PHYSICAL ACTIVITY AND PHYSICAL LITERACY IN CHILDHOOD

FROM PRESCHOOL TO SCHOOL-AGE: PHYSICAL ACTIVITY, PHYSICAL LITERACY AND HEALTH

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LAY ABSTRACT

Kids who are active every day will be healthier that those who aren't. Unfortunately, most Canadian kids are not active enough to be healthy. We still don't really know why some kids are active and some kids aren't active. We think that physical literacy might be the missing piece to help kids be more active as they grow. This thesis studied the links between physical literacy, physical activity and health in kids. We found that we could measure physical literacy well in school-age kids. We also found that physical literacy was linked to health in kids. Kids who were the most active as they grew had the highest physical literacy. We saw that boys were more active than girls as they grew. Kids should start being active as preschoolers to help develop physical literacy. We need more programs and activities for kids to be more active to help develop physical literacy.

ABSTRACT

Physical activity is associated with a host of health benefits across childhood. Despite this, most children are not engaging in enough physical activity to achieve health benefits, and there is growing evidence that lifelong physical activity habits may be established in childhood. Theories suggest that physical literacy may be associated with health benefits due to its reciprocal relationship with physical activity participation. The associations between physical literacy, physical activity and health in children remain largely unstudied. The purpose of this thesis was to explore the relationships between physical literacy, physical activity and health across early and middle childhood.

The first study assessed the measurement properties of the Physical Literacy Assessment for Youth Tools, an assessment battery for physical literacy. We determined that this assessment had acceptable internal consistency, construct validity, and offered unique perspectives of a child's physical literacy. We then determined that physical literacy was associated favourably with body composition, blood pressure, quality of life, and aerobic fitness in school-age children. Moderate-to-vigorous physical activity mediated the associations between physical literacy and aerobic fitness. Finally, the third study observed that physical activity trajectories from preschool to school-age were associated with school-age physical literacy.

These results highlight the importance of physical literacy in childhood, given its associations with physical activity and health indicators. Physical literacy was associated with favourable health indicators, supporting its position as a determinant of health. The participants in the lowest physical activity trajectory groups had the lowest physical literacy. These finds suggest that physical activity across early and middle childhood may

play a formative role in the development of physical literacy. Future work should determine if these results are applicable to other age groups, such as early years or adolescents, and if changes in physical activity over time are associated with changes in physical literacy over time.

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Lastly, I dedicate this thesis to my niece, Margot. Your lifelong physical literacy journey is just beginning, and I hope you always have fun HOPPing and SKIPping along.

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LIST OF ABBREVIATIONS

%BF	Percent Body Fat
%ile	Percentile
BIA	Bioelectrical impedance analysis
BOT-2	Bruininks-Oseretsky Test of Motor Proficiency Second Edition
BMI	Body mass index
CAMSA	Canadian Agility and Movement Skill Assessment
CAPL	Canadian Assessment of Physical Literacy
CPM	Counts per minute
DBP	Diastolic blood pressure
FFM	Fat free mass
HOPP	Health Outcomes and Physical activity in Preschoolers
HRQOL	Health-related quality of life
HRR	Heart rate recovery
ICC	Intraclass correlation coefficient
LPA	Light physical activity
MPA	Moderate physical activity
MVPA	Moderate-to-vigorous physical activity
PLAY	Physical Literacy Assessment for Youth
SKIP	School-age Kids health from early Investment in Physical Activity
SBP	Systolic blood pressure
VO_2peak	Peak oxygen uptake

VPA	Vigorous physical activity
YPHV	Years from peak height velocity

DECLARATION OF ACADEMIC ACHIEVEMENT

This thesis was prepared in the "sandwich thesis" format outlines in the McMaster University School of Graduate Studies Guide for the Preparation of Master's and Doctoral Theses, published in December 2016. Chapter 1 is an introduction, which describes the context and background information for the research chapters. Chapters 2, 3, and 4 include three original research papers for which the candidate is the first author. At the time of the thesis preparation, Chapter 2 was submitted for peer-review and appears in the thesis as submitted. Chapter 3 was published in a peer-reviewed journal and appears in the thesis as published. Chapter 4 is prepared in journal article format for submission. Chapter 5 is a discussion that concludes, summarizes and discusses the main findings of this research and implications for future work. The contributions of the candidate and coauthors are outlined below for each paper:

CHAPTER 2 (Study 1)

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Contributions

Conceived and designed the research: HATC, SRB, JC, BWT

Coordinated the study: NAD

Acquired and analyzed the data: HATC, NAD

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Drafted the manuscript: HATC

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CHAPTER 3 (Study 2)

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CHAPTER 4 (Study 3)

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CHAPTER 1: INTRODUCTION

1.1 Preamble

Physical activity participation is associated with numerous physical, social and mental health benefits across the lifespan (Warburton & Bredin, 2017). Low physical activity participation is linked to the development and progression of non-communicable chronic diseases, such as cardiovascular disease, obesity and diabetes (Warburton, Nicol, & Bredin, 2006). Chronically low physical activity participation in childhood and adulthood may lead to poor health outcomes in the future. There is growing evidence that physical activity patterns may start to be established in childhood, and early participation in appropriate amounts of physical activity is an important predictor of physical activity in adulthood (Telama et al., 2014). Despite decades of health promotion efforts in Canada, 28% of 3- to 4-year-olds, 53% of 5- to 11-year-olds and 69% of 12-to 17-year-olds are not participating in enough habitual physical activity to achieve health benefits (Chaput et al., 2017; Statistics Canada, 2019). Physical literacy has been proposed as the missing piece in physical activity promotion, as theories suggest that physical literacy is the foundation for lifelong participation in physical activity (Jurbala, 2015).

Physical literacy goes beyond physical activity participation and describes the confidence, motivation, physical competence, knowledge and understanding to engage in physical activity for life (International Physical Literacy Association, 2014). Physical literacy was recently theorized as a health indicator through its reciprocal relationship with physical activity, which stimulates positive psychological, social and physiological adaptations, and ultimately leads to numerous health benefits (Figure 1-1; Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019). As it relates to this thesis, the associations between physical literacy and several health indicators (body composition, blood pressure, quality of life, and aerobic fitness) will be examined, and it will be assessed if physical activity participation mediates these associations. Limited cross-sectional research has concluded that physical literacy is positively associated with physical activity in children and youth (Belanger et al., 2018; Bremer et al., 2019; Stearns, Wohlers, McHugh, Kuzik, & Spence, 2018), indicating that higher levels of physical literacy are associated with higher participation in physical activity, but more research is needed to explore this relationship using objective measures of physical activity (i.e. accelerometers) and in other age groups (i.e. early years and adolescence). Experimental

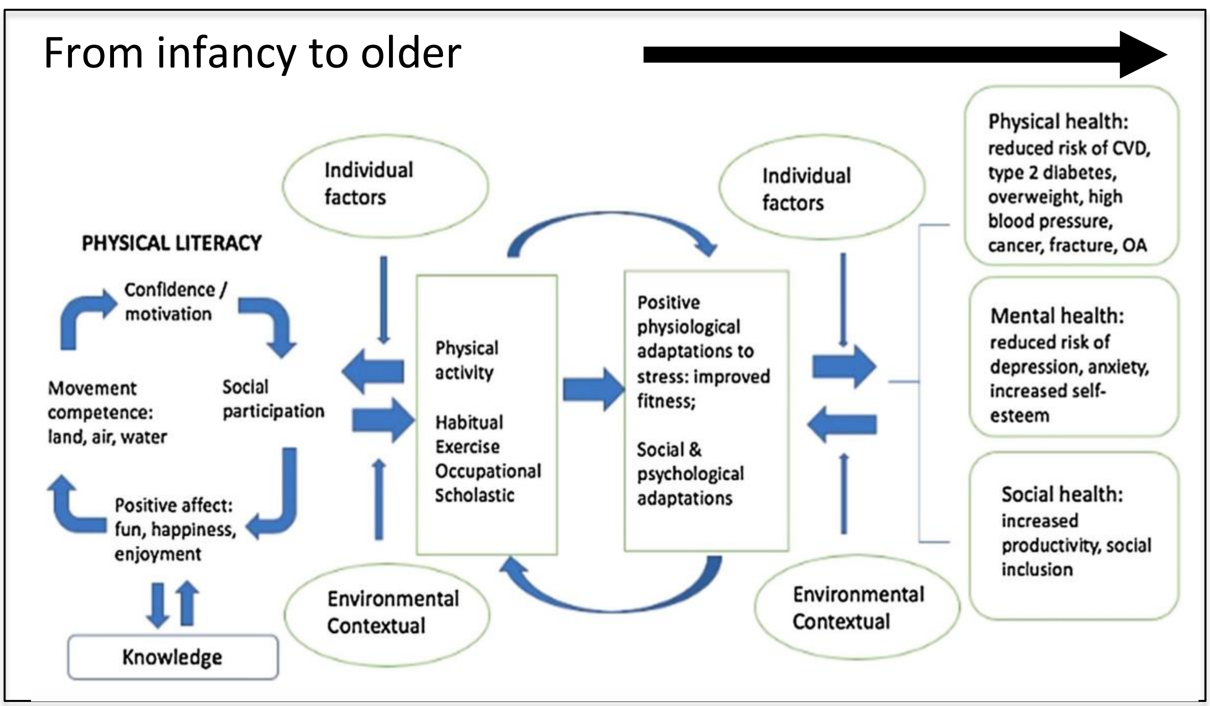

Figure 1-1. Conceptual model linking physical literacy, physical activity and health (adapted from Cairney et al. 2019).

and longitudinal studies are necessary to determine causality between physical activity and physical literacy. As the quantity and quality of research on physical literacy grows, its importance in physical activity promotion is being recognized.

In *'Let's Get Moving*--A common vision of increasing physical activity and reducing sedentary living in Canada', physical literacy is identified as one of five independent principles that is foundational to increasing physical activity and reducing sedentary living. The report describes that physical literacy results in more opportunities for physical activity, and that all governments, organizations, communities and leaders should recognize and promote physical literacy as an essential part of childhood development, like numeracy or literacy (Government of Canada, 2018). There is little evidence about how physical literacy is associated with physical activity in childhood, and even less evidence about the associations between physical literacy and health. Given the proposed links between physical literacy, physical activity and health, and the large research gaps on this topic, this thesis will investigate the relationships between physical literacy, physical activity and health in childhood.

1.2 Defining childhood age groups

In this thesis, the term preschooler refers to 3- to 5-year-olds and school-aged children refers to 6- to 13-year-olds. Adolescent refers to 14- to 19-year-olds.

1.3 Physical Literacy

There are several physical literacy definitions available and the differences, for the most part, are minimal. It is helpful to review multiple definitions and explanations to aid in the understanding of the concept. Canada's Physical Literacy Consensus Statement was released in June 2015 and adopted the International Physical Literacy Association's definition of physical literacy as "*the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life"* ("Canada's Physical Literacy Consensus Statement," 2015; International Physical Literacy Association, 2014). This definition is based on how Margaret Whitehead described physical literacy previously (Whitehead, 2010). More recently, Sport Wales described it as *"physical literacy= physical skills + confidence + motivation + lots of opportunities"* (Sport Wales, 2019).

In her text *Physical Literacy throughout the Lifecourse,* Whitehead describes 6 attributes of physically literate individuals, with the reminder that physical literacy is relevant to all individuals and whatever culture in which they live (Whitehead, 2010). Examples of these attributes include:

- *"Individuals who are physically literate will move with poise, economy and confidence in a wide variety of physically challenging situations;*
- *Physically literate individuals will be perceptive in 'reading' all aspects of the physical environment, anticipating movement needs or possibilities and responding appropriately to these with intelligence and imagination;*
- *These individuals will have a well-established sense of self as embodied in the world. This, together with an articulate interaction with the environment, will engender positive self-esteem and self-confidence; and,*
- *Physically literate individuals will have the ability to identify and articulate the essential qualities that influence the effectiveness of their own movement performance, and will have an understanding of the principles of embodied health with respect to basic aspects such as exercise, sleep and nutrition"*

Lastly, Whitehead describes the interrelationships between attributes of physical literacy. It is suggested that motivation encourages participation in physical activity, enhancing confidence and physical competence, which facilitates movement and physical activity in a variety of environments and contexts. In turn, this will result in an enhancement in motivation to take part in physical activity, and the cycle continues (Whitehead, 2010). Canadian researchers have proposed that physical literacy encompasses the foundational characteristics, behaviours, skills, knowledge and understanding related to healthy active living across the lifespan (Tremblay & Lloyd, 2010).

In a systematic review of physical literacy's defining properties, physical literacy was most frequently conceptualized as the interactive and simultaneous consideration of competence in physical skills, confidence, motivation, and valuing physical activity or movement (Edwards, Bryant, Keegan, Morgan, & Jones, 2017). In another review, the core elements of physical literacy were identified as physical, psychological, behavioral, social, reading/ interacting with the environment and the lifelong journey (Martins et al., 2020). Canada's Physical Literacy Consensus Statement identifies four elements related to physical literacy: motivation and confidence (affective), physical competence (physical), knowledge and understanding (cognitive), and engagement in physical activities for life (behavioural) ("Canada's Physical Literacy Consensus Statement," 2015; Tremblay, Costas-Bradstreet, et al., 2018).

Lastly, the Physical Literacy Consensus Statement includes five core principles that underlie the definition of physical literacy:

- *"an inclusive concept accessible to all;*
- *represents a unique journey for each individual;*
- *can be cultivated and enjoyed through a range of experiences in different environments and contexts;*
- *needs to be valued and nurtured throughout life; and,*

- *contributes to the development of the whole person"* ("Canada's Physical Literacy Consensus Statement," 2015).

Given the many definitions for physical literacy, this thesis will reference the International Physical Literacy Association's definition that "*physical literacy is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life"* (2014). Moving forward, the components mentioned in this definition will be referenced.

1.3.1 Measurement of Physical Literacy

As interest and enthusiasm for physical literacy has grown, so has research and practice about the measurement of physical literacy. Whitehead suggests that physical literacy is best measured more than once, and that its progress should be assessed over time (Whitehead, 2010). This approach reflects the theory that physical literacy is an individual lifelong journey. Valid and reliable measures of physical literacy are necessary to ensure it can be assessed accurately and similarly across settings and assessors to ease in the interpretation of results.

Canadian organizations have been leaders in the development of physical literacy assessments, and these have been adopted by researchers and practitioners in other countries. Each of these assessment batteries differ in target audience, target assessors, assessment time, materials, space requirement and assessment components; however, all three Canadian assessment batteries can evaluate the multiple domains of physical literacy (physical competence, confidence and motivation, and knowledge and understanding) (D. B. Robinson & Randall, 2017). Physical & Health Education Canada developed the Passport for Life to be specifically used in physical education settings and administered by teachers. Passport for Life is to be implemented in a gymnasium setting and can be set up to assess several students simultaneously. Passport for Life includes four components: active participation, living skills, fitness, and movement skills. The active participation and living skills components are assessed by self-report questionnaires that assess the confidence, motivation, knowledge and understanding domains of physical literacy. The fitness and movement skills components assess the physical competence domain of physical literacy and are assessed by teacher observation. This assessment is designed for students in grades 3 to 9, with future expansions planned for kindergarten to grade 2 and grades 10 to 12. All items are scored with a four-point scoring rubric: emerging, developing, acquired and accomplished (PHE Canada, 2020). In an early validation of Passport for Life, data were normally distributed for students in grade 4-5 and has satisfactory concurrent validity, such that the correlations between motor and fitness components were positive and significant. There was good scoring agreement between raters ($r=0.65-0.82$) and strong consistency in test re-test reliability (r=0.72-0.89) (Lodewyk & Mandigo, 2017)

The second Canadian physical literacy assessment is the Canadian Assessment of Physical Literacy (CAPL), designed by the Healthy Active Living and Obesity Research Group at the Children’s Hospital of Eastern Ontario to provide a valid, reliable and informative tool to monitor the physical literacy of Canadian children. The CAPL combines existing, validated measures of motivation and confidence, fitness and physical activity with novel CAPL-specific assessments of motor skill proficiency, knowledge and understanding to create four domains: physical competence, daily behaviour, knowledge and understanding, and motivation and confidence (Longmuir et al., 2015). Based on confirmatory factory analysis with CAPL data on 10,000 Canadian children and youth, the CAPL was updated to become the CAPL-2, a shorter version with new weights for the individual domains. The results suggested the CAPL-2 was a more appropriate assessment for the individual physical literacy domains and an overall physical literacy score than the original version (Gunnell, Longmuir, Barnes, Belanger, & Tremblay, 2018). To assess Physical Competence, the following assessments are completed: shuttle run test, Canadian Agility and Movement Skill Assessment (CAMSA), and a plank. Daily Behaviour is assessed with questionnaires and 7 days of physical activity monitoring with a pedometer. The Knowledge and Understanding Domain and Motivation and Confidence Domain are assessed with self-report questionnaires (Longmuir et al., 2018). Descriptive and normative data for CAPL are available from a Canadian multi-site study of over 10,000 8- to 12-year-old children to allow for comparisons between across studies (Tremblay, Longmuir, et al., 2018).

The third measure, the Physical Literacy Assessment for Youth (PLAY) Tools, represent a large suite of assessments that together provide a comprehensive assessment of an individual’s physical literacy (Sport for Life, 2013). The PLAY Tools were produced by Sport for Life to assess physical literacy of children and youth 7 years and older and include PLAYfun, PLAYbasic, PLAYself, PLAYparent, PLAYcoach and PLAYinventory. PLAYfun, PLAYbasic, PLAYparent and PLAYself were used to assess physical literacy in this thesis (see Appendix C for copies of PLAYfun, PLAYbasic, PLAYparent and PLAYself). PLAYfun is an 18-item assessment of fundamental skills/tasks, such as running, throwing, kicking and balance to assess physical competence and is administered by a trained professional (i.e., exercise physiologist, physical educator, coach, kinesiologist). PLAYfun includes 5 domains of skills: running, locomotor, object control—upper body, object control—lower body and balance, stability and body control. PLAYbasic, a 5-item simplified version of PLAYfun that includes one skill from each domain, provides a snapshot of a child's physical competence. PLAYfun and PLAYbasic are scored with a 100mm holistic visual analogue scale (VAS) that is divided into four categories: initial, emerging, competence, and proficient. Each skill is scored from 0 to 100 and the scores are averaged to produce the domain or total scores. PLAYself is a 1-page questionnaire used by children and youth to assess their own physical literacy and includes 4 sections: environment, physical literacy self-description, relative ranking of literacies, and fitness. PLAYparent is a 1-page questionnaire used by parents to assess their child's level of physical literacy and includes 5 sections: physical VAS, cognitive domain, environment domain, motor competence domain and fitness. PLAYself and PLAYparent assess the motivation, confidence, knowledge, understanding and valuing physical activity components of physical literacy. The PLAY Tools scoring sheets, instructions and workbooks are all available directly from Sport for Life (https://physicalliteracy.ca/play-tools/).

Stearns et al. examined the measurement properties of PLAYfun in a sample of 59 children and youth ages 9.0-to 14.1-years old from 2 northern communities in Canada, while Cairney et al. examined the measurement properties of PLAYfun in a sample of

215 children ages 6.5-to 14.1-years-old from several after-school programs in Ontario (Cairney et al., 2018; Stearns et al., 2018). Cairney et al. reported good inter-rater reliability with an intraclass correlation coefficient (ICC) of 0.87 across all PLAYfun items. Stearns et al. investigated the inter-rater reliability at two timepoints, across PLAYfun total score (ICC=0.78-0.90), PLAYbasic (ICC=0.72-0.88) and PLAYfun domain scores (ICC=0.55-0.87). The internal consistency of PLAYfun with Cronbach's alpha was considered acceptable, with higher consistency in the overall PLAYfun scale versus PLAYbasic or domain scores (Stearns et al., 2018). Using confirmatory factor analysis, it was determined that PLAYfun measures multiple aspects of land-based movements (running, locomotor, object control and balance) and distributions of scores within each domain are reasonably normally distributed (Cairney et al., 2018). PLAYfun scores increased with age in 6-to 14-year old children, as developmentally expected, and boys scored higher than girls on upper and lower body object control skills, confirming the construct validity of PLAYfun (Cairney et al., 2018). To assess convergent validity, Stearns et al. observed moderate-to-large correlations between PLAYfun and the CAPL CAMSA obstacle course (Stearns et al., 2018). Criterion validity of physical literacy assessment tools has not been established because a gold standard has not been identified in the literature. Convergent validity between PLAYfun and physical activity (assessed with pedometers) was also supported by the results of study that included 110 7-to 14-year old children (Bremer et al., 2019). These three studies have contributed greatly to what is known about the measurement properties of PLAYfun; however, additional research is necessary to determine measurement properties of PLAYbasic, PLAYparent

and PLAYself, and if the established indicators of reliability and validity hold true in other samples. Chapter 2 (Study 1) of this thesis builds on these foundations by further examining the psychometric properties of PLAYbasic, PLAYfun, PLAYparent and PLAYself in school-age children.

The PLAY Tools were chosen for use in this thesis for several reasons. Due to time and space restrictions, Passport for Life or CAPL were not feasible for use in these studies. Physical literacy assessments were added to an on-going longitudinal study that collected data on children's physical activity, fitness, motor skill proficiency, body composition, psychosocial health and cardiovascular health over six timepoints across the preschool and school-age years (Proudfoot et al., 2019; Timmons, Proudfoot, MacDonald, Bray, & Cairney, 2012). As such, a physical literacy assessment that did not replicate the ongoing assessments was necessary (such as physical activity or fitness assessments), and we were limited to the indoor space in our laboratory and surrounding area. PLAYfun was completed in our exercise laboratory and nearby hallway, and only added about 10-15 minutes to the study's existing 2-3 hour study visit protocol. PLAYparent was quick (5-10 minutes) for parents to complete on paper at the visit or at home, if necessary. PLAYself was also quick (5-10 minutes) for participants to complete during the study visit. PLAYfun and PLAYbasic provide a comprehensive assessment of physical competence that utilizes greater variability in scores and avoid ceiling effects. PLAYfun, PLAYparent and PLAYself were used in Study's 1, 2, and 3, and PLAYbasic was included in Study 1. To better represent the multiple domains of physical literacy included in common definitions of physical literacy (Edwards et al., 2017), a composite score of PLAYfun, PLAYparent and PLAYself was generated for use in Studies 2 and 3. In all, the PLAY Tools provided us with a comprehensive assessment of physical literacy that was appropriate to add to the ongoing SKIP Study, based on the study population, space availability, and the time needed to complete the assessments.

1.4 Physical Activity

1.4.1 Definition of Physical Activity

Physical activity is any bodily movement, produced by skeletal muscles, that increases energy expenditure (Caspersen, Powell, & Christenson, 1985) and is a complex health behaviour with a wide range of benefits from early childhood to adolescence (Carson, Tremblay, & Chastin, 2017; Poitras et al., 2016). In children and youth, physical activity is made up of several domains, including: active transportation, school physical activity, physical education, recess, active play & leisure-time activities, organized sports or clubs and outdoor play (Brusseau, Fairclough, & Lubans, 2020). Physical activity exists on a continuum from light to vigorous intensity (Eather N, Ridley K, & Leahy A, 2020), while the most research in children and youth has highlighted that moderate-to-vigorous physical activity (MVPA) (Poitras et al., 2016).

1.4.2 Physical Activity Guidelines & Current Trends

Physical Activity Guidelines have been developed in numerous countries (e.g., United States of America, Canada, Australia), in addition to the World Health Organization's recommended levels of physical activity (World Health Organization, 2010). The goal of physical activity guidelines is to provide a structured and systematic set of evidence-informed recommendations to help guide the public in how to engage in this health behaviour. Physical activity guidelines can also be used to help increase people's awareness of the health benefits provided by engaging in physical activity, and can be used as a set of measurable indicators to be tracked over time in a population (Brusseau et al., 2020). In Canada, the Physical Activity Guidelines are now part of larger recommendations, referred to as 24-Hour Movement Guidelines that encompass sleep, sedentary time, light physical activity (LPA) and MVPA (Tremblay et al., 2016, 2017). The specific physical activity guideline for preschoolers (aged 3-4 years) is "at least 180 minutes spent in a variety of physical activities spread throughout the day, of which at least 60 minutes is energetic play—more is better" (Tremblay et al., 2017). For children and youth (aged 5-17 years), the physical activity guidelines recommend "an accumulation of at least 60 minutes per day of MVPA involving a variety of aerobic activities. Vigorous physical activities (VPA), and muscle and bone strengthening activities should be performed at least 3 days a week", in addition to "several hours of a variety of structured and unstructured LPA" (Tremblay et al., 2016). Meeting physical activity guidelines is associated with numerous health benefits, as outlined in the following section.

The Global Matrix 3.0 Physical Activity Report Card for Children and Youth reported that only about 30% of children and youth from 49 countries met the recommendation of 60 minutes of daily MVPA (Aubert et al., 2018). Among Canadian children and youth, daily minutes of MVPA decreased in 8- to 10-year-old girls and increased in 11- to 14-year-old boys from 2007 to 2017. There were no temporal changes in MVPA in 8-to 10-year old boys, 11- to 14-year old girls, or 15-to 19-year old boys or girls (Colley et al., 2019). While physical activity levels have not changed drastically in the last 10 years, participation rates remain low. In the most recent Canadian reports, 62% of 3- to 4-year-old, 47% of 5- to 11-year-old, and 31% of 12-to 17-year old children and youth are meeting the physical activity guidelines for their respective age groups (Chaput et al., 2017; Statistics Canada, 2019). The low physical activity levels of children and youth in Canada, and globally, are worrisome and more work is required to understand physical activity participation across childhood.

1.4.3 Measurement of Physical Activity

In research studies, physical activity measurement methods need to be appropriately chosen for the research question at hand, to accommodate the study's resources and funding availability, and be suitable for the study population (Fairclough & Noonan, 2020). Child and youth physical activity is intermittent in nature and children spend varying amounts of time being sedentary or engaging in physical activity at various intensities throughout the day (Carson, Tremblay, Chaput, Mcgregor, & Chastin, 2019). Because of this, the measurement of physical activity in children and youth needs to accurately capture the frequency, duration and intensity of physical activity throughout the day.

