Assessing Movement Competence and Informing Injury Prevention in 8-12 Year Old Children: Development of the Child Focused Injury Risk Screening Tool (ChildFIRST).

Matthew Bruce Miller

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This is to certify that the thesis prepared

By: Matthew Miller

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complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the final examining committee:

______________________________ Chair
Dr. Charles Reiss

______________________________ External Examiner
Dr. Mark Lafave

______________________________ External to Program
Dr. Karen Li

______________________________ Examiner
Dr. Andrea Bergdahl

______________________________ Examiner
Dr. Geoffrey Dover

______________________________ Examiner
Dr. Loriann Hynes

______________________________ Thesis Supervisor
Dr. Richard DeMont

Approved by ______________________________
Dr. Rachel Berger, Graduate Program Director

March 26, 2021 ______________________________
Dr. Effrosyni Diamantoudi, Dean
School of Graduate Studies

ABSTRACT

Assessing Movement Competence and Informing Injury Prevention in 8–12 Year Old Children: Development of the Child Focused Injury Risk Screening Tool (ChildFIRST).

Matthew Bruce Miller, PhD, CAT(C)
Concordia University, 2021

Physical literacy is used to promote physical activity participation in children. When children increase participation in physical activities and sports they increase exposure to musculoskeletal injury. The concepts of physical literacy do not address injury prevention concerns. The results of multiple projects support a new process-based assessment of physical literacy to assess movement competence and potential for injury risk in 8–12 year old children. The Child Focused Injury Risk Screening Tool (ChildFIRST) includes ten movements with four evaluation criteria associated to each movement skill. Chapter one orients the reader to the major concepts within the document and states the objectives and hypotheses of each chapter. Chapter two describes the connection between physical literacy and injury prevention, forming the theoretical framework for the development of the ChildFIRST. Chapter three discusses the inter- and intra-rater reliability for the ChildFIRST. Eight movement skills achieved good-to-excellent inter-rater reliability (ICC=0.75-1.00), one movement achieved moderate (ICC=0.50-0.75), and one skill achieved poor (ICC=0.00-0.50). One skill achieved good intra-rater reliability, four skills achieved moderate, and five skill achieved poor. Evaluation criteria inter-rater reliability ranged from −0.04-0.835 Kα and 52–100% agreement, intra-rater reliability ranged from −0.328-0.303 Cohen's K and 45.8–98.6% agreement. The ChildFIRST can inform users about movement competence and be used to conduct cross-sectional studies in the 8-12 age group. Chapter four presents normative data, sex differences, and correlations. No significant differences between sexes were identified except in one movement. Higher levels of physical activity participation were associated with higher scores on the ChildFIRST, and higher BMI was associated with lower scores. This normative data can help users of the ChildFIRST compare their individual data to a larger sample. Chapter five explores new literature after the publication of chapters two and three, discussing future directions, and offering recommendations for future research.

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CONTRIBUTIONS OF AUTHORS

Three papers, two of which are published in peer-reviewed journals, comprise this dissertation. The authors of each paper are members of the Athletic Therapy Research Lab. John-Alexander Jimenez-Garcia and Chang Ki Hong were master's students at the time of the publication of the first publication, both students contributed to the concepts and writing of the literature review (chapter two). John-Alexander Jimenez-Garcia, now a PhD student, contributed to the writing of the reliability paper (chapter three), and the study design, data collection, and writing for the normative data paper (chapter four). Dr. Richard DeMont is my supervisor and the supervisor for the two students mentioned above. Dr. DeMont contributed significantly to the theoretical concepts, the study design, data collection, analysis, and editing for the publications within this dissertation. As a doctoral student I was the lead researcher for the reliability study (chapter three) and the normative data study (chapter four), I designed the research study, collected the data, analyzed the results, and wrote the papers. There were no funding agencies that supported this research, but I was personally funded by the Individualized Program Entrance Fellowship. The YMCAs of Quebec and the Champions for Life Foundation contributed to the data collection set up for these projects, specifically the normative data project. While these associations did not directly support me or the projects financially, their in-kind contribution deserves recognition.

