperatures, such as winter months, appear important to consider. Additionally, only a few associations were observed between outdoor play and health indicators. This thesis highlights the need for further studies to take into account outdoor MVPA, the context of outdoor play, and the immediate/acute effects to better understand the developmental implications of outdoor play for preschool-aged children. Finally, given sample limitations, future research is needed in the area of preschool-aged children with stronger study designs, including longitudinal and experimental studies with larger and more diverse samples.

5.6 References

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Appendix 1: Additional Methods

Original project

This thesis conducted secondary analyses from an existing dataset from the Parent-Child Movement Behaviours and Pre-School Children's Development project. The overall objective of the original project was to advance the field of movement behaviours in preschool-aged children through innovative measurement and data analysis approaches. Specifically, in a sample of 131 preschool-aged children, the project sought to (1) create a sleep classification technique, (2) examine the associations between movement behaviours and health indicators of development, (3) examine the prevalence of movement behaviours, and (4) examine the associations of parent-child proximity and parental movement behaviours with preschoolers' movement behaviours. This project created a method to accurately determine sleep in this age group. Key findings from the project also suggest that moderate- to vigorous-intensity physical activity (MVPA), relative to other movement behaviours, is important for physical development, and that the impact of parent-child proximity on children's physical activity varies by activity intensities.

Development outcomes

Additional information about the development outcomes measures that were not provided in Chapter 4: manuscript 2 due to journal word limits are outlined in this appendix section.

Physical development

This thesis included three health indicators of physical development, including adiposity, growth, and motor skills. For adiposity, children's height was measured to the nearest 0.1cm via a stadiometer, and their weight was measured to the nearest 0.1kg via a digital scale. Both height and weight were measured twice for each child. If there was a difference of ≥0.3 units between the two measurements, then a third measurement was done, and the average of the two closest measurements was used. The growth measure is described in Chapter 4.

For the motor skills assessment, the Test of Gross Motor Development—2nd Edition (Ulrich, 2000) was used. Children were placed in groups and rotated around stations that each had three to four skill tests and two research team members. One research team member was the facilitator, and one was the assessor. The facilitator demonstrated and verbally explained the skill twice for the children, followed by the children having one practice attempt and then two scored trials for each test. The assessors scored the children's performance via live scoring and captured their attempts on video using a body camera for additional scoring later. Each skill (n=12) consisted of three to five components that were scored as demonstrated (i.e., 1) or not demonstrated (i.e., 0). The live and video scores have been previously compared for all pair-wise complete observations by the lead researcher. Intraclass correlation coefficients (ICC) for object motor skill (ICC= 0.719), locomotor skill (ICC= 0.693), and total motor skills (ICC= 0.791) were previously reported (Kuzik et al., 2020). Consistent with a previous publication, video score values were used for analysis since they were scored by one assessor (lead researcher) and the live scores were scored by multiple assessors. However, if a child had missing video scores, then live scores were used instead. A recent systematic review found the TGMD-2 to be the only motor assessment tool to assess gross motor skills in isolation, as well as having the most evidence for construct validity and the ability to distinguish between age groups (Griffiths et al., 2018). This review noted test-retest (ICC= 0.81-0.92), intra-rater (ICC= 0.92-0.99), and inter-rater reliability (ICC= 0.88-0.93) among included studies (Griffiths et al., 2018).

Cognitive development

This thesis included three health indicators of cognitive development, including visual-spatial working memory (Mr. Ant task), response inhibition (Go/No-Go task), and expressive language (expressive language task) that were measured using specific tasks from the iPad-based Early Years Toolbox (Howard & Melhuish, 2017). During the Mr. Ant task, Mr. Ant was displayed with stickers (n=1-8) on various parts of his body for five seconds, followed by a blank screen for four seconds, and then Mr. Ant again with an auditory prompt for the children to place the stickers back on the correct parts of Mr. Ant (Case, 1985; Morra, 1994). The children had three trials in each level (maximum 8 levels), which progressed by increasing the number of stickers presented on Mr. Ant. Each level had a corresponding maximum of eight points, and the tasks ended once children either completed all eight levels or failed on all three trials of a specific level. Children earned one point for each level with at least 2/3 trials correct; however, once they scored 1/3 correct trials on a level, that level and all following levels were scored according to the number of correct trials with 1/3 of a point for each correct trial.