Child and youth physical activity can be measured subjectively, with self or proxy report questionnaires. This method provides the easiest and cheapest way to assess physical activity, but provides the least accurate results in terms of energy expenditure or volume of physical activity. Objective measures, such as direct observation, indirect calorimetry or doubly labelled water, have the highest accuracy, but are the most expensive and complex to use (Fairclough & Noonan, 2020). Devices, particularly accelerometers, have become a common tool to objectively measure the habitual, free-living physical activity of various intensities over several days or weeks (Troiano, McClain, Brychta, & Chen, 2014; Trost, 2001, 2007). While pedometers are cost-effective and can measure the frequency of movement, they cannot assess the intensity of physical activity, and most lack real-time data storage and downloading capabilities (Trost, 2007). Data collection and processing methods need to be considered to ensure methods are feasible, reliable and valid for the population of interest.

Accelerometers are considered the most promising tool to assess free-living physical activity in children and youth (Trost, 2007). An accelerometer is a small, unobtrusive, wearable device that measures the magnitude and volume of movement, when applied to the measurement of physical activity. ActiGraph devices are the most widely-used research-grade accelerometers (Bassett, Rowlands, & Trost, 2012; Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013; Trost, 2007). A number of considerations are needed to use accelerometers to measure free-living physical activity in children and youth, including the model, epoch length, non-wear time definitions, minimum wear time, and cut-points (Cain et al., 2013). In the device, accelerations create forces, which generate an electric charge relative to the magnitude of the acceleration. The forces are measured at a predetermined interval every second and averaged over a pre-defined measurement period, known as an epoch (Cliff, Reilly, & Okely, 2009). Accelerometers can be used to measure the frequency, intensity, and duration of physical activity over specific time intervals, such as days or weeks (Trost, 2007). The data collected with Actigraph monitors is filtered by a standard proprietary algorithm that eliminates any acceleration noise or spurious counts outside of a normal human activity frequency bandwidth to ensure it is only capturing true sedentary time and physical activity.

There has been rapid development in the field of physical activity measurement with accelerometry, resulting in an overwhelming amount of data collection and processing options available to researchers (Migueles et al., 2017). For children, accelerometers are most often attached to a belt, worn over the right hip because the trunk generates the most physical activity related energy expenditure versus wearing the device on the wrist, for example (Cliff et al., 2009; Migueles et al., 2017). Accelerometers can measure movement in either the vertical plane (uniaxial) or three planes (triaxial). Uniaxial and triaxial accelerometers give similar classifications for different PA intensities in preschoolers (Adolph et al., 2012), children (Ojiambo et al., 2012), and adolescents (Vanhelst et al., 2012). Uniaxial accelerometers have been validated and calibrated for use with preschoolers (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006) and school-age children (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008). For this reason, this thesis will focus on uniaxial accelerometer data collected in the vertical plane. This will allow the results of the study to be compared to previous research that used similar methods.

Accelerometry has been used to extensively to measure physical activity in preschoolers, children and youth, but does require several considerations. Most studies of physical activity in preschoolers and children use shorter epochs ($\leq$ 15 seconds) to capture the sporadic nature of children's physical activity (Migueles et al., 2017). Physical activity is then quantified as the activity counts per epoch, and these counts can then be classified as LPA, moderate physical activity (MPA) or VPA, using age-appropriate thresholds or cut-points. Physical activity can also be quantified without cut-points as counts or counts per minute (CPM), allowing for comparison of physical activity across age-groups when using age-appropriate cut-points is not feasible. For the measurement of physical activity in preschoolers, the Pate et al. cut-points are recommended, while the Evenson et al. cut-points are recommended for children and youth (Evenson et al., 2008; Migueles et al., 2017; Pate et al., 2006; Trost, Loprinzi, Moore, & Pfeiffer, 2011)

Another measurement consideration, wear-time, refers to the minimum number of days and hours per day that an accelerometer needs to be worn to represent habitual physical activity, and is considered the minimum amount of physical activity data needed for a participant to be included in analyses (Cliff et al., 2009). Wear-time criteria vary from study to study, and is calculated by subtracting non-wear time from 24 hours (Colley et al., 2013). Previous research has found that the reliability of wear time increases as the minimum number of days and daily wear time increases, as demonstrated in a sample of 9772 7-year-old children. Reliability was highest (r=0.90) when accelerometers were worn for ≥ 10 hours per day on ≥ 3 days (Rich et al., 2013). In addition to wear-time for the entire day, periods of non-wear time need to be considered. A variety of non-wear time periods have been used in previous studies, and it is suggested that a longer period of non-wear time, such as 60 minutes, retains more participants in the analysis (Toftager et al., 2013). In summary, accelerometers are a valid, reliable method to assess physical activity in children and youth, but do require several measurement considerations to ensure measurement is as accurate as possible.

1.4.4 Longitudinal changes in physical activity in childhood

There is growing evidence of the longitudinal changes in physical activity across early childhood, school-age years and adolescence. Several studies have previously published data on changes in physical activity with the same cohort of children included in this thesis. MVPA increased 4.2 minutes/day, while TPA was unchanged over 1 year in 3 to-5-year-old children. Both TPA and MVPA exhibited fair-to-moderate tracking over 1 year, suggesting physical activity habits are not yet "set" in the early years (Caldwell et al., 2016). With the same cohort, it was observed that VPA increased over 2 years, with the greatest changes seen in children with the highest motor skills (King-Dowling, Proudfoot, Cairney, & Timmons, 2020). Lasltly, trajectories of physical activity over 2 years in early childhood favourably impacted trajectories of cardiovascular fitness and arterial stiffness in the early years (Proudfoot et al., 2019). These preliminary findings suggest physical activity patterns are not yet established and are associated with motor skills and heart health in the early years. Building on these studies, this thesis reports on the longitudinal trajectories of physical activity across the preschool and school-age years.

A recent systematic review examined the longitudinal changes in accelerometer-measured MVPA across childhood and adolescence (2 to 18 years of age) (Farooq et al., 2020). On average across all age-groups, MVPA decreased by 3.4 mins/day per year, but there was variability across studies that ranged from -63 to +21 min/day of MVPA. MVPA began declining at age 6 in boys and 8 girls, with the greatest declines occurring at age 9. (Farooq et al., 2020). Similar changes were reported in another systematic review of physical activity changes during adolescence, with an average annual -7% change across adolescence. The declines in girls were greater in younger ages (9-12 years), but greater in boys in older ages (13-16 years) (Dumith, Gigante, Domingues, & Kohl, 2011). In a study of young children, MVPA increased from 19 months to 5 years, with concurrent declines in sedentary time and LPA. No sex differences in trajectories were observed in these young children (Hnatiuk, Lamb, Ridgers, Salmon, & Hesketh, 2019).

In recent years, studies have applied group-based trajectory modeling to examine the trajectories of physical activity across childhood. This method identifies subgroups of individuals whose physical activity follows a similar pattern of behaviours over time (e.g., increase, decrease or maintain physical activity over time) (Pate, Schenkelberg, Dowda, & McIver, 2019). By identifying the typical patterns of physical activity across childhood, this can inform how physical activity programs and initiatives may target various ages differently (Hnatiuk et al., 2019). In a sample of 600 children and youth followed from age 10 to 16 years, overall physical activity declined in the sample, but not all participants followed this trajectory. Three trajectories were identified within the sample: group 1's (n=27) physical activity remained high over time with increases from age 14 to 16 years, group 2 (n=365) started with similar physical activity to group 1, but declined and remained consistency lower across time, and group 3 (n=260) had the lowest physical activity at all times and declined from age 10 to 16 years. Interestingly, group 1 was predominantly male (78%), while group 3 was predominantly female (75%), suggesting sex is an important determinant of changes in physical activity from elementary to high school (Pate et al., 2019). A 2018 study aimed to identify the timing of changes in physical activity in a sample of 545 children from ages 7 to 15 years, citing that most previous research suggested physical activity declines begin in adolescence. This study observed that physical activity began to decline at age 7 and continued to decline into adolescence. The changes in physical activity were observed with group-based trajectories, and a small proportion of the boys (18%) increased physical activity while the remaining groups of boys and the groups of girls decreased physical activity over time (Farooq et al., 2018). In summary, previous research suggests that volume of physical activity increases in the preschool years, and then begins to decline in the school-age years and continues to decline into adolescence. However, studies that utilized group-based trajectory analyses have shown that groups of children follow different trajectories of physical activity across childhood, and that physical activity does not decline in all children. It appears that girls are less active than boys from a young age, and girls are more likely to follow a declining or low physical activity trajectory than boys. Future work should investigate the characteristics of why some children increase, decrease, or maintain physical activity across childhood. For example, physical literacy may be associated with physical activity trajectory group membership but has not been previously studied.

1.4.5 Benefits of Physical Activity Participation

The World Health Organization estimates that 3.2 million deaths worldwide are attributable to physical inactivity, making it the fourth leading risk factor for global mortality (World Health Organization, 2010). Physical activity promotion is an essential public health and health promotion strategy to improve child health (World Health Organization, 2010), and the health benefits of physical activity for children and youth, from toddlers to adolescents, have been well documented in several systematic reviews (Carson, Lee, et al., 2017; Janssen & Leblanc, 2010; Poitras et al., 2016; Timmons, LeBlanc, et al., 2012).

Comprehensive systematic reviews examining the relationships between physical activity and health in the early years were carried out to guide the development of the current 24-Hour Movement Guidelines for the Early Years and the previous Physical Activity Guidelines for the Early Years (Carson, Lee, et al., 2017; Timmons, LeBlanc, et al., 2012). In the most recent review, 80/96 (83%) studies included preschool samples while the remainder included infants and toddlers, and 38 (40%) studies measured physical activity objectively, while the remaining studies used proxy-report questionnaires, logs, or interviews (Carson, Lee, et al., 2017). In experimental studies, over 60% of studies reported an association between physical activity and improved motor development, cognitive development, psychosocial health, or cardiometabolic health. Furthermore, physical activity was consistently associated with fitness, bone, and skeletal health. Physical activity was not consistently associated with adiposity, and a meta-analysis of four studies reported no significant difference between intervention and control groups for body mass index (BMI) following a physical activity intervention

(Carson, Lee, et al., 2017). The results of these reviews highlight that preschoolers can benefit from increased physical activity participation, and many of the same benefits have been observed in older children and youth.

A 2016 systematic review summarized the results of 162 studies about the relationships between objectively measured physical activity (accelerometers, heart rate monitor, pedometer, arm band) and 11 health indicators in children and youth (Poitras et al., 2016). Physical activity was associated with favourable measures of adiposity, several cardiometabolic biomarkers, aerobic fitness, muscular strength and bone health. There was some evidence to suggest that physical activity was associated with favourable motor skill development, quality of life, and psychological distress, but results were not consistent. While it was observed that physical activity of all intensities (light, moderate and vigorous) was associated positively with health indicators, higher intensity physical activity (moderate and vigorous) had more consistent associations with health indicators than LPA. Twelve of the studies in this review examined the health benefits associated with meeting the physical activity guidelines of 60 daily minutes of MVPA. It was found that meeting the guidelines was associated with favourable adiposity and quality of life, while the associations with cardiometabolic markers or bone density were unclear. The associations between meeting the guidelines and other health indicators, such as fitness and motor skill development, were not assessed (Poitras et al., 2016). An earlier systematic review of 86 studies examined the associations between physical activity, fitness, and health in children and youth and concluded that there is a dose-response relationship between physical activity participation and health benefits. The authors of this review suggested that VPA may provide additional health benefits compared to lower intensity physical activity (Janssen & Leblanc, 2010).

In summary, there is substantial cross-sectional evidence to support physical activity as a behaviour to benefit health indicators across childhood, and MVPA appears to be associated with greater health benefits than LPA. It remains to be determined if physical literacy is also associated with health in childhood, and the role of physical activity in these relationships.

1.6 Health Indicators in Childhood

Given the previously outlined health benefits of physical activity, various health indicators that are referenced in thesis will be outlined and described.

1.6.1 Body Composition

1.6.1.1 Definition

Body composition is a health-related component of physical fitness that is related to the relative amounts of muscle, fat, bone and other vital parts of the body (Caspersen et al., 1985). Weight status is often defined by an individual's BMI, a measure derived using an individual's weight (kg) divided by height (m^2). BMI describes weight status at both the individual and population levels because it reflects excess body fat and is simple to use (Barlow & Dietz, 1998). In this thesis, body composition will be represented by percent body fat (%BF) and BMI percentile (%ile). %BF is included as a health indicator in Study 2, and BMI %ile is used as a descriptive statistic in Studies 1, 2 and 3. BMI %ile and %BF are complementary and necessary measures to assess adiposity in childhood.

1.6.1.2 Importance

Children and youth who are overweight or obese are at an increased risk to be overweight or obese in adulthood (Singh, Rhodes, & Gauvreau, 2008) and at an increased risk of premature mortality (Reilly & Kelly, 2011; Ruiz et al., 2009). Additionally, children and youth who are overweight or obese are at a heightened risk for psychological problems, low self-esteem, behavioural problems and cardiovascular risk factors, such as high blood pressure (Reilly et al., 2003). Body composition in childhood is a predictor of cardiovascular disease risk factors, such as unfavourable blood lipids, in adulthood (Ruiz et al., 2009). Taken together, this demonstrates why monitoring adiposity and weight status throughout childhood is important. Recent Canadian data reported that 8% of preschoolers were overweight or obese, based on World Health Organization criteria (Chaput et al., 2017). In children and youth (5-to 17-years old), 20% were overweight and 10-13% were obese, based on World Health Organization cut-offs (Roberts, Shields, De Groh, Aziz, & Gilbert, 2012).

1.6.1.3 Measurement

In children, BMI is typically expressed using age- and sex-specific %iles or z-scores rather than absolute values. It can also be used to estimate body composition in preschool-aged children but it does not consider fat mass and fat free mass (Eisenmann, Heelan, & Welk, 2004). BMI cut-offs of ≥25 and ≥30 kg/m^2 are used to classify adults as overweight and obese, respectively, based on the health risks associated with these cut-points (T. J. Cole, Bellizzi, Flegal, & Dietz, 2000). BMI cut-offs are not as straightforward in children and because BMI incrementally rises with increasing age across childhood (Shields & Tremblay, 2010). Age and sex-specific growth curves are used to classify BMI in children to account for their rapid growth and development (T. J. Cole et al., 2000). At a certain BMI, %BF can vary greatly, limiting the use of BMI as an individual measure of body composition in children (Malina, Bouchard C, & Bar-Or, 2004). The Center for Disease Control has established growth curves with data from nationally representative American surveys (Kuczmarski & Ogden, 2002). Children who have a BMI < 5th %ile are considered underweight, ≥5th and <85th %ile are normal weight, ≥85th %ile are overweight and ≥95th %ile are considered obese (Kuczmarski & Ogden, 2002). This thesis uses these cut-off values to define BMI %ile and describe weight status of the study population.

% BF can be accurately measured in a laboratory setting using bioelectrical impedance analysis (BIA) (Houtkooper, Lohman, Going, & Hall, 1989). The BIA technique is based on the principle that an electric current flows through tissues with higher water and electrolyte contest quicker than tissue that is less hydrated, such as fat tissue (Nichols et al., 2206). The resistance, or impedance, value for BIA relates to the amount of fat free mass (FFM) in the body. FFM can be calculated using an equation that was validated against dual-energy x-ray absorptiometry in 6-to 13-year old children: (FFM= [(0.77(SexCode)]+[0.46(1-Age)]+[0.32(1-Avg Weight)]+[0.41(1-Avg Height^2)/(Resistance)-0.77)], where sex=0 for boys, 1 for girls. %BF was then calculated as [(body weight- FFM)/ body weight] x 100 (Kriemler et al., 2009).

In summary, %BF and BMI %ile are feasible to assess in children and youth in laboratory settings. The application of age and sex-specific percentiles for BMI and appropriate equations for assessment of %BF with BIA can help increase the accuracy of results.

1.6.2 Aerobic Fitness

1.6.2.1 Definition

Aerobic fitness, also referred to as cardiorespiratory fitness, is a health-related fitness attribute that refers to one's ability to perform dynamic, large muscle, moderate-to-vigorous intensity exercise for a prolonged period of time (Caspersen et al., 1985).

1.6.2.2 Importance of Aerobic Fitness

Aerobic fitness is considered a health indicator because it may be the most important risk factor in predicting cardiovascular disease risk in healthy children and adolescents (Hurtig-Wennlöf, Ruiz, Harro, & Sjöström, 2007). There is strong evidence that cardiorespiratory fitness in childhood and adolescence is a predictor of abnormal blood lipids, high blood pressure and adiposity later in life (Ruiz et al., 2009). A recent statement from the American Heart Association highlighted the important of cardiorespiratory fitness as an important marker of physical (cardiometabolic) health, mental health, cognitive health and academic performance in children and youth (Raghuveer et al., 2020). Cardiorespiratory fitness is influenced by both nonmodifiable (age, sex, genetics, race/ethnicity, prematurity) and modifiable (habitual physical activity and exercise training, sedentary time, obesity, diet, social, economic and environmental factors) factors. It is important to accurately and reliably measure aerobic fitness to identify youth who would benefit from lifestyle interventions but is often missed when current standards of care are used, including subjective physical activity assessment and anthropometrics (Raghuveer et al., 2020).

1.6.2.3 Measurement of Aerobic Fitness

The assessment of peak oxygen update (VO_{2peak}) is the gold standard to assess aerobic fitness. VO_{2peak} is the highest rate at which an individual can consume oxygen during exercise and the best single measure of aerobic fitness and cardiorespiratory function. In a laboratory, VO_{2peak} is assessed with a progressive exercise test to exhaustion (usually on a treadmill or bicycle) in which the exercise intensity is incrementally increased throughout the test (Armstrong & Welsman, 2008). Measurement of VO_{2peak} is done through indirect calorimetry during an exercise test, and necessitates participants wear a mask or mouthpiece and nose plug, a requirement that would likely frighten young participants, unless provided ample time for habituation. In children, it is common to conduct exercise tests without directly measuring VO_{2peak}, and to terminate the test when a child reaches his or her volitional exhaustion (McManus & Armstrong, 2018). It is generally preferable for children to use treadmills as walking and running engages a larger muscle mass than cycle ergometers, and $VO_{2\ peak}$ is typically 8-10% higher during treadmill running than cycling (Armstrong & Welsman, 2008). Walking and running tests use energy demand that is related to body weight, and children may not be limited by their smaller size (Simons-Morton, Parcel, O'Hara, Blair, & Pate, 1988).

The Bruce Protocol is commonly used to measure, predict and evaluate VO_{2peak} in a laboratory setting on a treadmill (Bruce, Kusumi, & Hosmer, 1973). It is an incremental protocol, and the treadmill increases in speed and grade every 3 minutes. Subjects continue to walk and run on the treadmill until a determined endpoint of fatigue (Bruce et al., 1973). While the Bruce Protocol does not require gas exchange measurements, it is still considered a maximal test because it does not have a predetermined, arbitrary endpoint—a trait more commonly associated with submaximal tests (Bruce, 1974). Maximal treadmill walking and running tests have been demonstrated as feasible with participants as young as 3 years of age (Caldwell et al., 2016; Cumming, Everatt, & Hastman, 1978; Van Der Cammen-Van Zijp et al., 2010). Normative time to exhaustion values for children aged 4-to-18 years of age (n=327), have been developed (Cumming et al., 1978) and were more recently reproduced with 263 boys and girls (Wessel, Strasburger, & Mitchell, 2001). The endurance times in the new normative data set are lower than those reported previously, but with similar peak heart rate values. Endurance time was highly reproducible (r=0.94) in a sample of 20 participants aged 7-to 13-years-old who completed two tests 3-10 days apart (Cumming et al., 1978).

Heart rate recovery (HRR) refers to the decrement of heart rate after exercise, and is a simple tool to assess cardiac autonomic activity (Peçanha, Silva-Júnior, & Forjaz, 2014). The decline in heart rate following cessation of exercise is primarily due to parasympathetic reactivation, followed by cardiac sympathetic withdrawal (Imai et al., 1994; Peçanha et al., 2014). As exercise begins, sympathetic activity increases, and heart rate rises proportionally to exercise intensity. A faster HRR following exercise cessation is considered a marker of good physical fitness, and possibly of habitual physical activity participation (Shetler et al., 2001). In a sample of 993 children and youth, HRR parameters were negatively correlated with metabolic risks. In boys, waist circumference was a significant predictor of HRR, and waist circumference, serum glucose levels, and systolic blood pressure (SBP) were significant predictors of HRR in girls (Lin et al., 2008). HRR is accelerated in endurance athletes, and delayed in patients with chronic heart failure, when compared to sedentary adults (Imai et al., 1994). In addition, a slower HRR after graded exercise was a predictor of mortality in healthy, older adult males (C. R. Cole, Blackstone, Pashkow, Snader, & Lauer, 1999). Children generally have a faster HRR than adults and it declines across childhood (Mimura & Maeda, 1989; Singh et al., 2008). The determinants of HRR were assessed in a sample of 5-to 8-year-olds who completed maximal exercise testing with the Bruce Protocol. Sixty-second HRR was attenuated with increasing age (girls: r=-0.51; boys: r=-0.54; p<0.001), while children with higher BMIs exhibited slowed 60-sec HRR (Singh et al., 2008). For example, the 50th percentile for 60-sec HRR in boys was 49 bpm in 9-to 10-year old children, 44 bpm for 11-to-12-year-old boys and 35bpm for 13-to 14-year-old boys. In a sample of preschoolers who completed the Bruce Protocol, the average 60-sec HRR value was 65 bpm (Proudfoot et al., 2019). For the purposes of this thesis we will be using Bruce Protocol treadmill time and 60-sec HRR as indicators of aerobic fitness.

1.6.3 Blood Pressure

1.6.3.1 Definition of Blood Pressure

Blood pressure is the pressure exerted by circulating blood against the walls of the blood vessels. As the heart’s ventricles contract, it creates pressure, which is measured in mmHg. SBP is the maximum pressure exerted on the arterial walls during ventricular systole (contraction), and diastolic blood pressure (DBP) is the pressure exerted during ventricular diastole (relaxation) (Scanlon & Sanders, 2015). Blood pressure is affected by a number of physiological factors and processes, including venous return, heart rate, peripheral resistance and blood volume (Scanlon & Sanders, 2015).

1.6.3.2 Importance of Blood Pressure as a Health Indicator

Resting blood pressure increases throughout childhood; therefore, age-adjusted blood pressure cut-offs must be used to determine if a child has elevated blood pressure (Sorof, 2001). In older adults, high SBP and DBP values were associated with heightened risk of myocardial infarction or stroke. SBP was associated with total mortality and was a better predictor of cardiovascular events than DBP (Psaty et al., 2001). In children, elevated SBP hypertension was more common than DBP hypertension (Sorof, 2001). It has been suggested that elevated blood pressure in children warrants action to prevent elevated blood pressure and cardiovascular disease in adulthood (Flynn, 2018).

1.6.3.3 Measurement of Blood Pressure

It is recommended that blood pressure in children be measured after a child has been seated in a quiet room for several minutes, with the back supported and feet flat on the floor. It should be measured in triplicate, in the right arm, with the arm supported and an appropriately sized cuff (Flynn et al., 2017). Normative blood pressure values are defined according to age, sex and height. For children aged 1-to 13-years old, elevated blood pressure is defined as SBP and/or DBP $\geq 90^{th}$ percentile to $<95^{th}$ percentile or $\geq 120/80$ mmHg to (whichever is lower) and hypertension is SBP and/or DBP $\geq 95^{th}$ percentile or $\geq 130/80$ mmHg (whichever is lower) (Flynn et al., 2017).

1.6.4 Health-Related Quality of Life

1.6.4.1 Definition of Health-Related Quality of Life

Health-related quality of life (HRQOL) is an important health outcome in health services research and evaluation. HRQOL measurements must be multi-dimensional, and concurrently assess an individual or proxy's perception of physical, mental and social health (Schwimmer, Burwinkle, & Varni, 2003). HRQOL was initially used to assess a patient's perception of the impact of disease and treatment in several health dimensions (Varni, Seid, & Kurtin, 2001). More recently, it has been tested and validated in children and youth as a population health and as a school population health measure (Varni, Burwinkle, & Seid, 2006; Varni et al., 2003).

1.6.4.2 Importance of HRQOL as a Health Indicator

In childhood, morbidity and mortality are not relevant health outcomes, but measuring HRQOL can aid in identifying children who are at risk for health problems by identifying concerns with physical, emotional or school functioning (Varni et al., 2003). Children with chronic conditions consistently report lower HRQOL than healthy children (Varni et al., 2003, 2001). In a study of 106 participants, obese children and adolescents reported significantly lower HRQOL in all domains, compared to normal weight children and adolescents (Schwimmer et al., 2003)

The difference in HRQOL scores between obese (67.0 ± 13.6) and normal weight (83.0 ± 14.8) children and adolescents was about 16 points (out of 100), based on self-reports. The difference in parent reports was 23 points (63.3 ± 19.2 versus 87.6 ± 12.1). The values for obese children and adolescents in this study were lower than the previously established cut-off of 69.7/100 for poor health using the PedsQL (69.7) (Varni et al., 2003). A systematic review about the associations between physical activity and HRQOL in children and adolescents reported small, positive associations between physical activity and HRQOL in both descriptive and experimental studies (Marker, Steele, & Noser, 2018). In one study, physical activity was a significant predictor of HRQOL, and this relationship was mediated by aerobic fitness in healthy school-age children (Gu, Chang, & Solmon, 2016). Lower HRQOL has been reported by hypertensive versus children with normal blood pressure measures (Petek, Hertiš, & Marčun Varda, 2018). Among 10-year-old children, HRQOL was positive associated with aerobic fitness, but not grip strength, explosive leg strength or waist circumference (Andersen et al., 2017). There is growing evidence to support the use of HRQOL as an important indicator of self-perceived health in children and youth.

1.6.4.3 Measurement of HRQOL

HRQOL can be assessed with a questionnaire and this thesis will focus on the Pediatric Quality of Life Inventory 4.0 (PedsQL 4.0), which can be completed by children as a self-report or by parents as a proxy-report. Children 8-years-old and older can generally self-report their assessment of HRQOL, while an interview is used for 5 to-7-year old children. A parallel parent-proxy report is also available (Varni et al., 2001).

The PedsQL 4.0 Generic Core Scales (23 items) assesses global HRQOL and can be used with children with and without acute or chronic health conditions, and was initially developed to distinguish between healthy children and children with chronic conditions (Varni et al., 2003). PedsQL 4.0 includes 8 physical functioning items, 5 emotional functional items, 5 social functioning items and 5 school functioning items. For each item, the instrument asks how much a problem it has been over the last month and the responses are as follows: 0=never a problem, 1=almost never a problem, 2=sometimes a problem, 3=often a problem, and 4=almost always a problem. Items are then reverse scored with higher scores representing better HRQOL. Items are then averaged to determine the total and domain scores, allowing for missing data (up to 50% missing is permitted). The Psychosocial Health Score represents the average of items in the Emotional, Social and School subscales (Varni et al., 2001).