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CHAPTER ONE:

INTRODUCTION

1.1 General Introduction

Childhood obesity and physical inactivity are two of the most serious public health challenges in Canada with 1 in 10 children being diagnosed with clinical obesity.[1] The growing rate of childhood obesity has many causes, one of which is a significant increase in physical inactivity and sedentary behaviour.[2] In 2018 physical inactivity accounted for 13% of deaths across the world, and in 2020, the World Health Organization indicated 27% of adults and 81% of adolescents do not meet the recommended daily physical activity guidelines.[3–5] Associated with the increase in physical inactivity are increased societal burdens and rising health care costs, a governmental report estimates the health care costs of overweight and obesity in Canada to be $6 billion.[5,6] As a result of the increased societal and financial burden there is a pressing need to improve physical activity (PA) participation in children and help alleviate the effects of sedentary behaviour in childhood and across the lifespan.[5] Sedentary lifestyles effect childhood and adult obesity, but this effect can be diminished with physical activity promotion. Since the early 2000s physical activity has been promoted in children using the concept of physical literacy (PL).[7] Physical literacy is defined as having the confidence and motivation, daily behaviour, physical competence, and knowledge and understanding to participate in PA throughout life.[7,8] There are four main concepts of PL: 1) The confidence and motivation to engage in regular PA, 2) The daily behavior domain, which encompasses the adoption of positive PA habits and lifestyles that individuals pursue each day,[7] 3) The physical competence domain promotes good movement capabilities, typically through participating in a variety of fundamental movement skills (FMS), and 4) The knowledge and understanding domain focuses on promoting the importance of participating in PA.[7] These four domains of physical literacy are often discussed separately but they are inter-linked. For example, the knowledge and understanding domain helps build confidence and motivation to participate in physical activity, which in turn enhances daily behaviour and physical competence.[7]

Within physical competence, FMS are used to describe the movement skills necessary for participation in sport and physical activity.[7,8] Fundamental movement skills are typically categorized as object manipulation skills (i.e. using a hockey stick, or tennis racket), locomotion skills (i.e. hopping, rolling, running), and stability/balance skills (i.e. standing on one leg, holding a yoga pose).[9,10] Physical literacy concepts are implemented into physical education curriculums so there is an increased need for assessment tools to evaluate baseline PL and PL interventions. Some assessments evaluate all four domains of physical literacy, for example the Canadian Assessment of Physical Literacy 2nd Edition[11] and the Passport for Life,[12] but most PL assessments evaluate physical competence, specifically FMS. Many assessments of physical competence are product-based, and evaluate specific performance outcomes such as run speed, throw distance, or number of repetitions within a specific timeframe.[13] Fewer PL assessments are process-based, which involves evaluating movement quality, technique, and "how" the movement is being conducted.[9,13] Process-based assessments consist of evaluating movement quality and technique, also concepts found in injury prevention literature.[14] Evaluating these concepts give process-based assessments the ability to identify movement or technique errors, and high-risk body positions, such as knee valgus, associated with injury.[13,15] Most assessments of PL have yet to address the risk of injury resulting from participation in sports and PA, so identifying errors in movement technique and risky body positions is an advantage of process-based assessments.[16] Using this form of assessment to evaluate movement competence offers the opportunity to link between PL and injury prevention.