During the Go/No-Go task (Howard & Okely, 2015; Wiebe et al., 2012), children were instructed to tap the screen (Go) when a fish appeared on the screen (appeared 80% of the time). Conversely, they were instructed not to tap (No-Go) when a shark appeared on the screen (appeared 20% of the time). This task consisted of three trials, with no changes in difficulty, where in each trial, there were 75 stimuli presented (fish or sharks) in semi-random order for 1,500 milliseconds, followed by 1,000 milliseconds of no stimulus. No trial began with a shark, and sharks would not appear consecutively more than twice. The proportion of correct Go and No-Go stimuli will be multiplied to calculate the children's score values.

During the Expressive Vocabulary task (Howard & Melhuish, 2017), children were presented with pictures (maximum of 45 pictures) and were instructed to tell the lead researcher what they thought the picture was. If the children gave an incorrect description of the picture, the lead researcher would ask what else the picture could be called. If the children described the picture using another acceptable word, then it was scored correct. However, if the child could not produce the correct word, and the lead researcher felt confident that they could not produce the required word, it was scored incorrect. The task ended once children described all 45 pictures or had six consecutive incorrect descriptions. Their score was calculated by summing the number of correct descriptions.

Validity and reliability have previously been reported for the Early Years Toolbox. For criterion validity, correlations (r) ranging from 0.40 to 0.60 were observed between visual-spatial working memory, response inhibition, and expressive vocabulary with previously validated tasks in the British Ability Scales and the National Institute of Health's Toolbox (Howard & Melhuish, 2017). For internal consistency reliability, Cronbach's alphas ranging from 0.84-0.95 were observed for response inhibition and expressive vocabulary (Howard & Melhuish, 2017).

Social-emotional development

This thesis included five health indicators of social-emotional development, including sociability and prosocial behaviour, internalizing, externalizing, and self-regulation that was measured using the Early Years Toolbox Child Self-Regulation and Behaviour Questionnaire (CSBQ; Howard & Melhuish, 2017). If children had missing data, the subscales were calculated without the missing items. The first version of this questionnaire was previously shown to have correlations (r) ranging from 0.48 to 0.91 with comparable Strengths and Difficulties Questionnaire subdomains (Howard & Melhuish, 2017). Internal consistency reliability (Cronbach's α= 0.74-0.89) has also been previously reported for the CSBQ.

Appendix 1.1 References

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Appendix 2: Letter of Information and Consent Form

INFORMATION LETTER & CONSENT FORM

Parent-Child Movement Behaviours and Pre-School Children's Development

Project Lead:

Nicholas Kuzik, 1-167 Van Vliet Complex, University of Alberta, Edmonton, AB, T6G 2H9

Dear Parent/Guardian,

This research is being led by Nicholas Kuzik under the supervision of Dr. Valerie Carson from the University of Alberta. We are asking for you and your child to participate in this important new research study.

What is this study about? There are two main purposes of this study. 1) To examine the relationships between parental and children's movement behaviours (i.e., sleep, sedentary behaviour, and physical activity). 2) To examine the relationships between children's movement behaviours and their development.