With a diverse sample of 1700 children and parents, the feasibility, reliability and validity of the PedsQL was assessed (Varni et al., 2001). To determine feasibility, the number of missing items was calculated. For self and parent-proxy reports, 1.5% and 2.0% of responses were missing, respectively. A full range of scores for each item was reported, but distributions were skewed towards higher HRQOL. All scale and total scores demonstrated acceptable internal consistency (Cronbach's alpha=0.83-0.90), without being redundant. Construct validity was assessed as the difference in HRQOL between healthy, acutely ill and chronically ill children. All subscale and total scores, whether proxy or self-reports, were lowest for children with chronic conditions and highest for healthy children (Varni et al., 2001). To build on this research and determine if HRQOL can be used as a pediatric population health measure, the feasibility, reliability and validity were examined with over 10,000 families in California. For self-report, 1.8% of responses were missing, suggesting PedsQL is feasible. Cronbach's alpha values were 0.71-0.87 for self-report and confirms the instrument's internal consistency. Similar to the previously described study, healthy children reported higher values than children with chronic conditions. There were no significant differences in scores between boys and girls, and children ages 5-to 7-years old reported significantly lower scores than older children and adolescents. These results confirmed that it is appropriate to use the PedsQL 4.0 as a population health measure (Varni et al., 2003), in addition to its established role as an individual health scale (Varni et al., 2001). PedsQL is a feasible, valid and reliable measure to assess HRQOL in children, an important indicator of health.

1.7 Assessment of Motor/ Physical Competence

The physical competence domain of physical literacy can be assessed with various physical literacy specific assessment tools, including PLAYfun, the CAPL Physical Competence items and the Motor and Fitness Skills of Passport for Life (Gunnell et al., 2018; PHE Canada, 2020; Sport for Life, 2013). Previously, a variety of standardized assessment tools for gross motor competence were developed, tested and validated to identify, classify and diagnose motor problems (Griffiths, Toovey, Morgan, & Spittle, 2018). A traditional, standardized assessment of motor competence was used in this thesis, and the scores were compared to a novel assessment of physical competence, as part of a physical literacy assessment.

The Bruininks-Oseretseky Test of Motor Proficiency 2nd Edition (BOT-2) is an individually administered assessment that measures fine and gross motor skills of 4- to 21-year-olds. BOT-2 has both a short form that includes 14 items and takes approximately 15 minutes to administer. The 14 items represent the 8 subdomains of the full version: Fine Motor Precision, Fine Motor Integration, Manual Dexterity, Bilateral Coordination, Balance, Running Speed & Agility, Upper-limb Coordination and Strength). Each item on the BOT-2 is scored by a trained assessor and converted to a point score. The point score can then be converted to a sex-specific or combined standard score or percentile based on a child's chronological age (Bruininks & Bruininks, 2005). The BOT-2 has good test-retest (r>0.80) and inter-rater reliability (r>0.90) and acceptable internal consistency (α>0.80) (Deitz, Kartin, & Kopp, 2007; Griffiths et al., 2018). In addition, it is able to distinguish between non-clinical and clinical groups (such as developmental coordination disorder) in children and youth (Griffiths et al., 2018). Given the established reliability and validity of the BOT-2 to assess motor competence, it was an appropriate tool to compare to PLAYfun, as done in Study 1.

1.8 Measurement Properties

Researchers and practitioners should be aware of the measurement properties of any assessment tools they are using to assist with instrument selection and interpretation of results. If a tool has poor measurement properties, it may not be assessing what it purports to (Griffiths et al., 2018). This section will provide an overview of various measurement properties that will be referenced in this thesis.

Reliability refers to the degree to which an instrument is free from measurement error, or can be described as the proportion of the total variance in a measurement which is reflective of the true differences among participants (Mokkink et al., 2010). For example, if an assessment tool is used with similar participations in similar conditions, responses should be similar. Reliability can be assessed in several ways. Internal consistency, the degree of the interrelatedness among items in a scale, can be assessed using alpha or omega coefficients (Mokkink et al., 2010). Cronbach's alpha (α) is widely used to describe internal consistency and describes the split-half reliability of the scale, which is calculated by splitting the test in half and correlating the two parts. Alpha is affected by the number of items in a scale and may be less accurate if a scale has more items (such as 14 items (Streiner, Normal, & Cariney, 2015) or 20 items (Streiner, 2010)). It is suggested $\alpha \geq 0.70$ for early stages of research or $\alpha \geq 0.80$ for research tools is appropriate, while $\alpha \geq 0.90$ likely indicates redundancy in the scale (Streiner et al., 2015). In addition, alpha values for a scale are only relevant to the administration of that scale in that setting with that population; it is more a reflection of the administration of a scale rather than the tool itself (Streiner, 2010). As an alternative to alpha, McDonald's omega is considered a more robust index of internal consistency with less assumptions than alpha, and less problems with inflation of internal consistency (Dunn, Baguley, & Brunsden, 2014). For omega, the preferred benchmark is ≥ 0.75 (Reise, Bonifay, & Haviland, 2012). Inter-rater reliability describes the variation between 2 or more raters who assess the same group of subjects (Koo & Li, 2016). Inter-rater reliability can be assessed with an ICC and interpreted as <0.5 for poor reliability, 0.5-0.75 for moderate reliability, 0.75-0.9 for good reliability and >0.9 for excellent reliability (Koo & Li, 2016).

Another important measurement property of an instrument is validity, the degree to which an instrument measures what it purports to measure (Mokkink et al., 2010). More specifically, construct validity is the degree to which the scores on an instrument are consistent with hypotheses based on the assumption that the instrument validly measures what is intended to measure. For example, construct validity can be tested by examining associations between scores on an instrument and age and determining if associations are as expected based on theory and previous research. Convergent validity is a specific type of construct validity that assesses how closely a new instrument is related to other instruments that assess the same construct (Streiner et al., 2015).

Together, various measures of reliability and validity should be assessed when selecting a tool of instrument. If a tool is valid and reliable, researchers and practitioners be confident that they are accurately and consistently measuring what they intend to measure. If a tool is reliable and valid any differences or changes in observed scores can be attributable to actual changes and not due to measurement error.

1.9 Physical literacy and health in childhood

Whitehead theorized that physical literacy is associated with weight status, fitness, physical activity and motor competence, but these relationships have only been explored empirically in a small number of studies (Whitehead, 2010). As outlined previously, physical activity participation in childhood is associated with a wealth of health benefits (Poitras et al., 2016). If physical literacy is the foundation for lifelong physical activity as has been theorized (Jurbala, 2015; Whitehead, 2010), and physical activity is associated with health benefits, the connection between physical literacy and health warrants further investigation.

Cairney and colleagues recently proposed an evidence-based model of physical literacy as a determinant of health, based on research about physical competence, physical activity and health in children with and without motor coordination disorders. The paper positions physical literacy as a primary determinant of health through a reciprocal pathway with physical activity, which then leads to positive psychological, social and psychosocial adaptations, resulting in improved physical, mental and social health (Figure 1-1). Moderating effects of individual and environmental factors play important roles in physical activity participation and in responses to physical activity participation. In this model, motor competence, social, affective and motivational processes, and knowledge are reciprocal and reinforcing (Cairney et al., 2019). For example, if a child learns to ride a bicycle, this can lead to a sense of competence, which increases confidence to go on bike rides, and leads back to increased physical literacy and increased physical activity participation. These processes are dynamic and present across the lifespan—physical literacy does not start and stop in childhood. As the authors suggest, physical literacy is important for sustained participation in physical activity, and development of physical literacy is fostered through structured and unstructured physical activity. This proposed model is novel, and limited research has explored these relationships with empirical data.

In the small number of studies that reported on the associations between physical literacy and health, several used data collected as a large Canadian multi-site study. In these studies, physical literacy was assessed with the CAPL and participants were 8 to-12-years old. It was found that healthy weight children demonstrated slightly higher overall CAPL scores, and higher scores in all domains (Physical Competence, Daily Behaviour, Knowledge and Understanding and Motivation and Confidence) than children who were overweight or obese (Nyström et al., 2018). It was also determined that participants in the highest tertile for cardiorespiratory fitness demonstrated better physical literacy total and domain scores than participants in the lowest tertile for cardiorespiratory fitness (Lang et al., 2018). To test their model linking physical literacy, physical activity and health, Cairney and colleagues reported that an additive measure of physical literacy, that included measures of motor competence, predilection (motivation), enjoyment of physical education and perceived competence, was significantly associated with aerobic fitness, as assessed with the 20-m shuttle run (r=0.53, p<0.001) (Cairney et al., 2019). To our knowledge, these are the only studies to assess the relationships between physical literacy and health in childhood, which prompts future research in this area. Future research on this topic should include additional indicators of physical and mental health, and if these relationships are present when physical literacy is assessed with a physical literacy specific test battery other than the CAPL, such as the PLAY Tools.

1.10 Physical literacy and physical activity in childhood

Based on the definition of physical literacy outlined previously, children with higher physical literacy would be capable of moving with competence and confidence in a variety of environments, enabling children to participate in higher levels of habitual physical activity (Whitehead, 2010). Over the past few years, several studies have examined the associations between physical literacy and physical activity through observational designs.

Among 9 to-14-year-old children in Northern Canada, physical activity was assessed with the Physical Activity Questionnaire for Children, a self-report measure, and physical literacy was assessed with PLAYfun and PLAYbasic. Correlations between MVPA and physical literacy were small-to-medium (PLAYfun total score: r=0.24-0.44;

PLAYbasic: *r*=0.20-0.42). The correlations between MVPA and the PLAYfun domain scores were also small-to-medium, but with a wider range of correlation coefficients (*r*=0.15-0.40) (Stearns et al., 2018). When physical activity was assessed with pedometers and expressed as daily average step count, PLAYfun explained 30% of the variance in physical activity in a sample of Canadian school-age children (Bremer et al., 2019). The locomotor and balance domains were independent predictors of physical activity, while the running, object control—upper body, and object control—lower body domain scores were not significant predictors (Bremer et al., 2019). Using the CAPL and pedometers in a sample of 2956 boys and girls, it was determined that children and youth who met the Canadian Physical Activity Guideline of ≥ 12,000 steps/ day displayed significantly higher Physical Competence (Cohen's *d*=0.44), and Motivation and Confidence (Cohen's *d*=0.39) domain scores than those who did not meet the guidelines. In subsequent analyses, participants were at greater odds of meeting the physical activity guideline if they demonstrated the minimum recommended levels on the Physical Competence and Motivation and Confidence domains. The Knowledge and Understanding domain scores were not associated with meeting the physical activity guidelines (Belanger et al., 2018). These three studies offer preliminary findings that physical activity is associated with the physical competence measures of physical literacy, such as PLAYfun and CAPL Physical Competence scores, but the relationships between physical literacy and the affective and cognitive domains of physical literacy in children and youth require further study.

To further address the knowledge gap related to physical literacy and physical activity, an additional two studies have looked at the associations between composite scores of physical literacy and physical activity participation in children and youth. The composite scores were generated from previously collected data and were not assessed with a specific physical literacy assessment (i.e. PLAY Tools, CAPL or Passport for Life). In a sample of 2015 grade 5 students in Ontario, assessments of the subdomains (motor competence, motivation, enjoyment and confidence) were completed. Physical activity was self-reported at the same time, as well as 3 years later. Five latent profiles of physical literacy were identified in the sample: low physical literacy with low enjoyment, low physical literacy, low physical literacy with high enjoyment, moderate physical literacy, and high physical literacy. The moderate physical literacy group reported higher physical activity than the three low groups at both timepoints, and the high physical literacy group reported higher physical activity participation than the moderate group at both timepoints (Brown, Dudley, & Cairney, 2020). These results supported the theory that physical literacy is the foundation for an active future. Using measures of motor competence, motivation, enjoyment of physical education, and perceived competence to compute a physical literacy composite score, a significant correlation between physical literacy and self-report physical activity was observed (r=0.44, p<0.001). Moreover, in the same study, the association between motor competence and physical activity was much weaker (r=0.22, p<0.001), suggesting a composite score was more strongly related to physical activity than motor competence alone (Cairney et al., 2019). To advance this field, studies that assess physical activity with objective measures, such as accelerometers, and assess composite measures of physical literacy, that include more than motor competence alone, are necessary to better understand these relationships in children and youth.

1.11 Study Objectives and Hypotheses

Physical literacy describes the physical competence, confidence, motivation, knowledge and understanding to be active for life, and there is growing evidence of the reciprocal relationships between physical literacy and physical activity in childhood. The associations between physical literacy, physical activity and health are also weakly understood. Evidence suggests that physical activity patterns change across childhood, but little is known about how longitudinal patterns of physical activity are associated with physical literacy. The central purpose of this thesis is to explore the relationships between physical activity, physical literacy and health across childhood.

Chapter 2 (Study 1) assessed the measurement properties of physical literacy assessed with the PLAY Tools (PLAYbasic, PLAYfun, PLAYparent and PLAYself) in school-aged children and youth. Previously, only the measurement properties of PLAYbasic and PLAYfun have been examined, while PLAYparent and PLAYself have not yet been examined. Specifically, the inter-rater reliability of PLAYfun was described, internal consistency and construct validity of PLAYbasic, PLAYfun, PLAYself and PLAYparent, convergent validity of PLAYfun with BOT-2, the predictability of PLAYfun from PLAYbasic, and the associations between PLAYfun, PLAYparent and PLAYself. To assess construct validity, the associations between physical literacy scores and age and sex will be explored to determine if associations are similar to previous literature. It was hypothesized that inter-rater reliability and internal consistency of

PLAYfun would be strong, based on previous reports (Cairney et al., 2018; Stearns et al., 2018). Moderate associations were expected between the PLAYfun and BOT-2 and between PLAYfun, PLAYbasic, PLAYparent and PLAYself because each tool aims to assess different aspects of physical competence or physical literacy. Lastly, it was expected that PLAYbasic would be a strong predictor of PLAYfun, as suggested by the assessment tool workbook. PLAYfun, PLAYparent and PLAYself were used in Studies 1, 2 and 3, and PLAYbasic was also included in Study 1.

In Chapter 3 (Study 2), we determined the cross-sectional associations between physical literacy, physical activity and health indicators in school-age children. The primary goal was to examine the cross-sectional associations between physical literacy and body composition, fitness, blood pressure and health-related quality of life, and determine if these relationships were mediated by physical activity participation in Canadian school-age children. It was hypothesized that physical literacy would be positively associated with aerobic fitness and health-related quality of life, negatively associated with body composition and blood pressure, and that these relationships would be mediated by physical activity participation.

Chapter 4 (Study 3) investigated the relationship between longitudinal trajectories of physical activity from preschool to school-age and school-age physical literacy. We aimed to generate group-based trajectories of objectively measured physical activity (as total volume of physical activity and as MVPA) from the preschool to school-age years and to determine if trajectory group membership was associated with school-age physical literacy. It was hypothesized that children who demonstrated consistently high physical activity would demonstrate the highest physical literacy scores.

Together, the three studies included in this thesis will fill significant knowledge gaps related to physical literacy, physical activity and health. By understanding the psychometric properties of the PLAY Tools in Study 1, we can better interpret the results of Studies 2 and 3 as they utilize the PLAY Tools to assess physical literacy in children and youth. Study 2 will describe how physical literacy is associated with health indicators in school-age children and, finally, Study 3 will help us understand if physical activity patterns across early and middle childhood are associated with school-age physical literacy.

1.12 Methodological Note

The data included in this thesis were collected from participants enrolled in a prospective cohort study. Four hundred and eighteen 3-, 4-, and 5-year old children enrolled in the Health Outcomes and Physical activity in Preschoolers (HOPP) Study and completed 3 annual assessments (data collected from 2010-2014). Two-hundred and seventy-nine of these participants subsequently enrolled in the School-age Kids health from early Investment in Physical activity (SKIP) Study (data collected from 2015-2019), which also involved 3 annual assessments. In the final year of the SKIP Study, an assessment physical literacy was added and completed by 222 participants. A diagram of the flow of participants through the HOPP & SKIP studies is included in Appendix A. For this subset of participants, the average total follow-up period from the 1st to 6th timepoint was 6.3 ± 0.6 years (range: 5.1 to 8.4 years). The time between the 1st and 2nd timepoint was 1.0 ± 0.1 years, 2^{nd} and 3^{rd} timepoint was 1.0 ± 0.6 years, 3^{rd} and 4^{th} timepoint was 2.3 ± 0.8 years, 4^{th} and 5^{th} timepoint was 1.0 ± 0.1 years, and 5^{th} and 6^{th} timepoint was 1.0 ± 0.1 years. The longer time between the 3^{rd} and 4^{th} timepoints was the time between the HOPP Study ending and the SKIP Study beginning. The time between these timepoints ranged from 1.1 to 4.1 years, and 81% of participants completed their 3^{rd} and 4^{th} timepoints in the same season.

To address the objectives in this thesis, data from these 222 participants were used from the HOPP (Chapter 4) and SKIP (Chapters 2, 3, and 4) studies. Chapter 2 examines the measurement properties of physical literacy. Chapter 3 examines the cross-sectional associations between physical literacy, physical activity, and fitness in the final timepoint of the SKIP study. Chapter 4 examines the effects of physical activity trajectories over the HOPP and SKIP studies on physical literacy in the final year of SKIP.

CHAPTER 2: MEASUREMENT PROPERTIES OF THE PHYSICAL LITERACY ASSESSMENT FOR YOUTH (PLAY) TOOLS

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ABSTRACT

The Physical Literacy Assessment for Youth (PLAY) Tools are a suite of tools to assess an individual's physical literacy. The purpose of this study is to examine the psychometric properties of the PLAY Tools, including inter-rater reliability, internal consistency, validity and the associations between the tools. In this study, 218 children and youth (8.4- to- 13.7-years old) and a parent/ guardian completed the appropriate physical literacy assessments (i.e., PLAYbasic, PLAYfun, PLAYparent and PLAYself) and the Bruiniks-Oseretsky Test of Motor Proficiency (BOT-2). Inter-rater reliability for PLAYfun was excellent (ICC=0.94). The PLAYbasic, PLAYfun total, running and object control scores, and PLAYparent motor competence domain were higher in males than females, and PLAYfun locomotor skills were lower in males than females ($p<0.05$). Age was positively correlated with PLAYbasic and PLAYfun (r=0.14-0.32, $p<0.05$). BOT-2 was positively correlated with PLAYfun and PLAYbasic (r=0.19-0.59, $p<0.05$). PLAYbasic was a significant predictor of PLAYfun (R^2=0.742, $p<0.001$). PLAYfun, PLAYparent and PLAYself were moderately correlated with one another. PLAYfun, PLAYparent and PLAYself demonstrated acceptable internal consistency (α=0.74-0.87, ω=0.73-0.87). The PLAY Tools demonstrated moderate associations between one another, strong inter-rater reliability and good construct and convergent validity. Continued evaluation of these tools with other populations, such as adolescents, is necessary.

- In school-age children, the PLAY Tools demonstrated strong inter-rater reliability, moderate associations with one another, acceptable internal consistency and good construct and convergent validity.
- The results suggest that that PLAY Tools are an acceptable method of evaluation for physical literacy in school-age children.

KEY WORDS: measurement, children, youth, reliability, validity

INTRODUCTION

Physical literacy has been defined as the motivation, confidence, physical competence, and understanding to value and take responsibility for engagement in physical activity for life (International Physical Literacy Association, 2015). The concept has become increasingly popular in sport, recreation, education and public health policies and programs (Dudley, Cairney, Wainwright, Kriellaars, & Mitchell, 2017). As physical literacy grows in popularity, the measurement of physical literacy becomes increasingly important. It is suggested that any assessment of physical literacy be conducted over time and that charting progress is more important than a one-time assessment (M. Whitehead, 2010), making the assessment of physical literacy more challenging and highlights the importance of high-quality assessment tools to ensure progress seen over time is related to changes in an individual's physical literacy and not due to measurement error.

In Canada, three physical literacy assessments have been used in different sectors. Each assessment battery has a different target audience, targeted assessors, assessment time, materials, space requirement and assessment components, but all three include multiple domains of physical literacy (Robinson & Randall, 2017). Physical & Health Education Canada developed the Passport for Life to assess the development of physical literacy of students in physical education classes and psychometric properties of this tool have not been published (PHE Canada, 2020). The Canadian Assessment of Physical Literacy (CAPL) includes assessments of physical competence, daily behaviour, knowledge and understanding, and motivation and confidence (Longmuir et al., 2015). Construct validity for the CAPL was established previously (Longmuir et al., 2015). The third suite of assessments is Sport for Life's Physical Literacy Assessment for Youth (PLAY) Tools (Sport for Life, 2013). While physical literacy measurement has seen great progress in the past few years, continued evaluation of tools designed to assess its composite components is necessary.

The PLAY Tools include a series of workbooks designed to assess multiple domains of physical literacy in children 7 years and older (Sport for Life, 2013). The suite of PLAY Tools provide a comprehensive assessment of physical literacy, including movement competence (PLAYbasic and PLAYfun), a child's assessment of their own confidence, motivation and behaviour to be active (PLAYself) and a parent's perspective of a child's physical literacy (PLAYparent). In PLAYfun, an expert assesses 18 different movement skills on a 100mm visual analog scale (VAS). This differs drastically from traditional assessments of motor skill proficiency that focus on product-based outcomes (e.g., number of hops in 15 seconds) such as the Bruiniks-Oseretsky Test of Motor Proficiency (BOT-2) (Bruininks & Bruininks, 2005). A challenge with the BOT-2 is that a ceiling effect is often observed once participants develop proficiency in a skill. In addition, the BOT-2 is used to identify children with low motor skills rather than describing children across the entire spectrum of motor competence. The PLAYfun should, theoretically, produce greater variability in scores and not demonstrate ceiling effects (Streiner, Normal, & Cariney, 2015). This study included the PLAY Tools as this suite of assessments was most appropriate as an addition to our on-going longitudinal study. The addition of PLAYself, PLAYparent and PLAYfun was completed in space near our laboratory and the additional time commitment was minimal.

PLAYfun has very good to excellent inter-rater reliability (intraclass correlation (ICC)=0.87-0.90) (Cairney et al., 2018; Stearns, Wohlers, McHugh, Kuzik, & Spence, 2018). The internal consistency of PLAYfun has been examined in one cohort of 8-to 14-year-old children with Cronbach's alpha and is considered acceptable, with higher consistency in the PLAYfun versus PLAYbasic or domain scores (Stearns et al., 2018). PLAYfun scores increased with increasing age as developmentally expected and females did not perform as well as males on upper and lower body object control skills, which was consistent with previous literature on sex differences in object control skills, suggesting evidence for construct validity (Cairney et al., 2018). Based on Cohen's correlation effect sizes where small=0.10, medium=0.30, and large=0.50 (Cohen, 1988), medium-to-large correlations were observed between PLAYfun and an obstacle course that is part of the CAPL (Stearns et al., 2018). Small-to-medium correlations were reported between PLAYfun and self-reported physical activity (Stearns et al., 2018), while PLAYfun explained 13% of the variance in pedometer-measured physical activity (Bremer et al., 2019), showing convergent validity with physical activity. Criterion validity has not been established for the PLAY Tools because a gold standard for the measure of physical literacy has not been identified. Some psychometric properties of PLAYbasic have been described previously (Stearns et al., 2018), but no psychometric testing has been published on PLAYparent or PLAYself.

The objectives of this study are to describe several measurement properties of the PLAYbasic, PLAYfun, PLAYparent and PLAYself assessment tools with data collected in a sample of school-age children in Ontario, Canada. More specifically, the following will be described: 1) inter-rater reliability of PLAYfun, 2) internal consistency of PLAYbasic, PLAYfun, PLAYself and PLAYparent, 3) convergent validity of PLAYfun with BOT-2, 4) the predictability of PLAYfun from PLAYbasic, 5) agreement between PLAYfun, PLAYparent and PLAYself, and 6) variations in PLAYfun, PLAYself and PLAYparent scores by age and sex. It is hypothesized that inter-rater reliability and internal consistency of PLAYfun will be strong. Significant associations are expected between the PLAYfun and BOT-2 and between the various PLAY Tools, and it is expected that PLAYbasic will be a significant predictor of PLAYfun.

Methods

Study Design and Participants

Participants in this study were part of the School-age Kids health from early Investment in Physical activity (SKIP) study, a 3-year longitudinal cohort study of physical activity and health outcomes in school-age children. The SKIP Study was a follow-up to the Health Outcomes and Physical activity in Preschoolers (HOPP) Study, described previously (Timmons, Proudfoot, MacDonald, Bray, & Cairney, 2012). At enrollment, children with diagnosed medical conditions or known developmental or cognitive delays were excluded. Participants were recruited locally in Hamilton, ON and surrounding communities. The physical literacy assessments were added to the third and final year of the SKIP Study. The Hamilton Integrated Research Ethics Board provided ethical approval for the study. All parents provided informed, written consent and all children provided written, informed assent.

Physical Literacy Assessments

In combination, the PLAYfun, PLAYself and PLAYparent tools provide a multi-perspective assessment of a participant's physical literacy (Sport for Life, 2013). Participants in the SKIP Study completed PLAYfun and PLAYself and a parent or guardian of each participant completed PLAYparent. The PLAYfun assessment includes 18 movement skills within five domains: running, locomotor, object control—upper body), object control—lower body and balance, stability and body control. PLAYfun was administered with the same methods as previously described (Cairney et al., 2018; Caldwell, Wilson, Mitchell, & Timmons, 2020). The total PLAYfun score is the average of all 18 task scores (Sport for Life, 2013). PLAYbasic, a quick assessment of one's physical literacy, is extracted from PLAYfun as the average of 5 items, one from each domain (Sport for Life, 2013). PLAYbasic includes run there and back, hop, overhand throw, kicking, and balance walk (toe-to-heel) backward. Scores range from 0-100 and are interpreted as initial (0-24.9), emerging (25-49.9), competent (50-74.9) and proficient (75-100). All PLAYfun assessments were administered and scored by one of two investigators (HC and ND), who both completed comprehensive training and practice assessments before assessing study participants. HC and ND concurrently scored 35 participants to assess inter-rater reliability.

The PLAYself questionnaire is a 22-item self-evaluation of a child's perception of their own physical literacy. The PLAYself questionnaire includes four subsections: environment, physical literacy self-description, relative rankings of literacies (literacy, numeracy, physical literacy) and fitness (Sport for Life, 2013). Participants completed the questionnaire on paper independently.