In the United States (US) school aged children (6-17 years of age) experience at least 4.3 million sports and physical activity related injuries each year, 23% of these children took time off school, and 2.6 million children visited emergency rooms.[17,18] The cost of treating child sport related injuries is estimated at $US 1.8 billion.[19] In Canada, nation wide injury data is scarce under the age of 12, but youth aged 12-19 experience the highest likelihood of injury across all ages, two-thirds of these injuries are related to sports.[20] The injury rate for youth is similar in the US, as a result, injury prevention strategies are generally implemented at the age of 13 to help reduce the risk of injury into adulthood. [17,21] Along with acute effects of injury and the high costs associated with sports related injury, there are long term health effects. Children (age 12 and under) who experience an injury may lose their confidence and motivation to participate in physical activity/sport, develop a negative relationship with sport, and lose interest in participating.[22] The negative relationship with sport and PA as a result of injury can lead to decreased PA or complete drop out, in turn increasing levels of sedentary behaviour.[16] In response to the rate of sports related injuries, high cost of treatment, and long-term effects of injury, a variety of injury prevention programs have been developed. Common injury prevention programs include FIFA 11+ (now called 11+), HarmoKnee, 11+ kids, and the Prevent Injury and Enhance Performance (PEP) program.[23–26] A 2018 position statement from the National Athletic Trainers Association (NATA) states that preventative training programs should be performed 2 to 3 times a week, for 15-20 minutes a session and include feedback about movement technique and quality, in combination with strength, plyometrics, agility, flexibility, and balance exercises.[27] Although injury prevention programs are implemented around the age of 13, there is an opportunity to identify children at increased risk of injury in the ages of 8-12. The use of a process-based assessment of physical literacy with a focus on movement quality and technique can link these two areas only recently explored in the literature.[14]

Physical literacy concepts are integrated into physical education curriculums in children under the age of 12, and injury prevention programs are generally created for a specific sport at 13 years of age.[8] Incorporating injury prevention concepts into PL programs in children between the ages of 8-12 can: 1) identify children who demonstrate increased risk of injury before the age of 13, and improve interventions to mitigate injury, 2) promote physical activity participation while also encouraging sound movement quality, 3) target children with injury prevention benefits in physical activity and play settings (such as a playground or backyard), and 4) help children decrease their injury risk while participating in sport and physical activity throughout their life. The purpose of this dissertation is, 1) to explore the link between PL and injury prevention and how this link serves as the foundation for the creation of the Child Focused Injury Risk Screening Tool (ChildFIRST), and 2) to describe preliminary reliability evidence and normative trends in the 8-12 age group for the ChildFIRST. See Appendix A for the ChildFIRST tool.

Chapter two of this dissertation is a paper published in *Athletic Training and Sports Health Care*[28] that explores PL and injury prevention concepts in detail. Chapter two describes the various PL assessments and injury prevention programs in the literature and outlines a framework for how PL and injury prevention concepts are linked. The objectives of Chapter two are, 1) present the relevant and current literature in the domains of PL and injury prevention, 2) discuss the gap in literature between PL and injury prevention domains, and 3) provide evidence and a framework for a connection between PL and injury prevention domains.

Chapter three describes the reliability of the movement skills and evaluation criteria within a new physical literacy/injury risk assessment tool called the ChildFIRST. The paper in chapter three is published in *Measurement in Physical Education and Exercise Science* (MPEES).[28] As a note, the reliability paper was published in the same issue of MPEES as a project describing the content and face validity of the ChildFIRST (https://doi.org/10.1080/1091367X.2020.1793344).[29] Together these papers serve as validity and reliability evidence for the ChildFIRST. The objectives from Chapter three are, 1) evaluate inter- and intra-rater reliability of the movement skills within the ChildFIRST and 2) evaluate inter- and intra-rater reliability of the evaluation criteria within the ChildFIRST.

Chapter four is a manuscript describing the preliminary normative data and trends for a group of 8-12-year-old children evaluated with the ChildFIRST. Chapter four also explores differences between males and females, age, and other demographic variables. The objectives from chapter four include, 1) investigating normative data and trends for movement scores on the ChildFIRST in a group of 8-12-year-old children, and 2) evaluating differences between age, sex, height, weight, and physical activity habits, for scores on the ChildFIRST.

Finally, chapter five discusses the important findings from the three major projects enclosed in this dissertation. The discussion explores new additions to the literature since the publication of chapter two (the literature review), expands upon the connection between PL and injury prevention, and explains some additional concepts related to chapters three and four, and offers suggestions for future research, and overall conclusions.

1.2 Research Objectives & Hypothesis

The overarching goal of this dissertation is to present the theoretical background, reliability evidence, and normative values for a new process-based assessment of movement competence and injury risk for children aged 8-12 called the ChildFIRST. The research objectives and hypothesis for the projects enclosed within this dissertation are as follows:

Chapter Two Objectives

1) Present the relevant and current literature in the domains of physical literacy and injury prevention
2) Discuss the gap in literature between physical literacy and injury prevention domains
3) Provide evidence and a framework for a connection between physical literacy and injury prevention domains.