What will participation entail? **1)** You will complete some paperwork at the beginning of the study. This paperwork should take less than 5 minutes. **2)** Your child's motor skills (e.g., running, jumping, kicking) will be assessed at the Saville Community Sports Centre through fun games. Motor skills will be video recorded to help researchers determine children's motor development. You will be able to choose from several dates and times for the motor skills assessment. **3)** You and your child will be given a motion sensor on an elastic belt to wear for 7 consecutive days and nights. The motion sensor is called an accelerometer. It is safe, small (1" square), and light weight (0.5 ounces). It is safely worn on a comfortable adjustable elastic belt around the waist over clothing. The accelerometer will not impact day-to-day activities. Accelerometers will be given on the day of motor assessments, or they will be dropped off at your home at a time that fits your schedule. **4)** During the 7 consecutive days you will be asked to fill in a log book. Recorded in the log book are times when the accelerometer is off, sleep times, and time spent in child care (if any). This should take you about 5 minutes per day. Research staff will contact you mid-week regarding the continuous wear of the accelerometers. **5)** After the 7 days of accelerometer measurement, research staff will visit your home for approximately 30 minutes at a time that fits your schedule. Research staff will collect the accelerometers. Then, they will administer three fun cognitive tasks for your child on an iPad (about 15 minutes). Researcher staff will measure your child's height and weight and measure your height (optional). Lastly, you will complete a questionnaire that should take about 15 minutes, while your child completes the iPad games.

Is my participation voluntary? Yes. You and your child do not have to participate in this study. Participation is not a requirement to be involved in any Sportball activities. You do not need to answer any survey questions you do not wish to. If your child states they do not want to participate in any part of this project their choice will be respected. Even if you agree to participate, you and your child may withdraw from the study without any penalty. You can ask to have your data withdrawn and not included up to one month after the in-home visit.

Are there any benefits or risks by participating? There are no expected risks but there are some benefits. After completing the study, you will be sent a summary of results for your child. Specifically, motor and cognitive development in relation to age specific standards. Also, your child's levels of sleep, sedentary behavior, and physical activity in comparison to age-specific national guidelines. The findings from the study will have important implications on the understanding of children's movement behaviours and development.

What will happen to the information collected? All data collected will be kept confidential. Only the research team will have access to it. The study data will be kept in a secure place for a maximum of ten years. If the data is to be used for other studies, ethics approval will be obtained. The data may also be published in professional journals or presented at scientific conferences, but any such presentations will be of general (group level) findings and will never breach individual confidentiality. Should you be interested, you are entitled to a copy of the findings.

What if I have questions or concerns? If you have any questions or concerns regarding this study, please contact the project lead Nicholas Kuzik (780-902-3333 or nkuzik@ualberta.ca). As well, you can contact his supervisor Dr. Valerie Carson (780-492-1004 or vlcarson@ualberta.ca). The plan for this study has been reviewed by a Research Ethics Board at the University of Alberta. If you have questions about your rights or how research should be conducted, you can call (780) 492-2615. This office is independent of the researchers.

Consent Statement:
I have read this form. The research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to participate in the research study described above. I will receive a copy of this consent form after I sign it.

We hope to conduct similar research in the future. Would you be willing to be contacted in the future about research?

☐ Yes ☐ No

Dated in Edmonton this ________ day of _____________, 20_____.

Name of child participant (please print):

____

Name of parent/guardian (please print):

____

Birth date of child (please print):

____

(MM/DD/YYYY)

Child's preferred hand (e.g., for throwing): ☐ Left ☐ Right ☐ Unknown

Child's preferred foot (e.g., for kicking): ☐ Left ☐ Right ☐ Unknown

Your birth date (please print):

____

(MM/DD/YYYY)

Signature of parent/guardian:

____

Signature of person obtaining informed consent:

____

You may keep a copy of the information letter and consent form for your records.