The PLAYparent questionnaire is used to assess a parent's perception of their child's level of physical literacy, including questions about the child's ability, confidence, and participation. PLAYparent provided researchers with an additional perspective and identified positive and negative factors that affect the child's ability to lead a healthy lifestyle. The PLAYparent is divided into five subsections: physical literacy visual analogue scale, cognitive domain, environment, motor competence (locomotor and object control) and fitness (Sport for Life, 2013).

Motor Skill Proficiency

Motor skill proficiency was assessed using the short form of the BOT-2 plus the standing long jump item to maintain consistency with the assessments completed in the HOPP Study (Timmons et al., 2012). The BOT-2 short form is composed of 14 items and provides a total motor composite score across 4 areas: fine manual control, manual coordination, body coordination, and strength and agility. The BOT-2 is designed to identify individuals with mild to moderate coordination deficits. BOT-2 scores are presented as age-specific, and sex-specific or combined standard scores and percentiles (Bruininks & Bruininks, 2005).

Statistical Analyses

Statistical analyses were conducted in STATA Version 14.2 and internal consistency analyses were conducted in R Version 3.6.1. Inter-rater agreement was determined with ICC and interpreted as poor < 0.5, moderate 0.50-0.74, good 0.75-0.89 and excellent ≥0.9 (Koo & Li, 2016). Descriptive statistics of participants' age and sex as well as individual item scores, domain scores and total scores for PLAYfun, PLAYparent and PLAYself were calculated. Age and sex-dependent variation in PLAYfun, PLAYparent and PLAYself were examined with Pearson correlation and *t*-tests, respectively. Linear regression was used to determine to what degree PLAYbasic was predictive of PLAYfun, and therefore, whether or not the subset of items in PLAYbasic serve as a reasonable proxy for total PLAYfun scores. Pearson correlations were used to describe the relationships between PLAYbasic, PLAYfun, PLAYself and PLAYparent.

Internal consistency of PLAYfun, PLAYparent and PLAYself total and domain scores were analyzed with Cronbach's alpha (α) and McDonald's omega (ω). Cronbach's alpha is widely used to describe internal consistency and allows these results to be compared to other studies more broadly. McDonald's omega is considered a more robust index of internal consistency with less assumptions than alpha, and less problems with inflation of internal consistency (Dunn, Baguley, & Brunsden, 2014). Omega and alpha point estimates and confidence intervals were calculated using the MBESS package in R with 1000 bootstrap sample (Dunn et al., 2014). Previous literature has suggested $\alpha \geq 0.70$ for early stages of research or $\alpha \geq 0.80$ for research tools is appropriate, while $\alpha \geq 0.90$ likely indicates redundancy in the scale (Streiner et al., 2015). For omega, the preferred benchmark is ≥ 0.75 (Reise, Bonifay, & Haviland, 2012).

Results

Two hundred and fifty-two (10.7 ± 1.5 years old; 8.4 to-13.7-years-old; n=120, 47.6% females) participants took part in year 3 of the SKIP Study and 218 (86.5%) participants completed physical literacy assessments. The average body mass index percentile of the group was 47.9 ± 30.6 (0.4 to 99.0). Participants did not complete the physical literacy assessments for the following reasons: no laboratory visit (n=7, 21.2%), visit scheduled before ethics approval was granted for these additional assessments (n=3, 9.1%), participant and/or parent denied participation in the extra assessment (17, 51.5%), or an assessor trained in the assessment of physical literacy was unavailable (n=6, 18.2%).

Table 1. PLAYfun scores from two assessors (HC and ND) and intraclass correlation coefficients for inter-rater agreement.

	Assessor 1 Mean (SD)	**Assessor 2 Mean (SD)**	**ICC (95% CI)**
Running	54.11 (6.55)	54.91 (6.36)	0.715 (0.505, 0.845)
Run a square	50.29 (6.52)	55.03 (6.55)	0.494 (0.196, 0.708)
Run there and back	53.34 (9.64)	53.91 (7.64)	0.685 (0.459, 0.827)
Run, jump and land on two feet	58.77 (8.63)	55.6 (8.68)	0.769 (0.589, 0.877)
Locomotor	45.73 (8.68)	45.46 (8.74)	0.866 (0.752, 0.930)
Cross-over	27.09 (27.46)	25.06 (27.59)	0.986 (0.973, 0.993)
Skip	52.57 (13.39)	52.83 (16.75)	0.763 0.579, 0.873)
Gallop	37.38 (21.11)	43.03 (43.03)	0.805 (0.651, 0.898)
Hop	55.20 (8.48)	50.94 (9.45)	0.863 (0.746, 0.929)
Jump	54.8 (13.38)	52.71 (9.99)	0.728 (0.525, 0.853)
Object control—upper body	56.03 (10.94)	56.92 (10.93)	0.932 (0.869, 0.965)
Throw a ball	51.49 (9.05)	55.91 (9.40)	0.777 (0.602, 0.881)
Strike with a stick	53.57 (12.15)	54.43 (12.64)	0.888 (0.790, 0.942)
Catch a ball	58.54 (20.29)	58.74 (18.48)	0.926 (0.859, 0.962)
Hand Dribble	57.94 (7.96)	57.77 (9.09)	0.779 (0.605, 0.882)
Object control—lower body	47.66 (15.29)	49.94 (14.58)	0.952 (0.907, 0.975)
Kick	52.54 (13.82)	55.94 (10.33)	0.779 (0.604, 0.882)
Foot dribble	42.77 (21.05)	43.69 (21.35)	0.971 (0.943, 0.985)
Balance, stability and body control	45.67 (13.38)	44.06 (12.06)	0.942 (0.888, 0.970)
Heel to toe walk	41.4 (27.04)	37.86 (25.54)	0.964 (0.930, 0.982)
Toe to heel walk	37.8 (26.06)	35.54 (23.27)	0.935 (0.876, 0.967)
Drop to the ground and get back up	49.17 (12.06)	48.2 (8.54)	0.789 (0.621, 0.888)
Lift and lower	54.29 (8.50)	54.09 (7.83)	0.665 (0.417, 0.810)
PLAYbasic	50.10 (7.95)	42.38 (5.79)	0.854 (0.712, 0.919)
PLAYfun	49.36 (7.52)	49.92 (6.93)	0.936 (0.876, 0.967)

PLAY: Physical literacy assessment for youth; ICC: Intra-class correlation; CI: confidence interval; scores range from 0-100 and are interpreted as initial (0-24.9), emerging (25-49.9), competent (50-74.9) and proficient (75-100).

Summary scores and intraclass correlations of 35 participants' PLAYfun scores are included in Table 1. The ICC values for individual items ranged from 0.494 for run a square to 0.986 for cross-over. The ICCs for PLAYbasic and PLAYfun (0.854 and 0.936, respectively), suggest high inter-rater reliability between the two examiners.

Table 2 outlines the full sample descriptive statistics and sex differences in PLAYbasic and PLAYfun by individual item, domain scores and total score. The individual item scores range from 1 to 89, suggesting the raters made use of almost the entire scale. The mean values for the individual items fall into the emerging (25 to 50) and competent (50 to 75) ranges, according to the interpretations for scoring of the tool. Males scored higher on PLAYbasic and PLAYfun total scores, and running, object control—upper body and object control—lower body. Females scored higher on the locomotor domain. Males scored higher on the PLAYparent motor competence (object control) domain (Table 2). Males and females did not differ in any other PLAYparent or PLAYself domain or total scores.

Table 2. Sex differences in item scores on PLAYbasic, PLAYfun, PLAYparent and PLAYself items, domain and total score.

PLAYfun item	**Mean (SD)**	**Min**	**Max**	**Females Mean (SD)**	**Males Mean (SD)**	***t (216)***	***p*-value**
Run a square	51.0 (6.6)	26	66	49.9 (6.7)	52.2 (6.3)	-2.68	.008*
Run there and back	51.7 (8.9)	18	69	50.1 (8.9)	53.3 (8.6)	-2.65	.009*
Run, Jump and land on two feet	56.9 (8.3)	33	80	56.6 (8.6)	57.1 (8.0)	-0.50	.615
Cross-over	37.4 (26.1)	1	78	39.1 (25.5)	35.7 (26.6)	0.96	.336
Skip	52.0 (13.2)	1	71	56.2 (8.7)	47.8 (15.5)	4.95	<.001*
Gallop	41.7 (20.3)	1	69	46.3 (18.7)	37.0 (20.9)	2.48	.001*
Hop	54.40 (8.0)	20	78	55.5 (7.9)	53.4 (8.0)	2.10	.037*
Jump	52.8 (12.6)	5	80	54.5 (9.9)	50.5 (14.7)	2.55	.116
Throw a ball	51.5 (8.7)	10	72	48.6 (7.1)	54.4 (9.3)	-5.15	.000*
Strike with a stick	52.2 (10.4)	8	79	47.6 (8.3)	57.0 (10.3)	-7.40	.000*
Catch a ball	59.4 (17.8)	5	89	54.8 (17.1)	64.7 (16.4)	-4.35	<.001*
Hand dribble	56.0 (8.6)	8	81	54.0 (7.7)	58.1 (8.9)	-3.65	<.001*
Kick	50.1 (15.0)	6	80	44.5 (13.9)	55.9 (13.9)	-6.05	<.001*
Foot dribble	40.5 (39.2)	1	79	34.7 (23.6)	46.6 (19.9)	-4.02	<.001*
Heel to toe walk	39.2 (24.3)	1	73	36.8 (24.9)	41.8 (23.5)	-1.53	.130
Toe to heel walk	36.1 (23.7)	2	73	34.8 (24.5)	37.5 (22.9)	-0.86	.390
Drop to the ground and get back up	47.6 (13.9)	15	73	44.8 (13.8)	50.4 (13.6)	-3.04	.003*
Lift and lower	53.2 (9.6)	15	77	52.7 (8.3)	53.7 (10.7)	-0.78	.430
PLAYfun	49.1 (7.7)	21.2	68.4	47.9 (7.2)	50.4 (7.9)	-2.48	.014*
PLAYbasic	48.8 (8.0)	30.8	69.4	46.7 (7.6)	50.9 (7.9)	-3.96	<.001*
PLAYfun running	53.3 (6.4)	30.3	70.7	52.5 (6.4)	54.4 (6.1)	-2.19	.030*
PLAYfun locomotor	47.7 (10.3)	10.0	69.0	50.4 (9.3)	44.8 (10.6)	4.09	<.001*
PLAYfun object control—upper body	54.8 (9.2)	16.0	73.0	51.3 (7.7)	58.4 (9.2)	-6.34	<.001*
PLAYfun object control—lower body	45.3 (16.1)	8.0	79.5	39.6 (15.8)	51.2 (14.3)	-5.70	<.001*
PLAYfun balance, stability and body control	44.0 (13.6)	9.8	68.3	42.3 (13.6)	45.9 (13.5)	-1.96	.051
PLAYparent VAS	73.40 (16.44)	17	100	73.47 (14.79)	73.49 (18.04)	-0.01	.994
PLAYparent cognitive domain	15.41 (2.01)	10	18	15.39 (2.06)	15.42 (1.98)	-0.12	.903
PLAYparent motor competence locomotor	15.76 (2.44)	7	18	15.79 (2.27)	15.74 (2.61)	0.17	.869
PLAYparent motor competence object control	7.49 (1.50)	3	9	7.29 (1.56)	7.70 (1.42)	-2.02	.044*
PLAYparent environment	9.98 (1.72)	4	12	9.82 (1.76)	10.14 (1.66)	-1.38	.168
PLAYparent total	128.02 (16.04)	76.3	149.9	127.00 (16.06)	129.07 (16.02)	-0.95	.346
PLAYself environment	68.50 (13.81)	0	100	68.93 (14.87)	66.12 (16.81)	0.48	.630
PLAYself self-description	68.91 (14.25)	19.4	100	68.86 (13.36)	69.96 (15.20)	-0.05	.959
PLAYself literacy	73.38 (16.22)	22	100	74.91 (16.26)	71.79 (16.10)	0.142	.157
PLAYself numeracy	74.10 (16.09)	22.3	100	74.38 (14.75)	73.81 (17.44)	0.260	.795
PLAYself physical literacy	82.77 (15.33)	44.3	100	81.15 (15.25)	84.45 (15.31)	-1.59	.113
PLAYself total	73.50 (10.54)	39.4	97.5	73.66 (10.76)	71.23 (15.96)	0.228	.820

* denotes *p*-value <0.05; PLAY: Physical literacy assessment for youth; VAS: visual analogue scale.

Table 3 presents the correlations (Pearson) between the age of participants and each of the domain and total scores. The relationships between age and each of PLAYbasic and PLAYfun are small-to-medium and positive, indicating that older children perform better on skills of motor competence than younger children. Correlations between PLAYfun total score, object control—upper body and balance, stability and body control were stronger for females, while correlations for running were stronger for males. Correlations between age and PLAYparent or PLAYself domain and total scores were negative, suggesting self and parent-perceived physical literacy decrease with age; however, the strength of the correlations were very weak.

Table 3. Correlations with age on PLAYfun, PLAYparent and PLAYself domain and total scores.

	Full- Sample		**Females**		**Males**	
	r	*p*	*r*	*p*	*r*	*p*
PLAYbasic	0.242	0.003*	0.325	0.001*	0.300	0.002*
PLAYfun total	0.324	0.000*	0.384	0.000*	0.217	0.025*
PLAYfun running	0.143	0.035*	0.102	0.285	0.207	0.032*
PLAYfun locomotor	0.228	0.001*	0.220	0.020*	0.218	0.024*
PLAYfun object control—upper	0.234	0.001*	0.335	0.000*	0.241	0.012*
PLAYfun object control—lower	0.308	0.000*	0.365	0.000*	0.348	0.000*
PLAYfun balance, stability and body control	0.200	0.003*	0.275	0.004*	0.148	0.128
PLAYparent	-0.055	0.423	-0.123	0.201	0.059	0.545
PLAYself total	-0.065	0.346	-0.038	0.697	-0.099	0.324

PLAY: Physical Literacy Assessment for Youth; *r*= Pearson's *r*.

PLAYbasic was associated with PLAYfun (Figure 1; r=0.86, p<0.001) and PLAYparent (r =0.31, p<0.001), but not PLAYself (r =0.03, p=0.65). PLAYfun was associated with PLAYparent (r=0.41, p<0.001) and PLAYself (r=0.19, p=0.005). PLAYparent was associated with PLAYself (r=0.25, p<0.001). The associations between different tools (r=0,15-0.41) were small-to-medium strength relationships (Cohen, 1988).

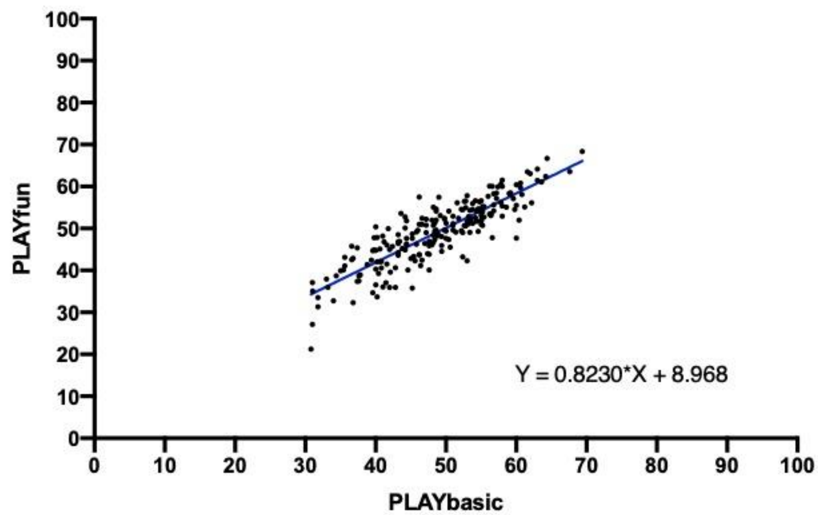

Figure 1. Relationship between PLAYfun and PLAYbasic.

Correlations between PLAYfun, PLAYbasic and the BOT-2 were significant and small-to-medium in magnitude (Table 4). The mean age and sex-specific standard score was 50.4 ± 7.8 (32 to 72), age and sex-specific %ile was 51.2 ± 25.2 (4 to 99), age and combined standard score was 50.1 ± 8.3 (31 to 72), age and combined %ile was 49.6 ± 26.2 (3 to 99), and long jump was 52.9 ± 8.7 inches (28 to 77). The strongest correlations were observed between domains of PLAYfun and the Long Jump.

Table 4. Correlations between the PLAYfun, PLAYbasic and the Bruininks-Osteretsky Test of Motor Proficiency-2.

	Sex-Specific Standard Score	Sex-Specific Percentile	Combined Standard Score	Combined Percentile	Long Jump
PLAYfun	0.450*	0.437*	0.454*	0.439*	0.593*
PLAYbasic	0.323*	0.314*	0.325*	0.315*	0.513*
running	0.393*	0.394*	0.397*	0.396*	0.522*
locomotor	0.473*	0.464*	0.468*	0.457*	0.407*
Object control—upper	0.322*	0.302*	0.334*	0.313*	0.546*
Object control—lower	0.238*	0.235*	0.251*	0.244*	0.423*
Balance, stability and body control	0.198*	0.190*	0.194*	0.185*	0.309*

PLAY: Physical Literacy Assessment for Youth; * denotes p-value <0.05

Table 5 includes point estimates and confidence intervals for the PLAYfun, PLAYparent and PLAYself total and domain scores. PLAYbasic showed the lowest internal consistency. Based on alpha coefficients, PLAYfun total, PLAYfun object control—upper body, PLAYparent total, PLAYparent locomotor, PLAYself total, PLAYself self-description and PLAYself relative ranking of literacies all demonstrate good internal consistency (Streiner, 2010). None of the PLAY Tool's total or domain scores demonstrate $\alpha \geq 0.9$, which suggests redundancy in the scale items. According to the omega coefficients, the PLAYfun and PLAYself scores exceed the benchmark of $\omega \geq 0.75$, while PLAYparent is borderline ($\omega = 0.73$) and PLAYbasic is well below this threshold ($\omega = 0.47$).

Table 5. Alpha and omega point estimates and 95% confidence intervals of PLAYfun, PLAYparent and PLAYself total scores and domain scores.

	Alpha	Omega
PLAYfun	0.81 (0.77, 0.85)	0.80 (0.75, 0.85)
PLAYbasic	0.47 (0.35, 0.57)	0.47 (0.36, 0.58)
PLAYfun running	0.67 (0.57, 0.76)	0.71 (0.59, 0.77)
PLAYfun locomotor	0.55 (0.44, 0.66)	0.58 (0.45, 0.66)
PLAYfun object control—upper	0.78 (0.73, 0.83)	0.81 (0.75, 0.86)
PLAYfun object control—lower	0.59 (0.48, 0.68)	0.59 (0.48, 0.70)
PLAYfun balance, stability & body control	0.69 (0.62, 0.74)	0.87 (0.84, 0.90)
PLAYparent	0.74 (0.66, 0.79)	0.73 (0.66, 0.80)
PLAYparent cognitive	0.66 (0.59, 0.72)	0.71 (0.65, 0.75)
PLAYparent locomotor	0.84 (0.80, 0.87)	0.85 (0.81, 0.88)
PLAYparent object control	0.51 (0.36, 0.61)	0.67 (0.51, 1.0)
PLAYparent environment	0.61 (0.48, 0.70)	0.64 (0.53, 0.72)
PLAYself	0.87 (0.85, 0.89)	0.87 (0.85, 0.89)
PLAYself environment	0.65 (0.54, 0.75)	0.65 (0.54, 0.76)
PLAYself Self-description	0.85 (0.82, 0.88)	0.85 (0.82, 0.88)
PLAYself relative ranking of literacies	0.81 (0.76, 0.84)	0.77 (0.73, 0.85)

PLAY: Physical Literacy Assessment for Youth

Discussion

As physical literacy assessment becomes more popular in research and practice, it is necessary to understand the psychometric properties of the available assessment tools. Our study builds on previous literature by examining the measurement properties of PLAYbasic, PLAYfun, PLAYparent and PLAYself. This was the first study to examine correlations between different measures in the suite, as well as the convergent validity of PLAYbasic and PLAYfun with BOT-2, the construct validity of PLAYparent and PLAYself by examining variance based on age and sex, and the internal consistency of PLAYparent and PLAYself. We also observed similar inter-rater reliability values to previously published research.

We observed moderate-to-excellent inter-rater reliability (ICC=0.94) on PLAYfun total scores between two assessors who observed and scored 35 participants, and this result was similar to values previously reported in the literature (Cairney et al., 2018; Stearns et al., 2018). Stearns and colleagues reported very similar inter-rater reliability values to our study for PLAYbasic and PLAYfun locomotor and running domains. We report excellent inter-rater reliability for the upper and lower object control and balance domains, while Stearns et al. reported good and moderate inter-rater reliability, respectively (Stearns et al., 2018). In a systematic review of the measurement properties of motor skill assessments for children, the highest inter-rater reliability (ICC=0.88-0.93) was similar to what we reported for PLAYfun (Griffiths, Toovey, Morgan, & Spittle, 2018). Our results suggest high agreement between our two raters; therefore, we are confident that the remaining participants, who were assessed by one of these two assessors, produced reliable results.

The participants in our study demonstrated the highest competence on object control—upper body skills (54.8) and the lowest scores on balance, stability and body control (44.0) and object control—lower body (45.3) skills. Stearns and colleagues also observed the highest scores on object control—upper body (63.6-71.6) and the lowest scores on object control—lower body (51.0-60.1) (Stearns et al., 2018). The children in Cariney et al.'s study also received the highest scores on object control—upper body (50.6), but the lowest scores on locomotor (41.6) (Cairney et al., 2018). The average scores in Stearns et al.'s study are much higher than what was observed in our study and in Cairney et al.'s study. The differences in scores may be attributable to different raters, sample demographics, such as different geographic locations and participants' habitual physical activity choices and patterns.

Consistent with predictions, we observed small, positive correlations between PLAYbasic and PLAYfun with age (r=0.16-0.32), which support the construct validity of PLAYfun. The relationships we observed were lower than those reported by Cairney et al. (*r*=0.14-0.58), but similar to those of Stearns et al. (*r*=0.12-0.46). The differences may be attributable to different age ranges between the studies. The participants were 8-13 years of age in our study, 6-14 years of age in Cairney et al.'s study and 8-14 years of age in Stearns et al.'s study. Several traditional motor skill assessments have also shown construct validity as they can discriminate between age and population groups (Griffiths et al., 2018). We did not observe associations between age and PLAYself or PLAYparent.

A correlation between age and a questionnaire measuring children's self-efficacy for physical activity, a similar domain to PLAYself, has not been observed (MacDonald et al., 2018). Additionally, parental measures of health behaviours, such as physical activity, do not generally agree with children's perceptions (Koning et al., 2018). As this is the first study to report on psychometric properties of PLAYparent and PLAYself, further research investigating these relationships is needed.

In our study, the males performed better than the females on 12 of the 18 PLAYfun items and demonstrated higher total PLAYfun, PLAYbasic and domains scores for running and upper and lower body object control skills. The females performed better than males on several locomotor items, including skipping, galloping and hopping. Cairney and colleagues did not observe the same higher total PLAYfun scores in males that we did. The females in their study demonstrated higher locomotor skills, though not significant (Cairney et al., 2018). Similar to our results, females have previously demonstrated greater locomotor skills than males (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009), while males have demonstrated better object control skills than females (Barnett et al., 2009; Barnett, van Beurden, Morgan, Brooks, & Beard, 2010; Cairney et al., 2018). Other research suggests that boys demonstrate higher motor proficiency, as demonstrated by higher PLAYfun scores in boys both before and after one semester of circus-arts based physical education, a student-centred learning of circus skills that included artistic movement expression, technical variations in expression and choice of progressions to foster self-challenges (Kriellaars et al., 2019). Interestingly, the difference between boys and girls in motor competence was smaller among students engaging in circus-based physical education and larger in students enrolled in the traditional physical education. Circus-based physical activity programming may be a viable option to close the observed gender gap in PLAYfun (Kriellaars et al., 2019). We did not observe any differences between males and females in motivation, confidence and knowledge about physical literacy from the PLAYself questionnaire. Higher PLAYself scores have been reported by participants who participated in a circus-arts based physical education program versus traditional physical education programming, suggesting programming can impact children's motivation, confidence and knowledge around physical activity (Kriellaars et al., 2019). Females have reported lower adequacy and predilection than males in a study of youth from across Canada (MacDonald et al., 2018). In the PLAYparent questionnaire, the only significant difference between males and females was observed in the Motor Competence (Object control) domain. This is in alignment with the observed sex differences in upper and lower body object control on the PLAYfun assessment.

This is the first study to report on the convergent validity of the PLAYbasic and PLAYfun with the BOT-2, and these were small-to-medium in magnitude. The strongest correlations were observed between domains of PLAYfun and the Long Jump, a single item that was completed in addition to the BOT-2. PLAYfun and BOT-2 are very different motor skill assessment tools as BOT-2 focuses on product-based outcomes (e.g., number of hops in 15 seconds) (Bruininks & Bruininks, 2005). A challenge of product-based outcomes is that a ceiling effect is often observed once participants develop proficiency in a skill (often a function of age), and the variability in scores is only due to several items in the assessment. In theory, the 100-point scale of PLAYfun should produce greater variability in scores (Streiner et al., 2015). In our study, the PLAYfun total scores ranged from 21.2 to 68.4, while the BOT-2 standard scores ranged from 3 to 72. The small-to-medium correlations between the two assessments suggest that these motor skill assessments measure different things (product vs. process) and may be appropriate for different purposes.

This study was the first examination of the relationships between the PLAY Tools. The PLAY Tools workbooks suggest PLAYbasic can be used as a quicker, short-form alternative to the PLAYfun (Sport for Life, 2013), and we observed they were strongly correlated. In our experience, an experienced assessor can complete a PLAYfun assessment in about 10 minutes, while PLAYbasic takes less than 5 minutes. Our results support Sport for Life’s guidance and PLAYbasic would be appropriate if time, personnel or space are limited and PLAYfun cannot be completed. We observed a small-to-medium association between PLAYfun and PLAYself, similar to another study of physical literacy (Longmuir et al., 2015). With the CAPL, weak-to-moderate associations were observed between the physical components of child’s physical literacy and children’s adequacy and predilection for participation in physical activity (MacDonald et al., 2018). Overall, the modest relationships we observed between PLAYfun, PLAYparent and PLAYself suggest it is not appropriate to use one of these tools as a proxy for the entire suite of tools. Each tool offers a different, important perspective of a child’s physical literacy.