Chapter Two Hypotheses

1) There is a gap between physical literacy and injury prevention concepts
2) There is a framework to suggest a link between physical literacy and injury prevention concepts.
3) A process-based assessment of movement competence and injury risk can begin to fill the gap between physical literacy and injury prevention.

Chapter Three Objectives

1) Evaluate inter- and intra-rater reliability of the movement skills within the ChildFIRST
2) Evaluate inter- and intra-rater reliability of the evaluation criteria within the ChildFIRST

Chapter Three Hypotheses

1) The movement skills of the ChildFIRST will demonstrate good-to-excellent inter- and intra-rater reliability
2) The evaluation criteria of the ChildFIRST will demonstrate good-to-excellent inter- and intra-rater reliability.

Chapter Four Objectives

1) Investigate normative data and trends for scores on the ChildFIRST in a group of 8-12-year-old children.
2) Evaluate differences between age, sex, height, weight, BMI, and physical activity participation, for scores on the ChildFIRST.

Chapter Four Hypotheses

1) In a sample of 8-12-year-old children, scores on the ChildFIRST will be normally distributed with distinct average scores for males and females at each age segment from 8 to 12 years.
2) Older children, children who are taller, children who weigh less, and children who participate in more physical activity throughout the week will achieve higher scores on the ChildFIRST.

CHAPTER TWO:

MANUSCRIPT ONE

Process Based Assessment of Physical Literacy and the Connection to Injury Prevention Programs

Matthew B. Miller, MSc, CAT(C); John A. Jimenez-Garcia, BSc; Chang Ki Hong, MSc; Richard G. DeMont, PhD, CAT(C).

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The document presented in chapter two is the accepted manuscript before final copyedit that was published in *Athletic Training and Sports Health Care.* Due to copyright laws the final PDF version could not be included in this thesis.

2.1 Abstract

Purpose: Sedentary lifestyle habits are increasing interest in physical activity promotion. Physical literacy promotes activity in children, but the link to injury prevention concepts is insufficient. Our purpose was to review current physical literacy assessments and their link to injury prevention.

Methods: We reviewed physical literacy and injury prevention literature, with a focus on process-based assessments. This literature was examined for concepts of physical literacy and injury prevention.

Results: Assessments of physical literacy are primarily focused on evaluating children's performance on various fundamental movement skills. Often skill assessments focus on performance outcomes, whereas technique and position are process-based outcomes. Physical literacy assessments generally do not address risk of injury, but the prevention literature suggests technique and position are important in reducing injury risk.

Conclusions: We provide perspective on physical literacy promotion while mitigating injury risk and discuss integrating injury prevention strategies into physical literacy assessments.

2.2 Background

Regular physical activity has positive effects on the well-being of children and adolescents, including psychological, musculoskeletal, and physiological health.[1-5] Health concerns have been rising over the past decade, and according to the World Health Organization physical inactivity is the fourth leading cause of mortality in the world.[6] The benefits of physical activity are clear, but among children and adolescents there have been increasing levels of sedentary lifestyle habits. [6,7] The growing concern of decreased rates of physical activity in children is likely linked to the rising number of obese children; recently reported as 340 million worldwide.[6,8] Responding to low levels of physical activity in children, governmental policies, intervention programs, and researchers have focused on promoting physical activity.[6,9-13] An emerging idea that promotes physical activity in children and throughout life is the concept of physical literacy (PL). Physical literacy is described as a way to enhance confidence, motivation, physical competence, and the knowledge and understanding to value engagement in physical activities for life. As individuals pursue physical activity endeavours, the exposure to physically challenging situations escalates, increasing the risk of injury. There are several risk factors for injury in children such as hormonal changes, static postural alignment, and sex that are not modifiable in prevention efforts.[14] Modifiable risk factors, such as movement technique, are critical to study. If movements are performed poorly they can result in high-risk positions which are often implicated in catastrophic injury.[14,15] Injuries during childhood and adolescence have the potential for life-long effects, so mitigating injury risks in children is necessary with the discussion of physical activity. Physical literacy addresses confidence, motivation, physical competence, and knowledge and understanding, while aiming to promote physical activity. The constructs of physical literacy should not only by used to promote physical activity but aim to prevent injury. Particularly in the physical competence domain of physical literacy, the relationship between injury prevention should be a priority. A connection between physical literacy and injury risk is apparent; however, there is no evidence to support this relationship.