Appendix 3: Parental Questionnaire

Parent-Child Movement Behaviours and Pre-School Children's Development

Parent Questionnaire

Instructions: Please take your time and read each question carefully. Choose the answer that best describes you and your child by placing an (✔) in the box provided or writing in the space provided. There are no right or wrong responses. If there is a question that you do not want to answer, you do not have to. **Your responses will be kept confidential.**

ID # _______________

Child Movement Behaviours

1. Think for a moment about a typical **weekday** for your child **in the last month**. How much time would you say your child spent playing outdoors on a typical weekday?
   _________ Hours __________Minutes

2. Now think about a typical **weekend** day for your child **in the last month**. How much time would you say your child spent playing outdoors on a typical weekend day?
   _________ Hours __________Minutes

3. Think for a moment about a typical **weekday** for your child **last January**. How much time would you say your child spent playing outdoors on a typical weekday?
   _________ Hours __________Minutes

4. Now think about a typical **weekend** day for your child **last January**. How much time would you say your child spent playing outdoors on a typical weekend day?
   _________ Hours __________Minutes

5. In a typical week, on how many days do you support your child's physical activities by…

	Never			to				Daily
	0	1	2	3	4	5	6	7
encouraging your child to do physical activity or sport?	☐	☐	☐	☐	☐	☐	☐	☐
playing outside or doing physical activity/sport with your child?	☐	☐	☐	☐	☐	☐	☐	☐
providing transportation to a place (e.g., park, pool) where your child can do physical activities or play sport?	☐	☐	☐	☐	☐	☐	☐	☐
watching your child participate in sport, physical activities or outdoor games?	☐	☐	☐	☐	☐	☐	☐	☐
telling your child that sport or physical activity is good for their health?	☐	☐	☐	☐	☐	☐	☐	☐

6. On average, how much time **per day** does your child watch television, videos, or DVDs **on** a television, computer, or portable device?
   Weekdays **(per day)** ________ Hours AND ________ Minutes
   Weekend **(per day)** ________ Hours AND ________ Minutes

7. On average, how much time **per day** does your child play video/computer games **on** devices such as a learning laptop, leapfrog leapster, computer, laptop, tablet, cell phone, the internet, Playstation, XBOX?
   Weekdays **(per day)** ________ Hours AND ________ Minutes
   Weekend **(per day)** ________ Hours AND ________ Minutes

8. On average, how long does your child usually sleep in total **per night** at the moment?
_______ Hours AND _______ Minutes

9. On average, how long does your child usually nap in total **during the day** at the moment?
_______ Hours AND _______ Minutes

10. How many naps does your child get in a typical 24-hour day?
☐ 0
☐ 1
☐ 2
☐ 3 or more

11. Does your child have consistent bedtimes and wake-up times?
☐ Yes, they don't vary by more than 30 minutes each day
☐ No, they vary by more than 30 minutes each day

12. Do you establish a calming bedtime routine for your child (e.g., bath time, saying goodnight, giving a kiss/hug, storytelling)?
☐ Every night
☐ Some nights
☐ Almost never

13. Does your child typically use electronics (e.g., TV, video game, computer, tablet or cell phone) before bedtime?
☐ Yes, within 30 minutes before bedtime
☐ Yes, within 1 hour before bedtime
☐ Yes, within 2 hours before bedtime
☐ No

14. Does your child have electronics in their bedroom (e.g., TV, video game, computer, tablet or cell phone)?
☐ Yes
☐ No

Child Demographic Information

15. Is your child male or female? ☐ Male ☐ Female

16. What is your child's birth date? ______/ ______/ ______________
D D M M Y Y Y Y

17. Please select your child's race/ethnicity (check all that apply):
☐ Aboriginal person, that is First Nations, Métis, or Inuk (Inuit)
☐ Caucasian
☐ South Asian (e.g., East Indian, Pakistani, Sri Lankan)
☐ Chinese

- ◻ African
- ◻ Filipino
- ◻ Latin American
- ◻ Arab
- ◻ Southeast Asian (e.g., Vietnamese, Cambodian, Malaysian, Laotian)
- ◻ West Asian (e.g., Iranian, Afghan)
- ◻ Korean
- ◻ Japanese
- ◻ Other (please specify): ___________________________

18. How many siblings does your child have **that live in the same home**, including step-brothers and step-sisters?

Younger siblings: ☐ 0 ☐ 1 ☐ 2 ☐ 3 or more
Older siblings: ☐ 0 ☐ 1 ☐ 2 ☐ 3 or more