The internal consistency of PLAYfun, PLAYparent and PLAYself scores were examined with alpha and omega coefficients. An alpha coefficient between 0.70 and 0.90

is recommended for measurement tools (Streiner, 2010). Traditional motor skill assessments have demonstrated similar and higher internal consistency than PLAYfun, but some of these tools target different age groups and include gross and fine motor skills (Griffiths et al., 2018). One study assessed the internal consistency of PLAYfun with Cronbach's alpha and, similar to our results, reported the lowest alpha values for PLAYbasic and the highest alpha values for PLAYfun. The higher value for PLAYfun may be related to the higher number of items as it has been suggested that alpha is sensitive to the number of items in a scale and may be elevated if there are more than 20 or items (Streiner, 2010). The total PLAYparent and PLAYself scores demonstrate an appropriate level of internal consistency, while some of the domain scores are below the $\alpha \geq 0.7$ threshold for acceptable internal consistency. PLAYparent and PLAYself scores demonstrate acceptable internal consistency ($\omega \geq 0.75$) (Reise et al., 2012). It has been suggested that, while commonly used, alpha is not the most appropriate measure of internal consistency. Omega is considered a better index of internal consistency because alpha has four assumptions that are rarely met, causing under or over estimations of the alpha coefficient (Watkins, 2017). Alpha as a point estimate fails to present the variability in the estimation process and can be improved by bootstrapping to produce confidence intervals (Dunn et al., 2014), as in Table 5. In our study, the omega values were similar to alpha. Internal consistency may also be related to a scale's factor structure. If a scale is multi-dimensional, internal consistency will be low. In a previous study that used confirmatory factor analysis, it was determined that PLAYfun measures multiple aspects of land-based movements (running, locomotor, object control—upper body, object control—lower body and balance) (Cairney et al., 2018).

This study examined measurement properties of the PLAYfun, PLAYparent and PLAYself in school-age children. Future work should examine how this suite of tools compares to another assessment of physical literacy, such as the CAPL. The CAPL involves assessments within four domains (physical competence, daily behaviour, knowledge and understanding and motivation & confidence), each worth a certain of number of points that add up to 100. It would be interesting to explore an aggregate score of the PLAY Tools and how that compares to the overall CAPL result (Longmuir et al., 2015). Recently, the convergent validity of PLAYfun as a predictor of pedometer-assessed physical activity was established (Bremer et al., 2019). Lastly, it has not been established if PLAYfun, PLAYparent or PLAYself are sensitive to change as a result of an intervention or physical activity programming.

A limitation of this study is the small sample size for our inter-rater reliability analyses. We were not able to determine test re-test reliability for any of the PLAY Tools and this is essential to better understand the internal validity of the PLAY Tools. In addition, confirmatory factor analysis would be valuable to carry out, but the results would be unreliable given our sample size. Criterion validity was not established as there is no gold standard for the assessment of physical literacy, or even motor competence (Griffiths et al., 2018). The convergent validity of physical literacy and physical activity still requires further examination in additional populations and with different physical literacy measurement tools. It would have been advantageous to complete the scores on

PLAYfun to another process-oriented rather than a product-oriented motor assessment tool, and this should be explored in the future. The BOT-2 also includes fine motor skills that were not assessed in PLAYfun. Lastly, without normative data for PLAYfun, PLAYparent and PLAYself, we cannot relate our results to the general population.

In conclusion, this study builds on previous work that investigated the measurement properties of PLAYbasic and PLAYfun (Cairney et al., 2018; Stearns et al., 2018) by further assessing the psychometric properties of these assessments. We also investigated the measurement properties of PLAYself and PLAYparent, which have not been previously reported. We determined that there is a moderate relationship between PLAYfun and BOT-2 and these two motor skill assessments measure different aspects of motor skill proficiency. We demonstrated moderate-to-excellent inter-rater reliability for PLAYfun and PLAYbasic. PLAYbasic is a strong predictor of PLAYfun and is an appropriate alternative if time or space limit the ability to use PLAYfun. PLAYfun increased with increasing age, and males demonstrated higher competence in object control and running skills than females, while females demonstrated higher competence in locomotor skills than males. PLAYparent and PLAYself were not associated with age or sex, except the parent's perception of motor skills was higher for males than females. PLAYfun, PLAYparent and PLAYself total scores demonstrated acceptable internal consistency while most domain scores demonstrated lower values. PLAYfun was moderately associated with PLAYparent, while PLAYself's relationship with PLAYfun or PLAYparent was weak. These results suggest that each tool offers a unique perspective of a child's physical literacy and measuring physical literacy with only one of these tools may not offer the whole picture of one's physical literacy.

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Conflicts of Interest: The authors declare no conflict of interest.

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CHAPTER 3: PHYSICAL LITERACY, PHYSICAL ACTIVITY, AND HEALTH INDICATORS IN SCHOOL-AGE CHILDREN

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Physical Literacy, Physical Activity, and Health Indicators in School-Age Children

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Abstract: It has been theorized that physical literacy is associated with physical activity and health. The purpose of this study is to investigate the associations between physical literacy and health, and if this relationship is mediated by moderate-to-vigorous physical activity (MVPA). Two hundred and twenty-two children (113 girls, 10.7 ± 1.0 years old) participated in this cross-sectional study. A physical literacy composite score was computed from measures of PLAYfun, PLAYparent, and PLAYself. Physical activity was measured over seven days with accelerometers, expressed as MVPA (min/day). Health indicators included: body composition (percent body fat), aerobic fitness (treadmill time and 60s heart rate recovery), resting systolic blood pressure, and quality of life. Physical literacy was significantly associated ($p < 0.001$) with percent body fat ($R^2 = 0.23$), treadmill time ($R^2 = 0.21$), 60 s heart rate recovery ($R^2 = 0.36$), systolic blood pressure ($R^2 = 0.11$), and quality of life ($R^2 = 0.11$). The relationships between physical literacy and aerobic fitness, but not other health indicators, were directly mediated by MVPA. Higher physical literacy in children is associated with favorable health indicators, and the relationships between physical literacy and aerobic fitness were influenced by MVPA. Future work should examine these relationships longitudinally and determine if changes in physical literacy leads to changes in health.

Keywords: youth; aerobic fitness–body composition; blood pressure; quality of life; mediation

1. Introduction

Physical literacy is theorized to be the foundation of lifetime physical activity participation and is defined as the motivation, confidence, physical competence, knowledge and, understanding to value and take responsibility for engagement in physical activities for life [1–3]. This definition of physical literacy includes four interconnected elements (affective, physical, cognitive, and behavioral) that change and adapt across the lifespan [3]. In childhood, increased physical activity participation is associated with numerous health benefits, including decreased adiposity, reductions in cardiometabolic disease risk, increases in aerobic fitness and muscular strength, and higher quality of life [4]. The majority of Canadian children and youth are not participating in enough physical activity to achieve health benefits and innovative strategies are needed to increase participation [5]. If physical literacy is the gateway to increasing physical activity, then physical literacy may be an indirect determinant of health, as increased physical activity is associated with health benefits [6]. The enthusiasm for physical literacy in physical education, public health, sport, and recreation has out-paced research on this topic [7].

As such, further empirical evidence about the relationships between physical literacy, physical activity, and health indicators is necessary to advance knowledge in this field.

In Margaret Whitehead's text, Physical Literacy Throughout the Lifecourse, she theorizes that physical literacy ought to be associated with weight status, fitness, physical activity, and motor competence [2]. More recently, it has been suggested that physical literacy be considered a determinant of health through the following reciprocal pathways: elevated physical literacy leads to greater physical activity participation, which leads to positive physiological, social, and psychosocial adaptations, resulting in improved physical, mental, and social health; this pathway would be present and dynamic across the lifespan from early childhood to old age [6]. Another important part of this proposed model is that some relationships are bidirectional. For example, physical literacy is proposed to be an important determinant of physical activity participation, but development of physical literacy is suggested to occur through structured and unstructured physical activity opportunities [6]. As this proposed pathway is novel, limited empirical research has explored these relationships.

Based on the above definitions and theories, physical literacy has gained attention as the foundation for lifelong physical activity participation, which would, in turn, lead to desirable physical and psychosocial benefits [3,6,8,9]. Several studies have outlined these associations in a large sample of Canadian children whose physical literacy was assessed with the Canadian Assessment of Physical Literacy (CAPL) [10,11]. In those studies, healthy weight children demonstrated slightly higher overall physical literacy and higher scores in modified physical competence, daily behavior, motivation and confidence, and knowledge and understanding domains than children who were overweight or obese [12]. Children and youth who met the Canadian Physical Activity Guidelines of 60 min of daily moderate-to-vigorous physical activity (MVPA) demonstrated higher physical competence, and motivation and confidence scores than those who did not meet the Physical Activity Guideline, while the knowledge and understanding score was not associated with meeting the Physical Activity Guideline [13]. Higher physical literacy scores were associated with higher cardiorespiratory fitness, but the associations between physical literacy and other aspects of fitness (i.e., muscle endurance and muscle strength) were not studied [14].

The Physical Literacy Assessment for Youth (PLAY) tools are another measure of individual physical literacy and includes several workbooks to assess different domains of physical literacy [15]. PLAYfun is a measure of individual movement competence with several domains, including running, locomotor, upper and lower body object control, and balance [15]. Physical activity participation (measured with pedometers) was significantly associated with the PLAYfun total score, locomotor domain score, and balance domain score in 7–14 year-old children [16]. The relationships between physical literacy, as assessed with the PLAY Tools, and fitness, body composition, blood pressure, and health-related quality of life have not been previously studied.

In light of the gaps in knowledge, the purpose of this study was to examine the cross-sectional associations between physical literacy and body composition, fitness, blood pressure, and health-related quality of life, and to determine if these relationships are mediated by physical activity participation in Canadian school-age children (8–13-year-old children). It was hypothesized that physical literacy would be positively associated with aerobic fitness and health-related quality of life, negatively associated with body composition and blood pressure, and that these relationships would be mediated by physical activity participation.

2. Materials and Methods

2.1. Participants and Design

Participants in this study were part of the school-age kids health from early investment in physical activity (SKIP) study, a 3-year longitudinal cohort study of physical activity and health outcomes in school-age boys and girls. The SKIP study was a follow-up to the health outcomes and physical activity in preschoolers (HOPP) study, described previously [17]. At enrollment, children with diagnosed medical conditions or known developmental or cognitive delays were excluded. Physical literacy assessments were added to the third and final year of the SKIP study. The Hamilton Integrated Research Ethics Board provided ethical approval for the study. All parents provided informed, written consent and all children provided written, informed assent.

2.2. Measures

2.2.1. Years from Peak Height Velocity (YPHV)

YPHV was calculated with validated equations that included the following variables: gender, date of birth, date of measurement, standing height, sitting height, and weight. Assessment of YPHV is a non-invasive, practical method to assess maturity status and the equations have been tested and cross-validated in longitudinal samples. The mean difference between actual and predicted maturity was 0.243 ± 0.650 years for boys and 0.001 ± 0.678 years in girls, allowing an accurate prediction of biological age [18]. Due to the age of participants in this study, models were adjusted for YPHV, rather than for chronological age.

2.2.2. Body Mass Index (BMI)

Height and weight were measured using standard procedures [17]. BMI was calculated as weight/height^2 (kg/m^2). BMI percentiles, based on sex and age, were calculated using Centre for Disease Control growth charts for descriptive purposes [19].

2.2.3. Physical Literacy

The PLAY Tools were developed by Sport for Life and represent a series of assessment tools to assess the multiple domains of physical literacy [15]. The PLAY Tools were designed for children 7 years and older. In combination, the PLAYfun, the PLAYself, and the PLAYparent tools provide a multi-perspective assessment of a participant's physical literacy [15]. Participants in the SKIP Study completed PLAYfun and PLAYself and a parent or guardian of each participant completed PLAYparent.

The PLAYfun assessment includes 18 movement skills within five domains: running, locomotor, object control (upper body, object control) lower body, and balance, stability, and body control. PLAYfun was administered with the same methods as previously described [7,20]. The total score is the average score of all 18 task scores [15]. All PLAYfun assessments were administered and scored by one of two investigators (HC and ND).

The PLAYself questionnaire is a 22-item self-evaluation of a child's perception of their own physical literacy [15]. The PLAYself questionnaire includes four subsections: environment, physical literacy self-description, relative rankings of literacies (literacy, numeracy, physical literacy) and fitness. The PLAYself score was calculated by adding up the totals of the subsections and dividing by 27, as outlined in the PLAYself workbook [15].

The PLAYparent questionnaire was used to assess a parent's perception of their child's level of physical literacy, including questions about the child's ability, confidence, and participation. PLAYparent provided researchers with an additional perspective and identified positive and negative factors that affect the child's ability to lead a healthy lifestyle. The PLAYparent questionnaire is divided into five subsections: physical literacy VAS, cognitive domain, environment, motor competence (locomotor and object control) and fitness [15]. The PLAYparent questionnaire was scored by summing the parents' responses and multiplying by 2.63 to give a total out of 150, as outlined in the PLAYparent workbook [15].

A physical literacy composite score was calculated using the standardized scores of PLAYfun, PLAYparent, and PLAYself. The standardized scores were summed, with higher values suggesting greater physical literacy.

2.2.4. Body Composition

Percent body fat (%BF) was measured by bioelectrical impedance analysis (BIA; RJL Quantum 2, Tanita Corporation, Japan). Fat free mass (FFM) was calculated using an equation that was validated against DEXA in children [21]; %BF was then calculated as ((body weight- FFM)/body weight] × 100).

2.2.5. Physical Activity

Physical activity was assessed using Actigraph GT3X accelerometers (Fort Walton Beach, FL, USA). The accelerometers recorded raw accelerations at 30 Hz during waking hours for seven days, except during swimming or bathing. Participants wore the accelerometer on a belt over their right hip. Participants and/or parents were instructed to record the times the accelerometer was put on and taken off in the provided logbook. Accelerometer data were downloaded in 3s epochs, visually inspected for any spurious activity counts, and processed with Actilife Software (Version 6.11.9, Actigraph, Pensacola, FL). A non-wear period was defined as 60 min or more of continuous zero counts or if the logbook indicated device removal. Only participants who wore the accelerometer for at least 3 days with a minimum wear time of 10 h per day were included in the analyses. This minimum wear time provides a reliability coefficient of 0.9 for children [22]. Daily minutes of MVPA were calculated using Evenson et al. (2008) cut-points (≥574 counts/15-sec) [23] that are recommended to estimate time spent in different intensities of physical activity in children and adolescents [24]. Cut-points were divided by 5 to account for the 3 s epoch used in the current study [25].

2.2.6. Aerobic Fitness

Aerobic fitness was assessed using a modified Bruce Protocol, a progressive treadmill test that increases in speed and grade every 3 min [26]. To ensure participant safety, participants were given the option to hold the handrails during the test and a researcher was positioned behind the treadmill. Participants were fitted with a heart rate (HR) monitor (Polar Electro, Kepele, Finland) to continuously monitor HR during the test and seated recovery. The test was terminated when the participants were exhausted, could no longer keep up with the speed of the treadmill and/or showed signs of emotional distress and/or refused to continue. In our sample, the average peak HR was 202 ± 7 bpm (183–226 bpm), suggesting participants were at, or near, exhaustion. Time to exhaustion with the Bruce Protocol is highly reproducible in school-age children (correlation coefficient = 0.94) [27]. Upon termination of the treadmill test, the participants were immediately seated and asked to remain as still as possible for 2 min. The second indicator of aerobic fitness was 60 s HR recovery (HRR), calculated as the difference between the peak HR (single beat highest value) and HR 60s into recovery. Higher values indicate faster autonomic recovery [28].

2.2.7. Blood Pressure

Automated measures of seated blood pressure (Dinamap Pro 100; Critikon Inc) were obtained from the right arm at least 4 times with a 1 min delay between each measure. The 2nd, 3rd, and 4th measures were averaged if within 5 mmHg; additional measures were taken if the measures differed by more than 5 mm Hg [29]. Blood pressure was expressed as seated systolic blood pressure (SBP), as SBP is a better predictor of hypertension and cardiovascular events compared to diastolic blood pressure [30,31].

2.2.8. Health-Related Quality of Life (HRQOL)

Participants completed the self-reported Pediatric Quality of Life (PedsQL) 4.0 Child Self-Report for 8–12-year-old children, a reliable, valid, 23-item questionnaire that evaluates children's quality of life in 4 core domains: physical (8 items), emotional (5 items), social (5 items), and school functioning (5 items). Children were asked to rate how problematic each item had been in the previous month on a 5-point scale (never a problem, almost never a problem, sometimes a problem, often a problem, almost always a problem). The PedsQL outcomes are an aggregate score, with higher scores suggesting better HRQOL [32]. PedsQL cut-off scores for designating an at-risk status for impaired HRQOL and minimal clinically important difference values are also available to aid in the interpretation of results [33].

2.3. Statistical Analyses

All statistical analyses were performed in STATA (Version 14.2). A *p*-value of 0.05 was used to specific statistical significance. Descriptive statistics (mean, standard deviation, minimum and maximum) of the participant's age, YPHV, sex, percent body fat, treadmill time, 60s HRR, blood pressure, HRQOL, and PLAY Tools were calculated. Sex-dependent variation in all measures were examined with *t*-tests. Physical literacy z-scores were calculated for PLAYfun, PLAYself, and PLAYparent as the individual values minus the group mean, divided by the standard deviation to achieve variables that had a mean of 0 and a standard deviation of 1. The physical literacy composite score was calculated as the sum of the PLAYfun, PLAYparent, and PLAYself z-scores.

Linear regression was used to determine the relationships between physical literacy composite score and percent body, treadmill time, 60 s HRR, blood pressure, and HRQOL in independent models. Regression models were adjusted for participant's sex and YPHV. Normality and skewness were assessed with the Shapiro–Wilk Test for Normality, the Skewness/Kurtosis Test for Normality, and visual inspection of P-P plots, Q-Q plots, and histograms. Collinearity between variables was assessed with the variance inflation factor.

To further explore Cairney et al.'s model (2019), mediation analyses were conducted to determine if the associations between physical literacy and the various health indicators were mediated by MVPA. The tests for mediation effects were conducted independently for each health outcome using the SEM command in STATA. For each model, the physical literacy composite score was entered as the independent (X) variable, MVPA as the mediator (M) and health indicator as the dependent variable (Y), with sex and YPHV included as covariates. Bootstrapping was set to 10,000 samples [34]. Sex was included as a covariate because male children and youth engage in more habitual physical activity than females, as demonstrated by our results (Table 1) and in the literature [5]. YPHV was included because it is recommended that pediatric exercise science studies control for the effects of maturity on their results [35].

Table 1. Participant demographics and descriptive statistics.

	Whole Sample			Girls	Boys	*p*-Value
	Mean (SD)	**Min**	**Max**	**Mean (SD)**	**Mean (SD)**	
Age (years)	10.76 (1.04)	8.38	13.66	10.83 (1.01)	10.69 (1.07)	0.330
YPHV (years)	−1.75 (1.24)	−4.07	1.61	−0.96 (1.01)	−2.57 (0.86)	<0.001 *
Height (cm)	145.71 (9.36)	124.45	174.65	145.78 (9.92)	145.63 (8.79)	0.904
Weight (kg)	38.03 (10.38)	22.30	91.75	38.53 (10.43)	37.52 (10.35)	0.470
BMI (m/kg^2)	17.68 (3.13)	13.02	31.40	17.89 (3.03)	17.45 (3.23)	0.294
BMI%ile	47.87 (30.55)	0.44	99.04	49.52 (30.17)	46.17 (31.0)	0.415
Percent Body Fat	21.08 (6.60)	3.10	39.71	22.93 (6.18)	19.16 (6.50)	<0.001 *
Treadmill Time (min)	10.91 (2.88)	4.27	21.47	10.36 (2.68)	11.47 (2.98)	0.005 *
60 s HRR (bpm)	56 (14)	27	100	50 (13)	61 (12)	<0.001 *
SBP (mmHg)	100 (7)	84	125	100 (7)	101.0 (7)	0.103
HRQOL	76.83 (11.27)	30.43	96.74	78.68 (11.42)	74.93 (10.84)	0.014 *
MVPA (min/day)	62.39 (21.07)	18.43	124.86	56.73 (19.91)	68.39 (20.70)	<0.001 *

SD: standard deviation; YPHV: years from peak height velocity; BMI: body mass index; HR: heart rate; HRR: heart rate recovery; bpm: beats per minute; HRQOL: health-related quality of life. *p*-value represents the results of independent *t*-tests to determine differences between boys and girls; * $p < 0.05$.

3. Results

3.1. Participants

Two hundred and forty-nine participants (121 girls, 128 boys) took part in the lab-based assessments of year 3 of the SKIP study, and 222 completed consent and assent forms to participate in the physical literacy assessments (113 girls, 109 boys, 10.7 ± 1.0 years). Only participants with consent and assent for the physical literacy assessments were included in subsequent analysis. Reasons for not participating in the physical literacy assessments included: the visit was scheduled before ethics approval was granted for these additional assessments ($n = 3$), participant and/or parent denied participation in the extra assessment ($n = 19$), or an assessor trained in the assessment of physical literacy was unavailable ($n = 5$). One participant who provided consent and assent became distressed in the visit and withdrew participation from PLAYfun and PLAYself, and the parents of two participants did not complete PLAYparent. Treadmill data (treadmill time and 60s HRR) from 11 participants was excluded from analyses for the following reasons: 1 participant did not participate in the treadmill test, 8 participants began the test but refused to continue and ended the test before reaching the termination criteria, and two participants stopped prematurely due to pre-existing musculoskeletal injuries. Two hundred and eight (93.7%) of the 222 participants met the accelerometer wear time criteria. Six children aged 8 did not complete the Peds-QL as per the study's protocol that only participants ≥9 years old completed questionnaires. Two participants were missing blood pressure measures because one participant declined the measurement and one did not complete the vascular component of testing. Missing data were not imputed, and pairwise deletion was used for analysis.

Descriptive statistics are included in Table 1. The Shapiro–Wilk test for normality showed that all variables, except 60s HRR, were not consistent with a normal distribution ($p > 0.05$). Visual interpretation of histograms further revealed that HRQOL (median: 78.26) and physical literacy composite (median: 0.07) were negatively skewed. Age was evenly distributed between 8–13 years old. YPHV, %BF, SBP, and MVPA appeared to be consistent with the normal distribution. Treadmill time was irregularly distributed and was not consistent with a normal or skewed distribution (median: 10.36). Variance inflation factors did not reveal collinearity among the independent variables.

There were no differences between boys and girls in age, height, weight, BMI or BMI%ile ($p = 294$–0.904). Girls had smaller YPHV values, suggesting that they were more mature than boys ($p < 0.001$), and displayed a higher %BF than the boys ($p < 0.001$). The boys exhibited longer treadmill times ($p = 0.005$) and faster 60 s HRR ($p < 0.001$). The girls self-reported higher HRQOL total scores than the boys ($p = 0.014$), which were attributable to significantly higher psychosocial composite scale scores (includes emotional, social, and school functioning scales) in the girls versus the boys (76.58 ± 13.03 versus 72.02 ± 12.18, $p = 0.008$, respectively). On average, participants wore their accelerometers for 12.76 ± 0.70 h per day, and there were no differences in wear time between boys and girls. Boys participated in more MVPA than girls ($p < 0.001$).

3.2. Physical Literacy and Health

Boys displayed higher PLAYfun scores than girls (Table 2; $p = 0.017$), but there were no differences in PLAYself and PLAYparent between boys and girls ($p = 0.423$–0.820). The physical literacy composite score ranged from −8.8 to 5.6, with no difference between boys and girls ($p = 0.151$).

Table 2. PLAYfun, PLAYself, PLAYparent, and physical literacy composite scores.

	Whole Sample			Girls	Boys	*p*-Value
	Mean (SD)	Min	Max	Mean (SD)	Mean (SD)	
PLAYfun	49.09 (7.56)	21.22	67.67	47.91 (7.13)	50.33 (7.82)	0.017 *
PLAYself	63.50 (10.54)	39.43	97.52	73.66 (10.76)	73.33 (10.35)	0.820
PLAYparent	127.98 (16.0)	76.27	149.91	127.13 (15.94)	128.87 (16.08)	0.423
Physical Literacy Composite Score	−0.007 (2.19)	−8.78	5.56	−0.22 (2.05)	0.22 (2.33)	0.151

SD: standard deviation; PLAY: Physical Literacy Assessment for Youth. *p*-value represents the results of independent *t*-tests to determine differences between boys and girls; * $p < 0.05$.

The physical literacy composite score was significantly associated with each health indicator (Table 3). The physical literacy composite score and YPHV were associated with %BF ($R^2 = 0.228$, F (3,205) = 20.19, $p < 0.001$) and MVPA ($R^2 = 0.235$, F (3,192) = 16.61, $p < 0.001$). The physical literacy composite score, sex, and YPHV were associated with SBP ($R^2 = 0.109$, F (3,204) = 8.31, $p < 0.001$).

Table 3. Associations between physical literacy composite score and percent body fat, physical activity, aerobic fitness, blood pressure, and HRQOL.

	β (95% CI)	T Statistic	*p*-Value	R^2
Percent Body Fat				0.228
Physical literacy composite	−0.56 (−0.93, −1.94)	−3.02	0.003	
Sex	−0.18 (2.36, 2.00)	−0.16	0.869	
YPHV	2.27 (1.340, 3.14)	5.13	<0.001	
Constant	25.16 (23.76, 26.55)	35.59	<0.001	
MVPA				0.235
Physical literacy composite	3.19 (2.00, 4.40)	5.25	<0.001	
Sex	6.66 (−0.58, 13.90)	1.81	0.071	
YPHV	−3.46 (−6.35, −0.56)	−2.35	0.020	
Constant	53.91 (49.36, 58.45)	23.39	<0.001	
Treadmill Time				0.212
Physical literacy composite	0.52 (0.36, 0.69)	6.21	<0.001	
Sex	0.61 (−0.36, 1.57)	0.49	0.219	
YPHV	−0.33 (−0.72, 0.07)	0.20	0.101	
Constant	10.01 (9.38, 10.65)	0.32	<0.001	
60 s HRR				0.357
Physical literacy composite	0.92 (0.22, 1.61)	2.59	0.010	
Sex	0.44 (−3.62, 4.51)	0.22	0.829	
YPHV	−6.12 (−7.76, −4.48)	−7.37	<0.001	
Constant	44.38 (41.71, 47.04)	32.80	<0.001	
Systolic Blood Pressure				0.109
Physical literacy composite	−0.54 (−0.93, −0.15)	−2.73	0.007	
Sex	4.40 (2.08, 6.72)	3.74	<0.001	
YPHV	2.04 (1.11, 2.97)	0.472	<0.001	
Constant	101.56 (100.08, 103.05)	134.93	<0.001	
HRQOL				0.156
Physical literacy composite	1.73 (1.05, 2.40)	5.06	<0.001	
Sex	−3.68 (−7.76, 0.40)	−1.78	0.077	
YPHV	0.68 (−0.96, 2.33)	0.83	0.412	
Constant	79.70 (77.13, 82.26)	61.32	<0.001	

YPHV: years from peak height velocity, MVPA: moderate-to-vigorous physical activity; HRQOL: health-related quality of life.