This review explores the relationship between physical literacy assessment tools and injury prevention programs. We compared and contrasted current physical literacy assessment tools with existing injury prevention programs. Our goal was to determine if physical literacy assessments include similar characteristics to injury prevention programs (i.e. movement capacities and fundamental movement skills). Additionally, we wanted to determine the need for emphasis of injury prevention strategies within physical literacy assessment tools. The physical literacy assessment tools, injury prevention programs, and other supporting literature were obtained through selected search criteria from common web-based academic search engines. Primary search criteria included, 'children', 'physical literacy assessment', 'injury prevention program', 'gross motor skill assessment', 'injury prevention', and 'reduce injury', searches were primarily conducted in PubMed and Web of Science. Other search criteria were selected based on literature, and secondary searches were performed using key words such as, 'fundamental movement skills', 'process-based assessments', and 'movement capacity', references from the selected literature were also examined for further resources. There is a large body of literature related to injury prevention, as such, we selected articles based on relevance to children, physical literacy, and movement assessment. We did not use any limits in our search criteria; however, we prioritized 'injury prevention' and 'movement assessment' as opposed to 'rehabilitation' and 'orthopedic assessment' in our search strategy. While the difference between assessments of PL and injury prevention interventions limit our ability to directly compare each tool, there are similarities between the movement skills found in each. Similarities between the movement skills highlight the importance of exploring how the concepts of physical literacy and injury prevention are connected, which is the focus of this review.

2.3 LITERATURE

2.3.1 Physical literacy

Physical literacy is an emerging concept in the physical education and health promotion domains; however, researchers often differ in their theoretical approach and definition.[16] A recent systematic review did a comprehensive search of physical literacy assessment tools and found that 70% of research addressing physical literacy utilized the definition of physical literacy proposed by Whitehead.[7] The approach to physical literacy proposed by Whitehead is defined as having the knowledge and understanding, daily behavior, physical competence, and motivation and confidence to participate in physical activity throughout the lifespan.[13] We used the Whitehead definition of physical literacy in this review because 1) it is the most widely used, 2) the Whitehead perspective of physical literacy is a holistic and individualized approach to participation in physical activity,[1] and we believe this individualized approach is key in the development of children's participation in physical activity and, 3) the individualized approach deemphasizes competition and promotes inclusion. The concept of physical literacy as proposed by Whitehead is often thought of in four domains, knowledge and understanding, daily behaviour, motivation and confidence, and physical competence.[1,13] Knowledge and understanding is an abstract concept that deals with the idea that knowing and understanding the importance of physical activity in one's life, will motivate an individual to participate in physical activity, as a result enhancing one's physical literacy.[1] The domain of daily behavior encompasses the habits and lifestyle that an individual chooses to pursue each day. Motivation and confidence are concepts that develop as an individual pursues physical activity participation. Finally, the physical competence domain aims to describe the movement capabilities of an individual. These four domains form the basis of physical literacy, and despite the four distinct ideas they are inter-linked.[1]