19. Typically, how many **hours per week** does your child spend in care other than yours (or the child's parents)? ______

Check all that apply and fill in number of hours per week:

- ◻ Day care centre _________
- ◻ Dayhome _________
- ◻ Another adult (e.g., friend, relative, nanny, babysitter) in your home _________
- ◻ Another adult (e.g., friend, relative, nanny, babysitter) outside your home _________
- ◻ Other (specify: __________________)

20. Does your child have any disability/condition/disease that may limit their cognitive or movement abilities?

▯ Yes ▯ No ▯ If Yes, please explain_____________________________________

Child Self-Regulation and Social Behaviour Questionnaire

Please circle the number that best fits what the child is like.

What is the child like?	Not True		Partly True		Very True
21. Chosen as a friend by others	1	2	3	4	5
22. Is calm and easy going	1	2	3	4	5
23. Aggressive to children	1	2	3	4	5
24. Is popular with children	1	2	3	4	5
25. Persists with difficult tasks	1	2	3	4	5
26. Chooses activities on their own	1	2	3	4	5
27. Regularly unable to sustain attention	1	2	3	4	5
28. Does not need much help with tasks	1	2	3	4	5
29. Interacts freely with adults	1	2	3	4	5
30. Gets over being upset quickly	1	2	3	4	5
31. Easily upset over small events	1	2	3	4	5
32. Persists with tasks until completed	1	2	3	4	5
33. Waits their turn in activities	1	2	3	4	5
34. Gets over excited	1	2	3	4	5

35. Good at following instructions	1	2	3	4	5
36. Rarely plays with other children	1	2	3	4	5
37. Most days distressed or anxious	1	2	3	4	5
38. Likes to work things out for self	1	2	3	4	5
39. Happy to share	1	2	3	4	5
40. Disagrees with or challenges people	1	2	3	4	5
41. Often stares into space	1	2	3	4	5
42. Is shy when meeting new children	1	2	3	4	5
43. Most days will lose temper	1	2	3	4	5
44. Helps others	1	2	3	4	5
45. Most days says feeling unwell	1	2	3	4	5
46. Shows wide mood swings	1	2	3	4	5
47. Plays easily with other children	1	2	3	4	5
48. Disrupts the play of other children	1	2	3	4	5
49. Not able to sit still when necessary	1	2	3	4	5
50. Is cooperative	1	2	3	4	5
51. Is impulsive	1	2	3	4	5
52. Sociable with new children	1	2	3	4	5
53. Frequently sad or miserable	1	2	3	4	5
54. Will wander around aimlessly	1	2	3	4	5

Household Demographic Information

55. What is the primary language spoken in your household? _______________

56. What is your highest level of education?
    - ☐ Less than high school diploma or its equivalent
    - ☐ High school diploma or a high school equivalency certificate
    - ☐ Trade certificate or diploma
    - ☐ College, or other non-university certificate or diploma
    - ☐ University certificate or diploma below the bachelor's degree
    - ☐ Bachelor's degree (e.g., B.A., B.Sc., LL.B.)
    - ☐ University certificate, diploma, or degree above the bachelor's level

57. **What is your best estimate of your total household income received by all household members, from all sources, before taxes and deductions, during the year ending December 31, 2017?**
    - ☐ **Less than $25,000**
    - ☐ **$25,000 to $50,000**
    - ☐ **$50,001 to $75,000**
    - ☐ **$75,001 to $100,000**
    - ☐ **$100,001 to $125,000**
    - ☐ **$125,001 to $150,000**
    - ☐ **$150,001 to $175,000**
    - ☐ **$175,001 to $200,000**
    - ☐ **More than $200,000**
    - ☐ **Do not know**