3.3. Mediation Analyses

As outlined above, physical literacy had a direct effect on all health indicators. Next, physical activity was explored as a mediator of the relationship between physical literacy and health indicators. With %BF as the dependent variable, there was a direct effect of physical literacy on MVPA (β = 3.20, 95% confidence interval (CI): 2.21–4.18, $p < 0.001$) and a non-significant direct effect of MVPA on %BF (β = −0.03, 95% CI: −0.07–0.001, $p = 0.057$). There was a non-significant indirect effect of MVPA on the relationship between physical literacy and %BF (β = −0.11, 95% CI: −0.22–0.003, $p = 0.06$), and this model explained 37% of the variance ($R^2 = 0.37$) in %BF. Similar results were found for HRQOL, with a direct effect of physical literacy on MVPA (β = 3.17, 95% CI: 2.07–4.27, $p < 0.001$), a non-significant direct effect of MVPA on HRQOL (β = 0.03, 95% CI: −004, 0.10, $p = 0.36$), and a non-significant indirect effect of MVPA on the relationship between physical literacy and HRQOL (β = 0.10, 95% CI: −0.11–0.31, $p = 0.36$). This model explained 34% of the variance ($R^2 = 0.34$) in HRQOL. For TM time and 60 s HRR, there was a direct effect of physical literacy on MVPA (TM Time: β = 3.04, 95% CI: 1.85–4.23; $p < 0.001$; 60 s HRR: β = 3.04, 95% CI: 1.85–4.23, $p < 0.001$), and a direct effect of MVPA on treadmill time (β = 0.04, 95% CI: 0.01–0.06, $p = 0.002$) and on 60 s HRR (β = 0.09, 95% CI: 0.02–0.16, $p = 0.01$). There was an indirect effect of MVPA on the relationship between physical literacy and treadmill time (β = 0.12, 95% CI: 0.02–0.22, $p = 0.02$), and between physical literacy and 60 s HRR (β = 0.27, 95% CI: 0.02–0.53, $p = 0.03$). These results suggest that aerobic fitness, expressed as a treadmill time or as 60s HRR, is partially mediated by participation in MVPA and that these models explained 32% ($R^2 = 0.32$) and 45% ($R^2 = 0.45$) of the variance in treadmill time and 60 s HRR, respectively. Lastly, for SBP, there was a direct effect of physical literacy on MVPA (β = 3.22, 95% CI: 1.98–4.46, $p < 0.001$), a non-significant direct effect of MVPA on SBP (β = 0.02, 95% CI: −0.02, 0.06, $p = 0.31$), and a non-significant indirect effect of MVPA on the relationship between physical literacy and SBP (β = 0.06, 95% CI: −0.06, 0.18, $p = 0.32$). This model explained 33% of the variance ($R^2 = 0.33$) in SBP.

4. Discussion

This is one of the first studies to empirically assess the relationships between physical literacy and health (body composition, fitness, blood pressure, and HRQOL) in school-aged children. The physical literacy composite score, a combination of PLAYfun, PLAYself, and PLAYparent, was associated with all health indicators. The strongest association was observed between PL and 60s HRR, an indicator of aerobic fitness. It was also determined that MVPA mediated the associations between physical literacy and aerobic fitness, as indicated by either treadmill time or 60 s HRR. These findings provide initial support for theories that position physical literacy as a determinant of health across the lifespan [6]. Evidence to support the proposed associations between physical literacy and health is necessary to move this field beyond physical education, recreation, and sport.

To date, most research on the topic of physical literacy and health in children was conducted with a cross-Canadian sample of over 10,000 school-age children using the CAPL to assess physical literacy and field-based measures of health indicators [11,36]. A weak relationship was observed between indicators of aerobic fitness and children's perceived adequacy and predilection toward physical activity, but not with other components of the CAPL [37]. The physical competence domain of CAPL and the total CAPL scores were associated with cardiorespiratory fitness, assessed with the PACER 20 m shuttle run test [14], similar to the associations we observed between physical literacy composite score and aerobic fitness. Lastly, it was observed that children who were a healthy weight had higher CAPL scores than children who were overweight or obese [12]. In the current study, while we did not classify participants based on weight status, we did observe that physical literacy was negatively associated with %BF.

To represent physical literacy, a composite score of PLAYfun, PLAYparent, and PLAYself was generated. In a review of 50 studies, core attributes of physical literacy were identified as movement competence, motivation, confidence, self-esteem, knowledge and understanding, and value and responsibility for physical activity [8]. This work, in addition to the International Consensus Statement on Physical Literacy, suggests that a composite score, rather than a single PL assessment tool, may better reflect the multiple domains of PL. Through confirmatory factor analysis, it was determined that several domains (perceived competence, motivation, enjoyment, and motor skills), work synergistically to produce physical literacy in school-age children; however, the domains were assessed with tools not specially designed to measure components of physical literacy [38]. In previous work, a composite physical literacy score was generated from a combination of physical literacy measures (PLAYfun) and validated questionnaires that assessed motivation, confidence, knowledge, and understanding related to physical activity. In that study, the physical literacy composite score increased in the intervention group and decreased in the control group following 11 weeks of physical literacy-enriched programming for university students [39]. Our study is the first study to generate a physical literacy composite score using the PLAY Tools, that were specifically designed to assess physical literacy.

Physical literacy is proposed to be the foundation of an active future and as a precursor to physical activity participation [2]. It has been observed that children who met the Canadian physical activity guideline of 60 min of daily MVPA displayed a higher physical competence and motivation and confidence physical literacy domain scores, as measured by the CAPL [13]. When physical literacy was assessed with PLAYfun, a positive relationship with pedometer-measured PA was reported ($R^2 = 0.30$, $p < 0.05$) [16]. Similar relationships have been reported between PLAYfun and self-reported PA in another Canadian study [40]. The current findings confirm that MVPA, measured objectively with accelerometers, is associated with the physical literacy composite score. While it is beneficial to better understand the associations between physical literacy and physical activity, it remains to be determined how physical literacy can be effectively fostered in children and youths. The next significant step in this field is to design and implement interventions based on the concepts of physical literacy and assess if they have an impact on physical activity levels and contribute to better health indicators. The results of this study suggest that physical literacy is associated with indicators of aerobic fitness, and that this relationship is influenced by children's participation in MVPA.

This study has potential limitations that should be addressed in future research. This study was conducted in Canadian children, and results may not be comparable to other populations. The composite score of PL was novel and psychometric properties are not available; therefore, it is unclear if the method used to combine PLAYfun, PLAYparent, and PLAYself was most appropriate. Based on the definition of physical literacy [41], it was not appropriate to use the scores of PLAYfun, PLAYparent, and PLAYself individually. Future work should consider how various PLAY tools can be combined into one score that reflects the multiple domains of physical literacy. With this study's cross-sectional design, it was not possible to determine the causal relationships between physical literacy, physical activity, and health. Mediation analysis would have been more appropriate if the physical literacy, physical activity, and health indicators were not measured at the same timepoint, but the results do help us understand these novel relationships that have not previously been investigated. Aerobic fitness was not assessed with the gold standard, VO2max, because the methodology of this study was developed for the participant's young age (3 to 5-years-old) at the beginning of the study [17]. The direct measurement of VO2max would not have been feasible in that young sample. Rather, time to exhaustion with the modified Bruce Protocol was used, and is strongly correlated with direct VO2max in children [27]. The accelerometers were not waterproof, and participants were asked to remove the devices for swimming, therefore underestimating the physical activity levels of some participants. Lastly, success on the PLAYfun or aerobic fitness assessments could have been impacted by a participant's motivation, and not all participants were similarly motivated to perform their best on the assessment, despite the continued encouragement from the assessors.

5. Conclusions

The present study determined that physical literacy was associated with health, represented as body composition, fitness, blood pressure, and HRQOL, and that the association between PL and aerobic fitness was mediated by MVPA. To our knowledge, this was the first study to explore these relationships using the PLAY Tools to assess physical literacy and lab-based measures to assess health. This study generated novel information that can inform future research in this field and contribute to the growing evidence that PL is the foundation for an active future [2], and that physical literacy is correlated with several health indicators [6]. Future research is needed to explore these relationships over time, and in additional demographics.

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CHAPTER 4: PRESCHOOL TO SCHOOL-AGE PHYSICAL ACTIVITY TRAJECTORIES AND SCHOOL-AGE PHYSICAL LITERACY: A LONGITUDINAL ANALYSIS

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Abstract

Purpose: Cross-sectional data highlight a positive relationship between physical activity and physical literacy in children, but the associations between longitudinal physical activity patterns across childhood and physical literacy have not been studied. The purpose of this study was to identify physical activity trajectories from preschool to school-age, and to determine if trajectory group membership was associated with school-age physical literacy.

Methods: Participants (*n*=222, 4.5 ± 0.9 years old, 51% girls) enrolled in this study as 3, 4 and 5-year-olds and completed assessments of physical activity with accelerometry over 6 time-points separated by 1.3 ± 0.7 years. Physical literacy was assessed at the final timepoint (10.8 ± 1.0 years old). Group-based trajectory analysis was applied to identify trajectories of total volume of physical activity and moderate-to-vigorous physical activity (MVPA) and to estimate the group differences in physical literacy.

Results: Three trajectories of total volume of physical activity were identified. Group 1 (39% of sample) had the lowest physical activity at all timepoints and declined over time. Group 2 (45%) and 3 (18%) increased from timepoints 1 to 3 and declined from timepoints 3 to 6, but group 3 was most active at all timepoints. MVPA declined over time in groups 1 (52% of sample) and 2 (41% of sample); overall, MVPA was lower in Group 1. Group 3 (8%) had the highest MVPA over time, increased from timepoints 1 to 4, and slightly declined from timepoints 4 to 6. Physical literacy was lowest in the low total physical activity and MVPA trajectory groups (p<0.05).

Conclusions: Physical activity should be promoted across early and middle childhood, particularly in girls, as it may play a formative role in the development of physical literacy

Keywords: youth, childhood, early years, active play, PLAY Tools

Introduction

Physical activity is associated with favourable physical and mental health benefits across early and middle childhood (Carson et al., 2017; Poitras et al., 2016). Longitudinal studies in adults suggest that physical activity plays an important role in the prevention of chronic diseases (Reiner, Niermann, Jekauc, & Woll, 2013). Despite the health benefits associated with physical activity participation, only 61% of preschoolers and 39% of children and youth in Canada achieve the desired amounts of daily physical activity to achieve health benefits (Chaput et al., 2017; Statistics Canada, 2019). It is important to understand if and when physical activity patterns change across childhood to inform the timing of interventions and health promotion programming.

In a longitudinal study of preschoolers, moderate-to-vigorous physical activity (MVPA) increased from 19 months to 5 years (Hnatiuk, Lamb, Ridgers, Salmon, & Hesketh, 2019). Evidence suggests that physical activity then begins to decline in the school-age years and into adolescence. A systematic review reported that MVPA declined 3.4 min/day per year across childhood, and the decline was steeper in girls than boys (Farooq et al., 2020). Group-based trajectory modeling is an empirical method to identify clusters of individuals following certain courses of development, such as changes in physical activity over time. This is a person-based approach to analyze the development of characteristics or behaviours over time (Nagin, Jones, Passos, & Tremblay, 2018). Using this method, total physical activity was modelled as three trajectories from ages 10 to 16 years (Pate, Schenkelberg, Dowda, & McIver, 2019). Less than 5% of the sample remained highly active over time, 55% were active at baseline and declined, and 40% had consistently low physical activity at all ages that declined over time. The high physical activity group was predominantly male and the least mature (Pate et al., 2019). In another study, 4 MVPA trajectories from 5 to 19-years old were reported: consistently inactive (15%), consistently active (18%), declining physical activity (53%), and substantially declining physical activity (14%) (Kwon, Janz, Letuchy, Burns, & Levy, 2015). In a second study with the same cohort of participants included in Kwon et al.'s study (2105), they did not observe differences in predicted age of peak height velocity, an indicator of maturity, between girls or boys MVPA trajectory groups (Janz, Letuchy, Burns, Francis, & Levy, 2015). The next step is to explore characteristics, such as physical literacy, that may differ between children in different trajectory groups.

Physical literacy has been positioned as an important determinant of physical, psychological and social health, based on its reciprocal association with physical activity (Cairney, Dudley, Kwan, Bulten, & Kriellaars, 2019). Cross-sectional evidence suggests that physical literacy is associated with favourable health indicators in school-age children and some relationships are mediated by MVPA (Caldwell et al., 2020). Physical literacy is defined as the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life (International Physical Literacy Association, 2015). In practice, physical literacy has guided the development and implementation of successful interventions, including a circus arts-based physical education curriculum for elementary school students (Kriellaars et al., 2019). The associations between physical literacy and habitual physical activity are beginning to be established in the literature, though current work has been cross-sectional.

Among a sample of youth from the Northwest Territories in Canada, physical literacy was moderately associated (r=0.20-0.44) with self-reported physical activity (Stearns, Wohlers, McHugh, Kuzik, & Spence, 2018). In another study, physical literacy explained 30% of the variance in pedometer-measured physical activity in a sample of 110 boys and girls (Bremer et al., 2019). Using a latent profile approach with over 2000 youth, five profiles of physical literacy were identified in children and youth across two timepoints. The children in the highest profile for physical literacy also demonstrated the highest physical activity over time (Brown, Dudley, & Cairney, 2020). The reciprocal relationship warrants further investigation as it remains to be determined how longitudinal patterns of physical activity participation are associated with physical literacy.

Theories suggest that physical literacy predicts lifelong physical activity participation. Limited evidence suggests that physical activity is positively associated with physical literacy in childhood, and it is unknown if longitudinal physical activity patterns are associated with physical literacy. The Health Outcomes and Physical activity in Preschoolers (HOPP) Study was a prospective, observational study of physical activity and health outcomes, such as cardiovascular health and fitness, that followed a cohort of children annually for 3 years (Timmons, Proudfoot, MacDonald, Bray, & Cairney, 2012). The School-age Kids health from early Investment in Physical activity (SKIP) Study was a follow-up to the HOPP Study that used the same measures to follow the same cohort for an additional 3 years, with physical literacy assessments added to the final timepoint. The purpose of this study was to examine group-based trajectories of objectively measured physical activity from the preschool to school-age years and to determine if trajectory group membership was associated with school-age physical literacy. Trajectories of both total volume of physical activity, assessed as accelerometer counts per minute (CPM) and MVPA, respectively, will be examined so the results may be relevant to the entire age spectrum of participants, to public health guidelines and to physical activity promotion (Tremblay et al., 2016, 2017). We hypothesized that children would follow several unique physical activity trajectories over time and that children who engaged in consistently high physical activity would demonstrate the highest physical literacy scores.

Methods

Study Design and Participants

Participants were part of the HOPP Study, the methodology of which has been reported previously (Proudfoot et al., 2019; Timmons et al., 2012), and its follow-up study, the SKIP Study, both conducted at McMaster University. Physical literacy assessments were added to the final timepoint of the SKIP Study. The Hamilton Integrated Research Ethics Board provided ethical approval for both studies. Written informed consent from the child's legally authorized representative (e.g., parent) was obtained, and participants aged 7 years and older provided assent to participate in the study.

Four hundred and eighteen 3-, 4-, and 5-year old children enrolled in the HOPP Study (data collected from 2010-2014), and 279 of these participants subsequently enrolled in the SKIP Study (data collected from 2015-2019). In the final year of the SKIP Study, an assessment of physical literacy was added and completed by 222 participants (see Appendix A for a flow chart of participants through the HOPP and SKIP Studies). For this subset of participants, the average total follow-up period from the 1st to 6th timepoint was 6.3 ± 0.6 years (range: 5.11 to 8.37 years) and average time between timepoints was 1.3 ± 0.7 years. Reasons for not participating in the physical literacy assessments included: the visit was scheduled before ethics approval was granted for these additional assessments (n=4), participant did not complete a timepoint 6 laboratory visit (n=7), participant and/or parent denied participation in the extra assessment (n=19), or a trained assessor was unavailable (n=5).

Physical Activity

Physical activity was assessed using accelerometers worn for all waking hours over the right hip for 7 days. Parents and/or participants were asked to keep a written record of when the device was removed, including for water activities. Data were downloaded and analyzed in 3-second epochs and analyzed with Actilife software (Version 6.13.4, Actigraph, Pensacola, FL). Non-wear time was identified as periods of at least 60 minutes of continuous zero counts and device removal as indicated in the participant's logbook. At least 3 days of at least 10 hours of wear were required for inclusion in the analyses (Rich et al., 2013). Physical activity was expressed as CPM and MVPA. CPM are a measure of overall volume of total physical activity that combines all movement recorded in the vertical/y-axis while the device is worn (total counts divided by total wear time). MVPA was expressed as minutes per day based on cut-points (>574 counts/ 15-sec) developed and validated by Evenson et al. (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008).

Physical Literacy

The Physical Literacy Assessment for Youth (PLAY) Tools were developed by Sport for Life and represent a series of assessment tools to assess the multiple domains of physical literacy. The PLAY Tools were designed for children 7 years and older. In combination, the PLAYfun, PLAYparent and PLAYself tools provide a multi-perspective assessment of a participant's physical literacy (Sport for Life, 2013). Participants in the SKIP Study completed PLAYfun and PLAYself, and participant's parents or guardian completed PLAYparent. The administration of PLAYfun, PLAYparent and PLAYself has been previously described (Caldwell et al., 2020).

Briefly, the PLAYfun assessment includes 18 movement skills within five domains: running, locomotor, object control—upper body, object control—lower body, and balance, stability and object control (4). All PLAYfun assessments were administered and scored by one of two assessors (HATC or NAD). PLAYfun has very good-to-excellent inter-rater reliability (ICC=0.87-0.90) and acceptable internal consistency (Cairney et al., 2018; Stearns et al., 2018). PLAYfun scores also increase with increasing age as developmentally expected (Cairney et al., 2018). The PLAYself questionnaire is a 22-item self-evaluation of a child's own physical literacy that includes four subsections: environment, physical literacy self-description, relative rankings of literacies (literacy, numeracy, physical literacy) and fitness. The PLAYparent questionnaire is an evaluation of a parent's perception of their child's physical literacy, including questions about the child's ability, confidence, and participation. PLAYparent provided researchers with an additional perspective of the children's physical literacy and identified positive and negative factors that affect the child's ability to lead a healthy lifestyle. The PLAY parent questionnaire is divided into five subsections: physical literacy visual analogue scale, cognitive domain, environment, motor competence (locomotor and object control) and fitness.

Physical literacy z-scores were calculated for PLAYfun, PLAYself and PLAYparent as the individual values minus the group mean, divided by the standard deviation to achieve variables that had a mean of 0 and standard deviation of 1. The physical literacy composite score was calculated as the sum of the PLAYfun, PLAYparent and PLAYself z-scores, with higher values suggesting higher physical literacy. This measure has been used previously and is associated with MVPA and health in school-age children (Caldwell et al., 2020).

Other Measures

At each study visit, the participant's height, weight, and sitting height were measured. Height and weight were used to calculate body mass index (BMI) (kg/m^2) and age-specific percentiles were calculated at each timepoint (Kuczmarski & Ogden, 2002). Sitting height was used to measure peak height velocity (YPHV) at timepoint 6 as an indicator of maturity at using predictive equations (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002).

Statistical Analyses

All statistical analyses were conducted in STATA (Version 14.2). Means, standard deviations, minimum and maximum values for all variables were calculated to describe the distribution of each variable. Sex-dependent variation in all measures were examined with independent *t*-tests. To identify patterns of trajectories of physical activity, group-based trajectory modeling with the TRAJ package in STATA (Jones & Nagin, 2012; Nagin et al., 2018) was conducted using the CNORM distribution of continuous data. Each participant's total volume of physical activity and MVPA (at six timepoints) were grouped within a pattern of conditional probabilities based on structural equation modelling theory that assumes individuals differ qualitatively as members of latent subgroups (Jones & Nagin, 2007). Individual-specific probabilities of belonging to each subgroup allowed assignment to a subgroup based on the highest probability. The relationships between total volume of physical activity and age, and MVPA and age, were fitted up to a quadratic polynomial model for 2, 3 and 4 groups. The final number of groups and best fitting polynomial model was determined by the Bayesian Information Criterion (BIC), the proportion of participants in each group, and the change in BIC between models (-2ΔBIC) (Jones, Nagin, & Roeder, 2001). A 10-fold difference in BIC is considered a meaningful difference (Pate et al., 2019). In addition, to confirm the number of groups chosen, posterior probabilities and odds of correct classification (OCC) were calculated. Posterior probabilities >0.7 suggest the trajectory includes participants with similar patterns or change, and an OCC >5 is recommended for all groups (Nagin, 2005). Once the number of groups was determined the models were rerun to eliminate non-significant quadratic terms. Under the assumption that data were missing at random, participants with incomplete data were included.

After identifying latent total physical activity and MVPA subgroups that followed similar profiles, physical literacy (PLAYfun, PLAYparent, PLAYself and composite score) were added to the models as distal outcomes. To examine the role of maturity status, YPHV was added as a covariate to the models to determine if YPHV was associated with trajectory group membership. The differences in physical literacy outcomes between groups were then examined using post-estimation analysis with Wald tests. A *p*-value of 0.05 was used to indicate statistical significance. Trajectories and the 95% CIs surrounding each trajectory were plotted.

Results

Participant characteristics are included in Table 1. Only participants who provided consent for the physical literacy assessments in year 3 of the SKIP Study are included in this analysis. Age (p=0.524), YPHV (p=0.108) and sex (p=0.097) were similar between participants who did and did not provide consent and assent to complete the physical literacy assessments at timepoint 6. One participant who provided consent and assent became distressed in the visit and withdrew participation from PLAYfun and PLAYself, and the parents of two participants did not complete PLAYparent. The average time between timepoints was 1.3 ± 0.7 years, and average follow-up time across the six timepoints was 6.3 ± 0.56 years (range: 5.1 to 8.4 years). Timepoints 1 and 2 were separated by 1.0 ± 0.1 years, 2 and 3 by 1.0 ± 0.6 years, 3 and 4 by 2.3 ± 0.8 years, 4 and 5 by 1.0 ± 0.1 years, and 5 and 6 by 1.0 ± 0.1 years.

Table 1. Descriptive characteristics of participants across the 6 timepoints.

	All			**Girls**	**Boys**	***p*-value**
	Mean (SD)	**Min.**	**Max.**	**Mean (SD)**	**Mean (SD)**	
Timepoint 1 (*n*=222)						
Age (years)	4.5 (0.9)	3.0	6.0	4.5 (0.9)	4.4 (0.9)	.646
Height (cm)	106.4 (7.6)	89.2	126.1	106.0 (8.0)	106.8 (7.3)	.434
Weight (kg)	17.72 (3.0)	12.1	34.2	17.54 (3.2)	17.92 (2.8)	.342
BMI %ile	49.54 (27.7)	0.0	99.6	51.1 (27.7)	47.9 (27.7)	.382
Total physical activity (CPM)	667.4 (151.3)	386.1	1179.6	617.9 (132.0)	715.4 (153.9)	<.001
MVPA (min/day)	69.8 (18.3)	35.3	130.7	62.6 (15.1)	76.9 (18.5)	<.001
Timepoint 2 (*n*=222)						
Age (years)	5.5 (0.9)	4.0	7.0	5.5 (0.9)	5.43 (0.9)	.614
Height (cm)	113.3 (7.6)	95.1	135.3	112.9 (7.9)	113.7 (7.3)	.416
Weight (kg)	20.1 (3.6)	12.9	43.0	20.0 (3.9)	20.2 (3.3)	.739
BMI %ile	50.0 (26.7)	0.2	99.2	52.4 (27.5)	45.3 (26.7)	.164
Total physical activity (CPM)	703.2 (157.5)	327.8	1404.7	674.3 (170.4)	731.8 (138.5)	.008
MVPA (min/day)	74.0 (18.5)	30.8	123.2	68.3 (18.0)	79.6 (17.4)	<.001
Timepoint 3 (*n*=220)						
Age (years)	6.5 (0.9)	5.0	8.1	6.5 (0.9)	6.5 (0.9)	.754
Height (cm)	119.8 (7.7)	101.2	143.6	119.3 (8.0)	120.4 (7.4)	.279
Weight (kg)	22.6 (4.4)	15.3	52.9	22.5 (4.8)	22.6 (4.0)	.904
BMI %ile	48.4 (27.5)	0.8	99.3	51.5 (28.0)	45.2 (26.7)	.907
Total physical activity (CPM)	713.3 (182.4)	317.3	1544.3	676.7 (163.5)	751.3 (193.7)	.003
MVPA (min/day)	75.2 (21.0)	34.4	141.4	68.5 (17.1)	82.1 (22.5)	<.001
Timepoint 4 (*n*=222)						
Age (years)	8.7 (1.0)	6.3	11.1	8.8 (1.0)	8.7 (1.1)	.274
Height (cm)	133.5 (8.7)	111.6	159.0	133.2 (8.8)	133.7 (8.5)	.701
Weight (kg)	29.6 (7.0)	17.6	65.2	29.8 (7.2)	29.5 (6.9)	.741
BMI %ile	48.5 (28.5)	0.4	98.5	49.7 (28.5)	47.1 (28.7)	.502
Total physical activity (CPM)	655.5 (191.3)	184.6	1422.7	617.0 (179.1)	695.4 (196.2)	.003
MVPA (min/day)	71.2 (21.5)	23.8	147.3	64.1 (17.9)	78.4 (22.6)	<.001
Timepoint 5 (*n*=217)						
Age (years)	9.8 (1.0)	7.4	11.9	9.8 (1.00)	9.7 (1.1)	.347
YPHV	-2.6 (1.1)	-4.8	0.5	-1.8 (1.0)	-3.3 (0.8)	<.001
Height (cm)	139.6 (9.0)	117.4	166.3	140.0 (9.4)	139.8 (8.7)	.728
Weight (kg)	33.6 (8.5)	19.3	77.6	33.8 (8.7)	33.4 (8.4)	.684
BMI %ile	48.3 (29.4)	0.6	98.9	49.9 (29.1)	46.7 (29.7)	.431
Total physical activity (CPM)	606.9 (176.9)	294.2	1372.3	557.3 (148.5)	657.0 (189.5)	<.001
MVPA (min/day)	67.7 (21.2)	29.3	136.8	60.9 (18.4)	74.4 (21.7)	<.001
Timepoint 6 (*n*=222)						
Age (years)	10.8 (1.0)	8.4	13.7	10.8 (1.0)	10.7 (1.1)	.330
YPHV (years)	-1.8 (1.2)	-4.1	1.6	-1.0 (1.0)	-2.57 (0.9	<.001
Height (cm)	145.7 (9.4)	124.5	174.7	145.8 (9.9)	145.6 (8.8)	.904
Weight (kg)	38.03 (10.4)	22.3	91.8	38.5 (10.4)	37.5 (10.4)	.470
BMI %ile	47.9 (30.6)	0.4	99.0	49.5 (30.2)	46.2 (31.0)	.415
Total physical activity (CPM)	554.3 (173.5)	227.5	1008.8	510.1 (163.1)	601.1 (172.6)	<.001
MVPA (min/day)	62.4 (21.1)	18.4	124.9	56.7 (19.9)	68.4 (20.8)	<.001

SD: standard deviation; YPHV: years from peak height velocity; BMI: body mass index; CPM: accelerometer counts per minute, a measure of the total volume of physical activity; MVPA: moderate-to-vigorous physical activity. *p*-value represents the results of independent t-tests to determine differences between boys and girls; $^*p<0.05$.