The physical competence domain of physical literacy is of particular interest for this literature review. Physical competence specifically relates to the movement capacities of an individual. Movement capacities encompass balance, strength, agility, endurance, flexibility, and body control, and these abilities are considered fundamental to human movement.[1] Movement capacities give individuals the ability to carry out a wide range of movement skills such as running, jumping, climbing, and balancing.[1] The movement capacities are often labeled fundamental movement skills (FMS), and are typically grouped in three areas: object manipulation (i.e. handling a ball, or tennis racket), locomotion (i.e. running, skipping, jumping), and stability and balance (i.e. standing on one leg, awareness of body position) (**Figure 1**).[11-13] Developing children typically establish their fundamental movement skills in early childhood (age 3 to 7 years of age), and these skills provide the basis for later specialized movements associated with sport related skills.[17] Around the age of 7, children enter a "context-specific period" in which they apply their fundamental movement skills to learn specialized movements required for participation in physical activity.[17] To ensure the passage into this "context-specific period", children require motivation, practice, and instruction in an environment that enhances learning, to break through a theoretical "proficiency barrier".[18] Failure to provide such opportunities will delay the application of fundamental movement skills to more specialized movements required for physical activity participation, which may potentially lead to injury.[19] The fundamental movement skills acquired by children 8 and older can either accelerate or restrict the development of these specialized skills which are essential in the child's participation in physical activity.[17] The assessment of fundamental movement skills through physical literacy assessments is critical to ensure the transition to specialized movement skills, which should help mitigate injury risk, and continued participation in physical activity.

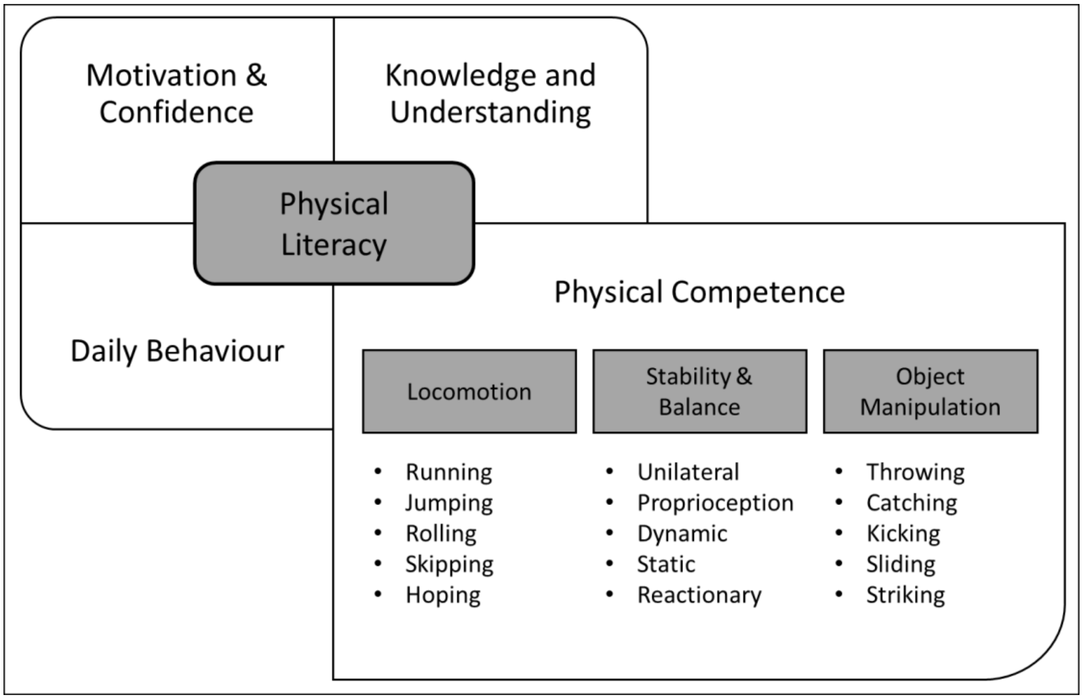

Figure 1. The fundamental movement skills in the physical competence domain of physical literacy. Created based on the concept of Whitehead.[1]

Physical literacy is a concept adopted by governmental and physical education domains in several countries (UK, Germany, USA, Canada, New Zealand, and Australia), as a result there is increasing research interest to further explore physical literacy.[8] As a product of these research initiatives, tools to assess physical literacy have been developed and are currently being used. There are qualitative tools such as interview techniques, reflective diaries, focus groups and participant observation, and quantitative tools such as accelerometers, questionnaires, and physical assessments.[16] Due to the large number of assessment tools and the goals of our review, we evaluated tools that primarily seek to assess the level of physical competence an individual possesses by evaluating a series of movement based skills that contribute to a child's physical literacy. Three tools, the Canadian Assessment of Physical Literacy (CAPL), the Physical Literacy Assessment for Youth (PLAY) tools, and the Passport for Life (P4L) have been developed to assess all four constructs of physical literacy. The Assessment of Basic Motor