58. What type of home do you live in?
    - ☐ Single storey detached
    - ☐ Double storey detached
    - ☐ Row or Terrace
    - ☐ Duplex
    - ☐ Low-rise apartment (fewer than 5 stories) or flat
    - ☐ High-rise apartment (5 stories or more)
    - ☐ Institution

☐ Hotel; rooming/lodging house; camp
☐ Mobile home
☐ Other - Specify

59. How big is your yard? *(Please tick ONE)*
   ☐ No yard at all
   ☐ No private yard
   ☐ A small yard (eg unit or courtyard)
   ☐ A medium yard (eg standard block of land)
   ☐ A large yard (eg ¼ acre block or larger)

60. What is your relationship to the child in this survey?
   ☐ Mother
   ☐ Father
   ☐ Other, please specify ___________________

61. What is the child's biological **mother's** height?
   _____ cm **or** _____ feet and inches

   a. Which of the following methods did you use to obtain this height measurement?
   ☐ Measured using a tape measure
   ☐ Guessed
   ☐ Other (e.g., looked at drivers licence): _________________________ (please specify)

62. What is the child's biological **father's** height?
   _____ cm **or** _____ feet and inches

   a. Which of the following methods did you use to obtain this height measurement?
   ☐ Measured using a tape measure
   ☐ Guessed
   ☐ Other (e.g., looked at drivers licence): _________________________ (please specify)

63. What is your marital status?
   ☐ Married
   ☐ Living common-law
   ☐ Widowed
   ☐ Separated
   ☐ Divorced
   ☐ Single, never married

64. Are there any other adults living in your home? ☐ Yes ☐ No **If no, please go to question 66.**

65. **If yes**, please state their relationship to your child (e.g. stepfather, grandmother):

   ____

Parent Movement Behaviours

66. **In the last seven days, how much of your free time did you spend reading books, magazines or newspapers, including in electronic formats? Include time spent reading as part of your homework, but do not include time spent reading at work, during class time, while travelling in a vehicle or while exercising.?**

___________ Hours AND ___________ Minutes

67. In the last seven days, how much of your free time did you spend watching TV, DVDs, movies or Internet videos? Do not include time spent watching while exercising.

___________ Hours AND ___________ Minutes

68. In the last seven days, how much of your free time did you spend playing video games that require physical activity, such as Wii® Fit, Xbox® Kinect or the game "Just Dance"?

___________ Hours AND ___________ Minutes

69. In the last seven days, how much of your free time did you spend playing other video or computer games? Include games played on a game console, computer or hand-held electronic device such as a tablet or smart phone.

___________ Hours AND ___________ Minutes

70. In the last seven days, how much of your free time did you spend on a computer, tablet or smart phone, doing activities such as using the Internet, emailing, using Facebook® or doing homework? Do not include time spent at work, during class time or while travelling in a vehicle.

___________ Hours AND ___________ Minutes

71. Think about your mobile phone usage, do you agree or disagree with the following statements?

	Strongly Disagree		to			Strongly Agree
	1	2	3	4	5	6
When my mobile phone alerts me to indicate new messages, I cannot resist checking them	☐	☐	☐	☐	☐	☐
I often think about calls or messages I might receive on my mobile phone	☐	☐	☐	☐	☐	☐
I feel like I use my mobile phone too much	☐	☐	☐	☐	☐	☐

72. On a typical day, about how many times do the following devices interrupt a conversation or activity you are engaged in with your child?

	None			to			More than 20 times
	0	1	2	3	4	5	6
Cellphone/ Smartphone	☐	☐	☐	☐	☐	☐	☐
Television	☐	☐	☐	☐	☐	☐	☐
Computer	☐	☐	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐	☐	☐
iPod	☐	☐	☐	☐	☐	☐	☐
Video game console	☐	☐	☐	☐	☐	☐	☐

73. On average, how long do you usually sleep per night at the moment?

___________ Hours AND ___________ Minutes

74. On average, how long do you usually nap **during the day** at the moment?

___________ Hours AND ___________ Minutes