Physical Activity Trajectories

Valid accelerometer data (≥10 hours on ≥3 days of wear time) were available for 203 participants (91%) at timepoint 1, 213 participants (96%) at timepoint 2, 215 participants (98%) at timepoint 3, 211 participants (95%) at timepoint 4, 209 participants (96%) at timepoint 5, and 207 participants (93%) at timepoint 6. Of the participants with valid wear time, the average number of days worn across all timepoints was 5.7 ± 1.3 to 6.3 ± 1.01 days (range: 3-7 days), and daily wear time was 757.7 ± 57.5 to 767.9 ± 44.0 min/day (range: 632-958 min/day). There were no observed differences in valid days or wear time between males and females (p=0.075-0.950) at any timepoints. Summary data on total volume of physical activity (CPM) and MVPA, at each timepoint, are shown in Table 1.

Three physical activity trajectories were identified for total physical activity and MVPA using BIC, 2ΔBIC and consideration of group sizes. The group trajectories were supported by posterior probabilities >0.7 and OCC values > 5 (Nagin, 2005). For total volume of physical activity, posterior probability values were >0.9 (OCC >12.7). For MVPA groups, posterior probability values were >0.9 (OCC> 14.0).

The longitudinal trajectories for changes in total volume of physical activity are shown in Figure 1. Three distinct trajectories were identified, and total physical activity declined across the 6 timepoints. Group 1 was comprised of 74% girls and 26% boys, and increased from timepoint 1 to 2, and then declined from timepoints 2 to 6. Group 2, comprised of 43.5% girls and 56.5% boys, increased from the 1st to 3rd timepoints and declined from the 3rd to 6th timepoints. Group 3, the most active group, included 30%

girls and 70% boys, and increased from the 1st to 3rd timepoint and then declined from the 3rd to 6th timepoint. Figure 2 displays the 3 longitudinal trajectories of MVPA. Groups 1 and 2 displayed an overall decline in MVPA over the course of the study. Participants in Group 3 (7.9% of participants) increased MVPA from the 1st to 4th timepoint and declined to the 5th and 6th timepoints. Participation in MVPA remained higher in Group 3 than Groups 1 and 2 across all timepoints. Group 1 included 74.3% girls and 26.7% boys, Group 2 was 32.9% girls and 67.1% boys, and Group 3 was 12.5% girls and 87.5% boys.

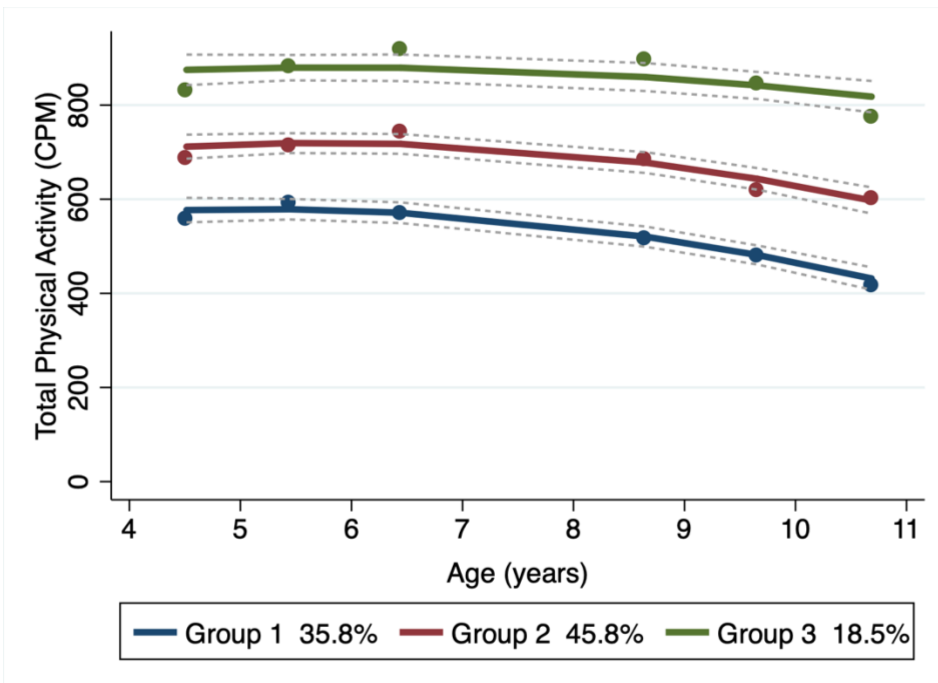

Figure 1. Trajectories of total volume of physical activity (CPM) across childhood based on latent group membership, represented as mean minutes and 95% confidence intervals by trajectory groups. Percentages represent the proportion of participants in each trajectory group.

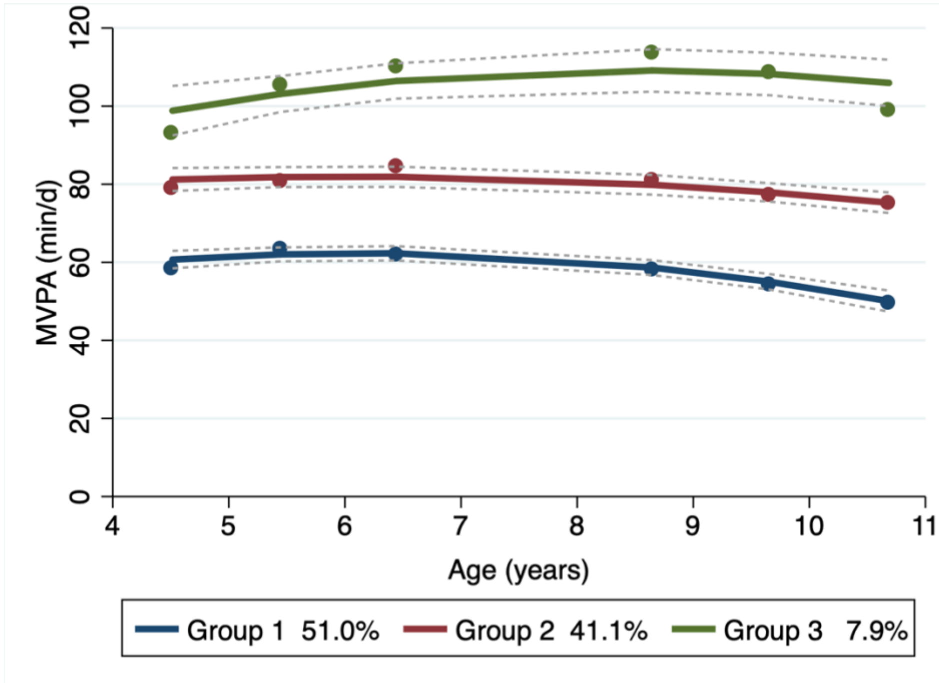

Figure 2. Trajectories of moderate-to-vigorous physical activity (min/day) across childhood based on latent group membership, represented as mean minutes and 95% confidence intervals by trajectory groups. Percentages represent the proportion of participants in each trajectory group.

Physical Literacy

Boys displayed higher PLAYfun scores than girls (Table 2; p=0.017), but there were no differences in PLAYself and PLAYparent between boys and girls. The physical literacy composite score ranged from -8.8 to 5.6, with no difference between boys and girls.

Table 2. PLAYfun, PLAYself, PLAYparent and physical literacy composite scores.

	Whole Sample			Girls	Boys	*p*-value
	Mean (SD)	**Min.**	**Max**	**Mean (SD)**	**Mean (SD)**	
PLAYfun	49.1 (7.6)	21.2	67.7	47.9 (7.11)	50.3 (7.8)	.017*
PLAYself	73.5 (10.5)	39.4	97.5	73.7 (10.8)	73.3 (10.4)	.820
PLAYparent	128.0 (16.0)	76.3	149.9	127.1 (15.9)	128.9 (16.1)	.423
Physical Literacy Composite Score	-0.01 (2.2)	-8.8	5.6	-0.22 (2.1)	0.22 (2.3)	.151

SD: standard deviation; PLAY: Physical Literacy Assessment for Youth. p-value represents the results of independent t-tests to determine differences between boys and girls; *p<0.05.

Physical Activity Trajectories and Physical Literacy

Physical literacy scores for total physical activity and MVPA groups are included in Table 3. Total physical activity group 1 (least active) had lower PLAYfun, PLAYparent, PLAYself and physical literacy composite scores than groups 2 and 3 ($p<0.05$). Total physical activity group 3 (most active) had higher PLAYfun, PLAYparent and physical literacy composite scores than group 2 ($p<0.05$), but similar PLAYself scores to group 2 ($p=0.515$). Similarly, the least active MVPA group had lower PLAYfun, PLAYparent, PLAYself and PL composite scores than groups 2 and 3. MVPA group 3 (most active) had higher PLAYfun and physical literacy composite scores than group 2 (p=0.003-0.005), and similar PLAYself and PLAYparent scores to Group 2.

Table 3. Physical literacy at timepoint 6 across total physical activity and MVPA trajectory group membership.

	Group Mean (95% CI)			Pairwise comparisons (*p*-values)		
Total Physical Activity	**Group 1**	**Group 2**	**Group 3**	**Group 1 vs. 2**	**Group 1 vs. 3**	**Group 2 vs. 3**
PL Composite Score	-1.2 (-1.7, -0.7)	0.3 (-0.2, 0.7)	1.6 (0.9, 2.3)	<.001*	<.001*	.003*
PLAYfun	46.43 (44.8, 48.1)	49.3 (47.9, 50.9)	54.5 (52.0, 56.9)	.012*	<.001*	.001*
PLAYself	69.6 (67.1, 72.1)	75.5 (73.1, 77.9)	76.7 (73.1, 80.3)	.001*	.002*	.515
PLAYparent	121.0 (117.3, 121.0)	129.88 (126.60, 133.2)	137.3 (132.2, 142.3)	.008*	<.001*	.020*
	Group Mean (95% CI)			**Pairwise comparisons (*p*-values)**		
MVPA	**Group 1**	**Group 2**	**Group 3**	**Group 1 vs. 2**	**Group 1 vs. 3**	**Group 2 vs. 3**
PL Composite Score	-0.8 (-1.2, -0.4)	0.6 (0.1, 1.1)	2.2 (1.2, 3.2)	<.001*	<.001*	.005*
PLAYfun	46.84 (45.5, 48.2)	50.6 (49.0, 52.1)	56.6 (53.0, 60.2)	.002*	<.001*	.003*
PLAYself	71.1 (69.0, 73.1)	75.5 (73.2, 77.8)	79.4 (74.2, 84.6)	.004*	.003*	.193
PLAYparent	123.1 (120.1, 126.0)	132.1 (128.8, 135.5)	138.5 (130.9, 146.1)	<.001*	<.002	.127

Note: CI: confidence interval; APHV: Age at peak height velocity; PLAY: physical literacy assessment for youth; MVPA: moderate-to-vigorous physical activity; *denotes statistical significance $p<0.05$.

Physical Activity Trajectories and Maturity Status

YPHV at timepoint 6 was considered as a covariate in the trajectory analysis and, being less mature (younger) increased the likelihood of being in group 2 (log-odds estimates: -0.38 to -0.52; p=0.001 to 0.013) or in group 3 (log-odds estimates: -0.51 to -0.61; p=0.003 to 0.026). These results suggest being less mature was associated with higher physical activity over time.

Discussion

We determined that children followed varied physical activity trajectories from preschool to school-age, and trajectory group membership was associated with school-age physical literacy. For MVPA trajectories, over 90% of participants displayed a decline in MVPA, while 8% of participants increased MVPA over time. For total volume of physical activity, all three trajectory groups gradually declined over time. The groups with the highest physical activity were comprised of predominantly boys and the groups with the lowest physical activity were predominantly girls. Results indicated that low and declining physical activity was associated with lower physical literacy.

Using group-based trajectory analysis, we observed overall group declines in MVPA in groups 1 (-1.5 min/day per timepoint) and 2 (-0.9 min/day per timepoint), and these 2 groups included over 90% of participants. Group 3 experienced consistently high MVPA across timepoints with a slight increase (+0.9 min/day per timepoint). Considering our follow-up time ranged from 5.1 to 8.4 years, our observed trajectories are less dramatic than the average (-3.4 min MVPA/day per year year) reported in Farooq et al.'s systematic review (2020). We also observed distinct trajectory groups for total volume of physical activity, and all 3 groups increased in the preschool years (approximately 4.5 years-old to 5.5 or 6.5 years-old), and then declined to lower than baseline at timepoint 6, when participants were 8-to 13-years old. These results align with a previous study that reported increases in MVPA from age 19 months to 5-years-old (Hnatiuk et al., 2019). In a sample of 650 students followed from 5th to 11th grade (ages 10-16 years), 3 total physical activity trajectory groups were observed: one group remained high and increased from ages 14 to 16 years, the second declined and remained low as children aged, and the third had the lowest physical activity that declined over time (Pate et al., 2019). Farooq and colleagues observed trajectories of physical activity over 8 years from age 7 to 15 years in a cohort of 545 girls and boys. Using similar analysis methods to ours, they observed three declining trajectories of total physical activity in boys, and 1 steep declining trajectory of total physical activity in girls. For MVPA, they observed 3 declining and 1 increasing trajectory in boys, and three declining trajectories in girls (Farooq et al., 2018). These patterns are similar to the 3 groups we observed for MVPA. In the Iowa Bone Development Study, 4 distinct MVPA trajectories were identified in a cohort of over 500 children from ages 5 to 19 years old: consistently inactive (15%), consistently active (18%), decreasing physical activity (53%), and substantially decreasing physical activity (14%). The substantially decreasing group saw the steepest decline starting at around 13-14 years old, a trend that may be seen if our cohort continues to be followed over time (Kwon et al., 2015). In summary, we observed several trajectory groups of physical activity across childhood, and consistent with previous studies, the most active trajectory groups included the smallest proportion of participants.

We observed that girls were over-represented in the lowest and under-represented in the highest physical activity trajectory groups. The participants in the least active groups were also the most mature at the last timepoint. These results reinforce the established differences in physical activity between girls and boys, including a sharper decline in physical activity in girls than boys across childhood (Farooq et al., 2020). Similarly, in the Iowa Bone Development Study, the inactive MVPA trajectory group was predominantly females, and the consistently active group was predominantly males (Kwon et al., 2015). We determined that being less mature increased the likelihood of being in the moderate and high trajectory groups, compared to the low physical activity groups. In a study of physical activity from 10-to 16-years-old, the high physical activity group was predominantly male and the least mature, while the least active group was predominantly female and the most mature, similar to our results (Pate et al., 2019). However, it should be noted that maturity was assessed at baseline in this study, while we included timepoint 6 maturity status in our analysis. Future studies should continue to explore the associations between physical activity, physical literacy, gender and maturity status.

To date, there is limited research on the associations between physical activity and physical literacy, though the field is growing rapidly. In a cross-sectional analysis in this same cohort of participants, it was reported that physical literacy composite score explained 24% of the variance in daily minutes of MVPA in school-age children (Caldwell et al., 2020). Similarly, in a sample of over 2000 grade 5 boys and girls, five unique physical literacy profiles were identified which were associated with physical activity, such that the participants in the high physical literacy profile had the highest physical activity participation. The physical activity differences observed between profiles remained stable over 3 years and the authors concluded that physical literacy plays an important role in physical activity participation over time in children (Brown et al., 2020), but the reciprocal relationship had not been studied until now. We observed that longitudinal physical activity trajectory groups from preschool to school-age were associated with school-age physical literacy, suggesting physical activity patterns over time may play an important role in the development of physical literacy.

Several limitations in this study should be considered. There were missing data from participants who missed study visits or did not meet our accelerometry minimum wear-time criteria; however, overall missing data in this study was minimal (<10%). We employed Evenson accelerometer cut-points across our entire sample to assess MVPA, despite these cut-points being validated in 5-to 8-year-olds (Evenson et al., 2008). Nevertheless, it was more appropriate to use the same cut-points across all timepoints, rather than apply different cut-points to the preschool and school-age data. It was recently recommended that the Evenson cut-points be used to estimate physical activity in 5-to 15-year-olds, an age range which encompasses most of our sample (Trost, Loprinzi, Moore, & Pfeiffer, 2011). Our sample size limited our ability to generate separate trajectories for boys and girls. The high physical activity groups were relatively small and future research with a larger sample is needed. The physical literacy composite score was included to reflect the multiple elements of physical literacy (International Physical Literacy Association, 2015), but psychometric properties of this measure have not been investigated. Despite these limitations, a major strength of this study was the objective assessment of physical activity across six timepoints. Physical activity was expressed as total physical activity and MVPA to increase the generalizability of these findings to other studies. Lastly, group-based trajectory analysis, an emerging method to assess data longitudinally, was used to identify the subgroups of participants who followed distinct physical activity trajectories.

In conclusion, this study identified three distinct patterns of total volume of physical activity and MVPA from preschool to school-age. A small proportion of children, predominantly boys, avoided age-related declines in physical activity and increased MVPA over time. Physical activity trajectory group membership was associated with school-age physical literacy, such that children with the lowest physical activity over time had the lowest physical literacy at study endpoint. This was the first study to explore how physical activity trajectories across the preschool and school-age years were associated with school-age physical literacy. Findings suggest that school-age physical literacy may be fostered with higher physical activity participation across early and middle childhood, and that chronically low physical activity participation may be associated with low physical literacy. Future work is needed to determine how physical literacy changes in response to changes in physical activity over time, and how other measures of physical activity (such as light physical activity) and sedentary behaviour change over time and their relationship with physical literacy.

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CHAPTER 5: DISCUSSION

5.1 Discussion Overview

The overall purpose of this thesis was to further our understanding of the relationships between physical literacy, physical activity, and health in childhood. The long-term goal of this work is to better understand how physical literacy is associated with physical activity and health, and how this knowledge can inform physical activity interventions, programming, and promotion across childhood. To do this, we conducted three studies. In Study 1 (Chapter 2), we determined that the PLAY Tools (PLAYfun, PLAYparent, and PLAYself) are appropriate to assess physical literacy in school-age children based on their inter-rater reliability, convergent validity, construct validity, and internal consistency. In Study 2, we determined that school-age physical literacy was favourably associated cross-sectionally with body composition, aerobic fitness, blood pressure and HRQOL, and that MVPA mediated the associations between physical literacy and aerobic fitness. Lastly, in Study 3, we observed 3 trajectories of total volume of physical activity and 3 trajectories of MVPA across the preschool and school-age years, suggesting children follow different longitudinal patterns of activity. The children who consistently demonstrated the lowest physical activity over time (36-51% of the sample) demonstrated the lowest physical literacy as school-age children compared to those with higher levels of physical activity over time. A major strength of this thesis is the objective assessment of physical activity across six timepoints in childhood, with very high participant compliance (>90% at all timepoints). Strategies to obtain high compliance included: describing the wear instructions to parents and/or participants in the laboratory, regular communication with parents, and encouraging participants to wear the monitor beyond 7 days if they missed any days of wear. This general discussion outlines a summary of the findings in these three studies, theoretical and practical implications, and recommendations for future research.

5.2 Addressing Knowledge Gaps

The research presented in this thesis addresses significant research gaps related to physical literacy, physical activity, and health in childhood. The results of Chapter 2 (Study 1), which examined the measurement properties of the PLAY tools, were foundational to the entire thesis. As physical literacy becomes a more common measure in research and practice, it is necessary to identify and use tools that are feasible, reliable, and valid when assessing it. Also, by understanding the psychometric properties of the PLAY Tools, we were better able to interpret the results in Studies 2 and 3. For example, based on the high inter-rater reliability we observed between observers on PLAYfun, we were confident that assessments completed by both of our assessors were reliable and assessor bias was limited. With a better understanding of the psychometric properties of a measure, changes over time can be attributed to changes in the measure and not flaws in the measure. We determined PLAYfun had moderate-to-excellent inter-rater reliability, confirming the results of previous research (Cairney et al., 2018; Stearns et al., 2018). We determined PLAYfun and PLAYbasic had construct validity as scores increased with increasing age and sex differences were as expected based on prior research about sex differences in motor and physical competence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009, 2010; Cairney et al., 2018; Griffiths et al., 2018; MacDonald et al., 2018; Stearns et al., 2018). We observed positive, small-to-moderate associations between PLAYfun and BOT-2, which is likely a reflection of the different assessment methods (process versus produce-based outcomes). Small to medium associations were observed between PLAYfun, PLAYself and PLAYparent, suggesting these tools offer unique perspectives of physical literacy, and should not be used in isolation or as replacements to one another. PLAYbasic was a strong predictor of PLAYfun, but demonstrated low internal consistency. Similar associations were observed between the domain scores of the CAPL, such that Physical Competence domain scores were moderately associated with Motivation and Confidence scores in a large sample of Canadian children (Nyström et al., 2018). Lastly, we observed that PLAYfun, PLAYparent and PLAYself had acceptable to high internal consistency, similar to previous work and suggests the items are not redundant and assess multiple facets of physical literacy (Dunn, Baguley, & Brunsden, 2014; Streiner et al., 2015). In summary, the results of Study 1 confirmed that the PLAYTools can reliably and validly assess physical literacy in school-age children. These results gave us confidence to use the PLAY Tools as an assessment of physical literacy when examining the associations between physical literacy, physical activity, and health in children. This work filled significant research gaps related to the measurement properties of the PLAY Tools and the results may be applied in future research and in practice settings that utilize the PLAY Tools to asses physical literacy in children and youth.

This thesis is one of the first examinations of the proposed associations between physical literacy and health (Cairney et al., 2019), and the first study to use the PLAY Tools and laboratory and clinical assessments of health. The health indicators included in Study 2 (body composition, aerobic fitness, blood pressure and HRQOL) are each independently associated with physical activity in childhood, as identified in previous systematic reviews (Poitras et al., 2016). As expected, we observed small-to-moderate associations between physical literacy composite score and all assessed health indicators (%BF, SBP, aerobic fitness and HRQOL), such that a higher physical literacy composite score was associated with favourable health indicators. Previous work has examined the associations between physical literacy and weight status and aerobic fitness in children (Cairney et al., 2019; Lang et al., 2018; Nyström et al., 2018), but this was the first study to demonstrate that physical literacy is also associated with SBP and HRQOL, indicators that are important to current and future health. We did not divide the participants in our study by weight status to assess associations between weight status and physical literacy (Nyström et al., 2018), but we assessed weight status with %BF, a predictor of cardiovascular disease risk factors and meaningful assessment of body composition at an individual level (Ruiz et al., 2009). We found that physical literacy explained 23% of the variance in %BF when controlling for biological age (maturity status) and sex. We observed a small-to-medium association between physical literacy and aerobic fitness, similar to previous research (Cairney et al., 2019; Lang et al., 2018). These results helped fill a significant knowledge gap related to the proposed relationship between physical literacy and health, and can inform future research on this topic.

This thesis generated important knowledge about the association between physical literacy and physical activity in children and youth by building on the results of previous studies. In Study 2, we observed that physical literacy composite score explained 24% of the variance in MVPA using a cross-sectional study design. We also found that MVPA mediated the association between physical literacy and aerobic fitness, assessed as treadmill time and 60-sec HRR. Recently, positive associations between physical literacy and physical activity in children and youth have been observed (Belanger et al., 2018; Bremer et al., 2019; Brown et al., 2020; Stearns et al., 2018), but none with the PLAY Tools and accelerometer-assessed physical activity. We also determined that longitudinal physical activity trajectories from preschool to school-age were associated with school-age physical literacy. We observed overall physical activity declines across all timepoints, but this pattern was not followed by all participants. For total volume of physical activity, 3 distinct, declining activity trajectory groups were identified. For MVPA, a high physical activity group increased over time, while the low and middle physical activity groups declined slowly over time. This supports previous work that followed a cohort of 650 students from 10 to 16 years old and also observed three unique trajectories of physical activity, including one group that remained high (5% of participants, predominantly male and the least mature) and two declining groups (Pate et al., 2019). Declining total physical activity trajectories were also observed in a study that followed children for 8 years from 7 to 15 years-old, while for MVPA they observed three declining trajectories for girls, and 3 declining and 1 increasing trajectory in boys (Farooq et al., 2018). Other than sex and maturity, differences between physical activity trajectory groups across childhood have scarcely been studied.

With physical literacy as an outcome measure, group-based trajectory modeling confirmed that longitudinal physical activity patterns were associated with later physical literacy. The least active participants, based on total volume of physical activity or MVPA, displayed the lowest physical literacy. The participants in the highest physical activity groups, based on both physical activity measures, had the highest PLAYfun and physical literacy composite scores. PLAYself was similar between the middle and high physical activity groups, suggesting that even a moderate level of physical activity is associated with higher self-confidence, motivation and knowledge about physical activity. PLAYparent was similar between the middle and high MVPA groups, but not total volume of physical activity groups, and may suggest parents perceive higher physical literacy when their children engage in at least average levels of MVPA. The highest physical activity groups were predominantly male and least mature, confirming previous research (Pate et al., 2019). The group-based trajectory modeling outlined in Study 3 was novel and is one of the first studies to use this method to study longitudinal changes in physical activity in Canadian children. These results generated novel information about the importance of physical activity across childhood to foster future physical literacy. While age-related declines in physical activity may occur across childhood, those that started with and maintained the highest physical activity had the highest physical literacy.

5.3 Implications

5.3.1 Theoretical Implications

The results of this thesis make an important contribution to Cairney's physical literacy and physical activity model (Cairney et al., 2019). In this model, physical literacy has a reciprocal relationship with physical activity, such that increasing physical literacy increases physical activity participation, which leads to further developing physical literacy. Increased physical activity participation can lead to positive physiological and psychological adaptations. These adaptations then eventually lead to better physical, mental and social health outcomes. The findings of this thesis support the proposed association between physical literacy and health (Study 2) and the bidirectional associations between physical literacy and physical activity (Studies 2 & 3) (See Figure 5-1). The specific contributions of this thesis will be discussed in more detail below.

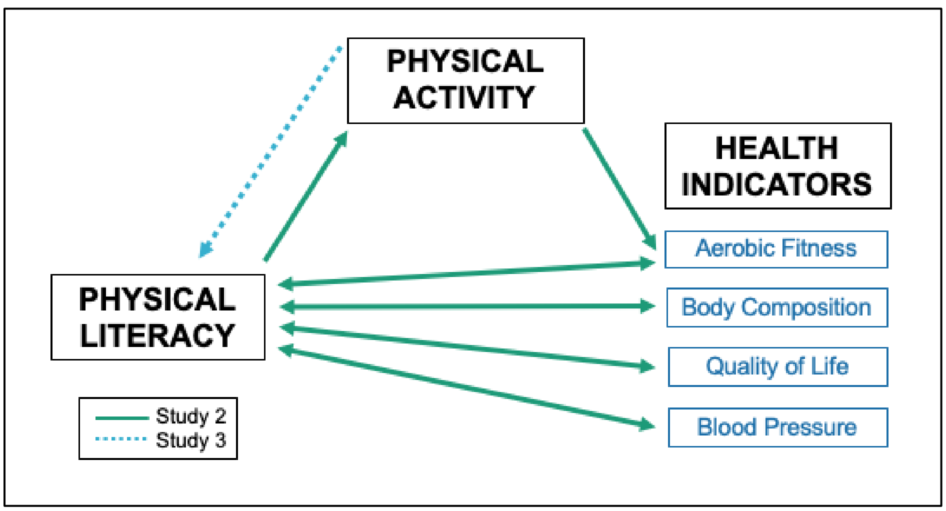

Figure 5-1. Associations between physical literacy, physical activity and health indicators, based on the results from Studies 2 and 3 in this thesis. [Adapted from Cairney et al. (2019), *Sports Medicine]*.

Physical Literacy and Health. To date, limited research has addressed theories about the associations between physical literacy and health. While our results do not exhaustively test Cairney et al.'s proposed model (2019), we used laboratory and clinical assessments of health and accelerometry-assessed physical activity to generate initial evidence to support this theory and inform future work. Existing models have proposed and tested associations between motor competence, perceived motor competence, fitness, physical activity and health (Robinson et al., 2015; Stodden et al., 2008), but not as a combination of the physical, cognitive, behavioural and affective domains included in common definitions of physical literacy (Edwards et al., 2017). Findings from Study 2 confirmed our hypotheses that physical literacy is negatively associated with %BF and SBP, and positively associated with treadmill time, 60-sec HRR and HRQOL in school-age children. The results also provided initial support for the mediating role of MVPA in the association between physical literacy and aerobic fitness.

Physical Literacy and Physical Activity. The proposed connection between physical literacy and physical activity is commonly referenced in the physical literacy literature, and most work focuses on physical literacy as a predictor of physical activity participation (Jurbala, 2015). Conversely, Cairney's proposed model suggests physical literacy and physical activity is a bi-directional, reciprocal relationship that continues to develop across the lifespan (Cairney et al., 2019). Our study design could not determine if physical literacy was foundational to physical activity participation, yet we confirmed that longitudinal physical activity participation from the preschool to school-age years was associated with school-age physical literacy and that physical literacy and physical activity were associated cross-sectionally in school-age children. Several previous cross-sectional studies established that physical literacy and physical activity are associated in children and youth (Belanger et al., 2018; Bremer et al., 2019; Stearns et al., 2018), but ours provides robust cross-sectional and longitudinal support for this relationship using accelerometer-assessed physical activity. Our results suggest that physical activity trajectories from preschool to school-age are associated with physical literacy, such that those with the lowest physical activity over time have the lowest physical literacy at school-age. These findings, in combination with the positive associations between physical literacy and health found in this thesis and previous studies (Lang et al., 2018; Nyström et al., 2018), suggest that the promotion of physical activity should begin early in life as high physical activity engagement can promote physical literacy development, forming a strong foundation for an active future and positive health outcomes.

5.3.2 Practical Implications

Physical literacy assessment in children and youth. We offer several practical recommendations for researchers and practitioners using the PLAY Tools, based on our experience conducting these assessments and our examination of their measurement properties. Sport for Life has several recommendations for the administration of the PLAY Tools. The results from my thesis (Study 1) provide support for some of these recommendations. Moving forward, it is not recommended that only one tool be used to assess physical literacy. Physical literacy is a complex, multi-component construct that should be assessed from multiple perspectives, including participants, parents, coaches, and/or trained assessors' perspectives. We determined weak agreement between

PLAYfun, PLAYself and PLAYparent, likely because these tools represent different domains of physical literacy (physical competence, confidence, motivation, knowledge and understanding). To assess physical competence, PLAYfun is recommended over PLAYbasic. While PLAYbasic was strongly associated with PLAYfun, its internal consistency was below the threshold for an acceptable value. Based on our experience, high inter-rater reliability cannot be achieved without practicing the administration and scoring of PLAYfun and PLAYbasic. We recommend that new assessors spend time practicing the administration and scoring of PLAYfun on adults and children before using it in research or practical settings (i.e., schools, sports, etc.). This will help ensure assessors can accurately and reliably assess PLAYfun. As a process-based assessment of motor competence, the assessor is monitoring and assessing several components of a movement at once and accurate scoring requires training and practice. When new to conducting assessments with PLAYfun, it may be appropriate to film the assessment and score it afterward to ensure an assessor has time to analyze the movement. This can also be helpful to establish inter-rater reliability if a study or program has multiple assessors. Inter-rater reliability between multiple assessors should be assessed with ICC, such that values >0.75 indicate excellent agreement, 0.6-0.74 indicates good agreement, 0.4 to 0.59 indicates far to moderate, and <0.4 indicates poor agreement (Streiner et al., 2015). We recommend reminding parents or other observers to not comment or coach the participant because part of the PLAYfun assessment is the knowledge of skills, and parents/ caregivers may want to remind their children how to do certain skills. With appropriate training and practice, assessors can use the PLAY Tools to reliably and validly assess physical literacy in school-age children. Our recommendations are based on assessments in a laboratory setting and may not be directly relevant to other settings, such as physical education classes or sports practices.

Physical literacy-based interventions. The results in this thesis (Study 2) demonstrated that physical literacy is associated with increased physical activity and favourable health indicators in school-age children. Physical activity mediated the association between physical literacy and aerobic fitness, suggesting development of physical literacy and MVPA are necessary to elicit changes in aerobic fitness. Also, longitudinal physical activity habits across the preschool and school-age years were associated with school-age physical literacy. There is growing evidence that physical literacy-based programming can improve physical literacy in children and youth. This evidence, combined with our findings, suggests appropriately designed and delivered interventions may help develop physical literacy in children and youth. For example, children and youth who participated in programs that scored highest on the Physical Literacy Environmental Assessment Tool reported higher PLAYself scores and demonstrated higher PLAYfun object control—upper body skills than children and youth in the lowest scoring programs (Caldwell, Wilson, Mitchell, & Timmons, 2020). Students in grades 4-7, improved physical literacy, as assessed with CAPL, without a resulting change in physical education physical activity levels, following a 10-week Run Jump Throw Wheel intervention (Coyne et al., 2019). Grade 4-5 students who participated in a circus-arts based physical education program improved PLAYfun and PLAYself scores versus students who participated in regular physical education programming (Kriellaars et al., 2019). These studies show that the use of physical literacy-based programming can improve children's physical literacy in various populations and contexts. A less studied, but increasingly popular, area of research is the importance of outdoor play for physical activity promotion in children. A systematic review suggests that time spent outdoors is associated with increased physical activity acutely and habitually in children and youth (Gray et al., 2015). Future interventions and programs may consider exploring whether outdoor activities and unstructured play may enhance physical literacy through increased physical activity. To date, changes in habitual physical activity participation and health outcomes as a result of physical literacy have scarcely been examined. Next steps in this area are to study if physical literacy interventions are associated with favourable changes in physical activity, and/or health.

5.4 Novelty of Findings

The field of research about physical literacy is growing, and this is complemented by interest and enthusiasm from practitioners. This thesis generated novel information about physical literacy, physical activity, and health that can be applied to future research and practice. The novel findings and contributions of this thesis to the field of physical literacy research are summarized as follows.

Study 1 confirmed the use of the PLAY Tools as a reliable, valid assessment battery to assess physical literacy in children and youth. This was the first study to describe the associations between PLAYfun, PLAYparent and PLAYself, the convergent validity of PLAYfun with BOT-2, the construct validity of PLAYparent and PLAYself with age and sex, and the internal consistency of PLAYparent and PLAYself. We determined

PLAYbasic was strongly associated with PLAYfun and it may be used only if time and space are limited. We also determined that PLAYfun, PLAYself, and PLAYparent present unique perspectives of physical literacy and cannot be substituted for another.

Studies 2 and 3 examined the theorized associations between physical literacy, physical activity and health (Cairney et al., 2019; Gately, 2010; Jurbala, 2015; Whitehead, 2010). These were the first studies to examine these relationships using the PLAY Tools, accelerometer-measured physical activity, and clinical and laboratory assessments of health. Building on the conclusions of Study 1, Studies 2 and 3 generated a composite physical literacy score that included PLAYfun, PLAYself, and PLAYparent. The results suggest that physical literacy is associated with favourable measures of body composition, aerobic fitness, blood pressure, and HRQOL in school-age children. Study 2 generated some of the first evidence to support the theory that physical literacy is associated with health indicators, laying the foundation for future work in this area.

Studies 2 and 3 generated important findings of the associations between physical literacy and physical activity. Physical literacy may be a particularly important contributor to aerobic fitness because it mediated the association between physical literacy and aerobic fitness in Study 2. In Study 3, distinct trajectories for total volume of physical activity and MVPA were generated. Physical literacy was highest in the groups with the highest physical activity levels, and lowest in the groups with the lowest physical activity levels. The high physical activity groups were predominantly boys and included only a small proportion of all participants. The results of Studies 2 and 3 suggest that physical activity trajectories from preschool to school-age may play a formative role in the development of physical literacy, and that school-age physical literacy is associated with various health indicators (Figure 5-1).

5.5 Limitations

This dissertation helped fill significant research gaps related to physical literacy, physical activity, and health in school-age children. Despite this, it is not without limitations. This work is limited by the sample size of our population. Four-hundred and eighteen preschoolers participated in year 1 of the HOPP Study, and 279 of those children enrolled in the SKIP Study (67% of HOPP sample). At year 3 of the SKIP Study, 249 (89% of SKIP sample) participants took part, of which 222 (80% of SKIP sample, 53% of HOPP sample) consented to complete the added physical literacy assessments. As a result, the analysis in Study 3 could not be stratified by gender to better understand the physical activity trajectories of boys and girls. The loss of participants over time is natural in longitudinal studies and we were still able to observe meaningful findings, despite the smaller sample size.

In all 3 thesis studies, physical literacy was assessed while participants visited our laboratory at McMaster Children's Hospital. The measurement properties of the PLAY Tools discussed in Study 1 are based on assessment in this controlled, familiar environment. This setting limits the ecological validity of conducting these assessments in another setting, such as a school gymnasium with a large group of students. PLAYfun was completed at the end of a 2-3 hour study visit, and participants had developed a rapport with the assessors from this visit in addition to previous study visits. This may have made participants feel more comfortable to try their best, particularly for movements they felt less comfortable performing.

Despite the longitudinal study design, physical literacy was only assessed at one timepoint and does not allow for the determination of causality in the associations between physical literacy and health. The mediation analysis in Study 2 would have been more appropriate with a longitudinal design, and these results cannot be assumed to indicate that physical literacy increases MVPA which in turn leads to higher aerobic fitness. These results are preliminary and can be used to inform future research. In Study 3, we were able to determine that physical activity across the preschool and school-age years was associated with school-age physical literacy, but not how changes in physical activity inform changes in physical literacy or if physical literacy is predictive of future physical activity participation.

5.6 Future Research Directions

The findings of the three studies included in this thesis address significant gaps in our understanding of physical literacy, physical activity, and health across childhood. In light of these findings, the results highlight several areas that require further investigation. First, the PLAY Tools were designed to be used with children and adults age 7 years and older. Research is needed on the feasibility, reliability, and validity of the PLAY Tools with an older sample, including adolescents, as well as children with chronic conditions. Test-retest reliability of the PLAY Tools needs to be assessed to determine that the measure is accurate and reliable over several testing occasions. Determining the convergent validity between PLAYfun and a process-oriented (i.e. Test of Gross Motor

Development), rather than a product-oriented assessment of motor competence (i.e. BOT-2) should also be assessed to determine the similarities and differences in the scores on these measures. Lastly, the psychometric properties of a composite or combination of PLAY Tools should be explored to assess the multiple domains of physical literacy within one measure, such as the PLAY Tools composite score used in Studies 2 & 3 (Caldwell, Di Cristofaro, et al., 2020).

The greatest knowledge gaps related to physical literacy, physical activity, and health research relate to how changes in these measures correspond with one another. For example, the cross-sectional association between physical literacy and physical activity in children and youth has been investigated in several studies, yet there is very limited work on the associations between longitudinal changes in physical activity and changes in physical literacy. Research of this nature can help support or refute theories that physical literacy is the foundation for an active future. Likewise, research on the impact of physical literacy and physical activity on health indicators across the lifespan could provide further support for physical literacy as a determinant of health. In addition to physical health indicators, it is necessary to start exploring the proposed associations between physical literacy and mental health indicators (other than HRQOL). In Ontario, about 1 in 5 children and youth met criteria for mental disorder, such as depression or anxiety, and it has been established that physical activity can benefit the mental health of children and youth (Georgiades, Duncan, Wang, Comeau, & Boyle, 2019; Rodriguez-Ayllon et al., 2019). This type of work is particularly important given the low physical activity rates of children and youth in Canada (Statistics Canada, 2019).

Physical literacy was highest in participants with the highest physical activity levels from preschool to school-age, and lowest in those with the lowest physical activity levels. A next step is to investigate additional modifiable factors associated with group membership, such as fitness, to inform future physical activity promotion initiatives. The results of this future work would help inform the design and delivery of programming, interventions, and health promotion initiatives that aim to promote physical activity in children. Physical activity interventions should be designed for long-term, sustainable changes in physical activity, and physical literacy may be a key ingredient to this type of work. Based on the results of Study 2, such programing should target the development of individual physical literacy, which may lead to increased MVPA and consequently improvements in aerobic fitness. Given the associations we observed between composite physical literacy scores and fitness and body composition, interventions should also target all domains of physical literacy (physical competence, confidence, motivation, knowledge and understanding) to influence health. Also, the under-representation of girls in the high physical activity groups warrants future study, particularly the role of physical literacy in reducing this gender gap between boys and girls.

It would be extremely interesting to continue following this cohort and assess physical activity, physical literacy and health into adolescence and early adulthood to understand if childhood physical activity patterns and physical literacy are predictive of long-term physical activity participation and health.

5.7 Conclusions

There is increasing evidence that physical activity participation among children and youth worldwide is inadequate to achieve the associated health benefits (Aubert et al., 2018). Physical activity is a complex behaviour with numerous barriers, facilitators, and associated outcomes (Sallis, Prochaska, & Taylor, 2000). In recent years, physical literacy has been positioned as the foundation for an active future and a framework for physical activity promotion (Jurbala, 2015). For example, physical literacy has been identified as one of five independent principles that are foundational to increasing physical activity and reducing sedentary living among Canadians (Government of Canada, 2018). To advance the field of physical activity promotion through a physical literacy lens, additional research is needed to better understand the associations between physical literacy, physical activity, and health in children and youth. The results of this thesis can inform future research and practice that aims to improve children's physical activity and physical literacy.

In this thesis, we confirmed that physical literacy can successfully be assessed in a laboratory setting with children and youth. We determined that assessment of physical literacy with the PLAY Tools has appropriate inter-rater reliability, construct validity, convergent validity, and internal consistency. We confirmed that PLAYbasic was an appropriate alternative to PLAYfun if space and/or time is limited. It was necessary to determine that physical literacy could be appropriately assessed in this age group before exploring the associations between physical literacy, physical activity, and health. Next, we tested the theory that physical literacy is associated with health indicators (Cairney et al., 2019). We observed that physical literacy was associated with favourable health indicators (body composition, aerobic fitness, blood pressure, and HRQOL) and higher MVPA in school-age children and that MVPA mediated the association between physical literacy and aerobic fitness. These results need to be confirmed through longitudinal or experimental study designs but offer initial evidence to support theories on this topic. Lastly, we generated group-based trajectory models of total volume of physical activity and MVPA across the preschool and school-age years. Participants were categorized into one of three trajectory groups based on their longitudinal physical activity patterns and we observed that those with the lowest physical activity over time had the lowest physical literacy, a worrisome finding if physical literacy is the gateway to an active future. Future research and practice should explore how physical literacy-based interventions or programming can modify physical activity behaviour and health over time in children and youth.

CHAPTER 6: REFERENCES

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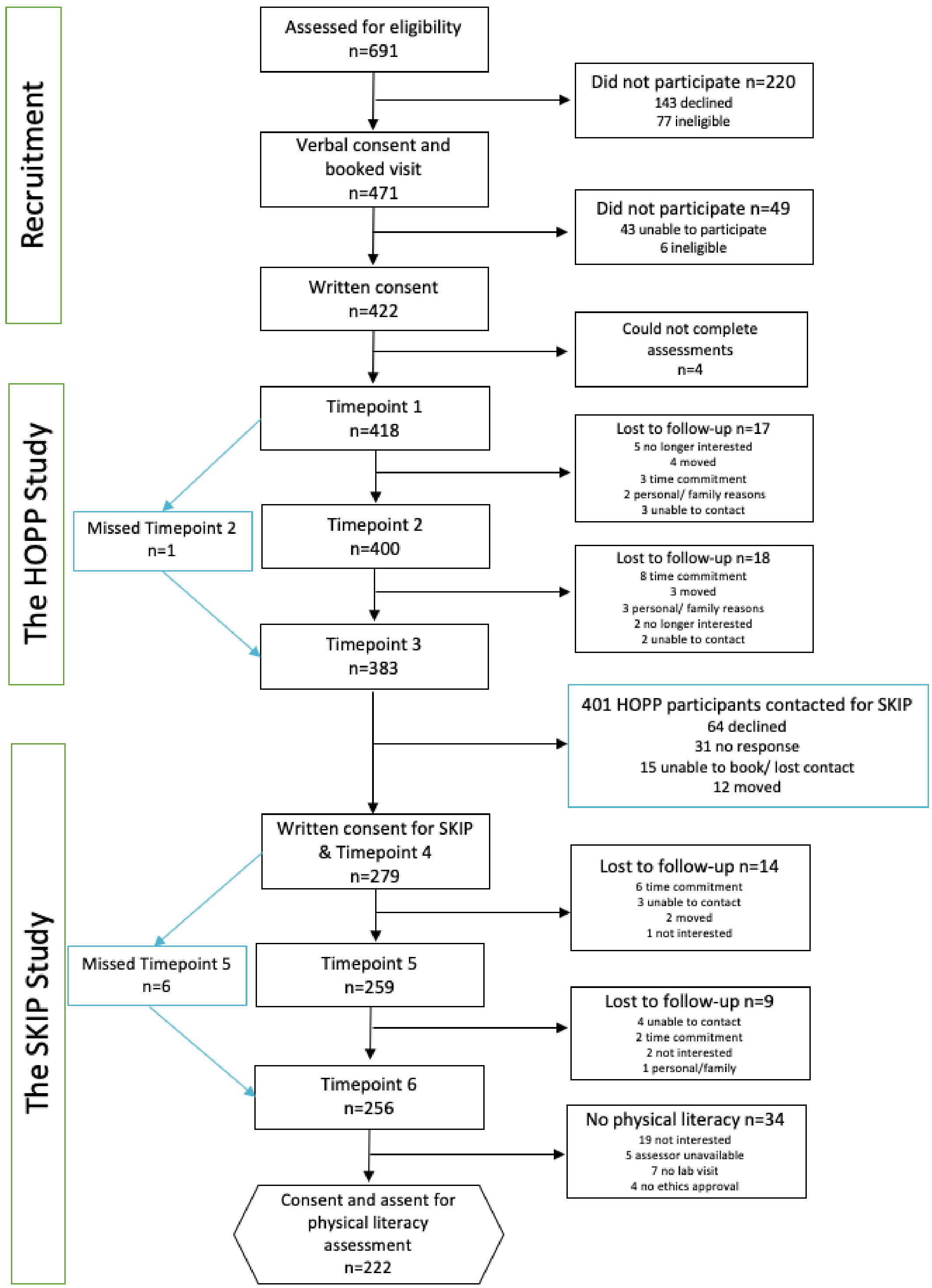
APPENDIX A: HOPP & SKIP STUDY FLOW OF PARTICIPANTS



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APPENDIX C: PHYSICAL LITERACY ASSESSMENT FOR YOUTH (PLAY) TOOLS

C1. PLAYfun

cut here

PLAY*fun*

Physical Literacy Assessment for Youth

canadiansportforlife.ca
play.physicalliteracy.ca

PLAY*fun* is intended for children aged 7 and up.

Participant's Name ______________ Gender: M F Age: ___

Place a mark in the box that best represents the child's ability. Indicate if the child had low confidence, or needed a prompt, mimic, description, or demonstration for each task.

	Competence				Confidence	Comprehension			
	Developing		Acquired						
Task	Initial	Emerging	Competent	Proficient	Confidence	Prompt	Mimic	Describe	Demo
1. Run a square									
2. Run there and back									
3. Run, jump, then land on two feet									
4. Crossovers									
5. Skip									
6. Gallop									
7. Hop									
8. Jump									
9. Overhand throw									
10. Strike with stick									
11. One-handed catch									
12. Hand dribble stationary & moving forward									
13. Kick ball									
14. Foot dribble moving forward									
15. Balance walk (heel-to-toe) forward									
16. Balance walk (toe-to-heel) backward									
17. Drop to ground & back up									
18. Lift and lower									

C2. PLAYbasic

cut here

PLAY*basic*

Physical Literacy Assessment for Youth

PLAY*basic* is intended for children aged seven and up.

canadiansportforlife.ca
play.physicalliteracy.ca

Participant's Name ______________________ Gender: M F Age: ____

Place a mark in the box that best represents the child's ability. Indicate if the child had low confidence, or needed a prompt, mimic, description, or demonstration for each task.

	Competence				Confidence	Comprehension			
	Developing		Acquired						
Task	Initial	Emerging	Competent	Proficient	Confidence	Prompt	Mimic	Describe	Demo
1. Run there and back									
2. Hop									
3. Overhand throw									
4. Kick ball									
5. Balance walk (toe-to-heel) backward									

You can score and track your assessment online at play.physicalliteracy.ca. There you'll be able to create groups and input **PLAY*basic*** scores for any number of children.

C3. PLAYparent

PLAY*parent*

Physical Literacy Assessment for Youth

Child's Name ______________________________ Gender: M F Age: ____

If individuals are physically literate when they have acquired the skills and confidence to enjoy a variety of sports and physical activities, how would you rank your child's overall level of physical literacy? Place a tick anywhere along the box.

Not Physically Literate ———————————— Perfect Physical Literacy

Assess your child using the table below:

	Low	Medium	High
1. Confidence to participate in physical activity and sport			
2. Motivation to participate in physical activity and sport			
3. Understands movement terms like skip, gallop, hop and jump			
4 Desire to participate in activities alone			
5. Desire to participate in activities with others or in groups			
6. Knowledge related to healthy physical activity			
7. Coordination when moving			
8. Safety while moving in the environment relative to others			
9. Number of movement skills acquired			
10. Ability to balance during movement			
11. Ability to run			
12. Ability to start, stop and change direction			
13. Ability to use hands to throw, catch and carry objects			
14. Ability to use feet to kick or move objects			
15. Ability to use left and right sides equally during activity			
16. Amount of participation in water activities			
17. Amount of participation in indoor activities			
18. Amount of participation in outdoor activities			
19. Amount of participation in snow/ice activities			
20. Overall fitness level			

Please list physical activities or sports that your child routinely participates in:

____

____

____

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C4. PLAYself

PLAY*self*

Physical Literacy Assessment for Youth

Your Name ____________________ Gender: M F Age: _____

I am most active in (check all that apply): ◯ summer ◯ winter ◯ active in both

How good are you at doing sports and activities?	Never tried	Not so good	OK	Very good	Excellent
1. In the gym?					
2. In and on the water?					
3. On the ice?					
4. On snow?					
5. Outdoors?					
6. On the playground?					

What do you think about doing sports and activities?	Not true at all	Not usually true	True	Very true
7. It doesn't take me long to learn new skills, sports or activities				
8. I think I have enough skills to participate in all the sports and activities I want				
9. I think being active is important for my health and well-being				
10. I think being active makes me happier				
11. I think I can take part in any sport/physical activity that I choose				
12. My body allows me to participate in any activity I choose				
13. I worry about trying a new sport or activity				
14. I understand the words that coaches and PE teachers use				
15. I'm confident when doing physical activities				
16. I can't wait to try new activities or sports				
17. I'm usually the best in my class at doing an activity				
18. I don't really need to practice my skills, I'm naturally good				

19. Reading and writing are very important	Do you agree or disagree with this statement?			
	Strongly disagree	Disagree	Agree	Strongly agree
In school				
At home with family				
With friends				

20. Math and numbers are very important	Do you agree or disagree with this statement?			
	Strongly disagree	Disagree	Agree	Strongly agree
In school				
At home with family				
With friends				

21. Movement, activities and sports are very important	Do you agree or disagree with this statement?			
	Strongly disagree	Disagree	Agree	Strongly agree
In school				
At home with family				
With friends				

22. My fitness is good enough to let me do all the activities I choose	Disagree	Agree

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