Competencies (MOBAK), Test of Gross Motor Development 2 (TGMD-2), McCarron Assessment of Neuromuscular Development (MAND), POLYGON-FMS, and Basic Human Movements (BHM) only assess the physical competence domain of physical literacy. The majority of the physical literacy assessment tools are used to evaluate movement skills within the physical competency domain of physical literacy.[13,20-27]

The CAPL, PLAY, P4L, POLYGON-FMS, and MOBAK are similar in design; they include a series of movement skills included in the 3 areas of physical competence (object manipulation, locomotion, and balance).[13,20,25,26] The CAPL also includes anthropometric measures (body mass index, waist circumference) and standardized strength and flexibility measures (grip strength and sit & reach).[13] The TGMD-2 includes gross motor movements (locomotion skills) and the MAND includes gross and fine motor movements of the hands and fingers.[23,24] The BHM provides a unique perspective on the movement skills, suggesting there are 7 basic human movements that must be mastered before learning balance, locomotion, or object manipulation skills.[21] The BHM framework is also unique by using a process-based assessment which evaluates movement process, as opposed to movement performance. Movement process is discussed in detail later in this paper.

Stringent psychometric testing will help researchers, physical educators, personal trainers, parents, and other users of physical literacy assessments to select the most appropriate assessment for their population of interest. The PLAY, CAPL, P4L, POLYGON-FMS, MOBAK, and TGMD have achieved content and face validity, and can be used to assess physical literacy skills in children at various ages (CAPL & MOBAK for children ages 8-12, P4L in children aged 7-14, POLYGON-FMS in 8 year olds, and the TGMD-2 for children with the mean age of 12), the PLAY, CAPL and MOBAK have also achieved construct validity.[13,20,24,25,28] The MAND and BHM have yet to be assessed for validity. The CAPL, POLYGON-FMS, P4L, TGMD have reported reliability estimates, with the P4L, POLYGON-FMS, and TGMD tools reaching reliability coefficients for inter and intra class correlations of over 0.80, and the CAPL reporting reliability coefficients between 0.46 and 0.99. The P4L also reported internal consistency values of 0.62 to 0.86 on various aspects of the assessment. The remaining physical literacy assessments have yet to publish any reliability data.[13,24,25,28] There are a large number of available assessments of physical literacy, some of which are validated, but the majority do not include any link to injury prevention programs. This review is not a comprehensive analysis of all physical literacy assessments, but we have examined several popular and readily available assessment tools. The link between physical literacy and injury prevention is missing, in that, the physical literacy assessments we reviewed do not consider injury risk or injury prevention strategies. This oversight may inhibit a child's transition into more specialized movements by neglecting to adequately prepare them for more challenging physical activities, which could leave children vulnerable to injury and life-long consequences.

2.3.2 Injury Prevention Programs

Injury is an unfortunate, but integral part of sport participation with lower extremity injuries consisting of 66% of all sports injuries.[29] A non-contact ACL injury requiring surgical reconstruction can cost $5000 to $17,000 USD per patient, and long-term costs on society are estimated as much as $38,000 USD.[29,30] Between 2001 and 2008 an estimated 2.6 million children were seen in emergency rooms for sports related injuries in the United States with peak injury frequency occurring at age 14, highlighting the importance of teaching injury prevention strategies in childhood.[31] The yearly costs on society of treating sport related injuries experienced by children is estimated at $US 1.8 billion.[32] The high costs associated with childhood injury as a result of sport participation have likely increased since these numbers have been published, highlighting the importance of reducing injury risk and investigating injury prevention program effectiveness. While this is not an exhaustive review of prevention programs, there have been several injury prevention programs created to mitigate modifiable injury risks (i.e. FIFA 11+, Harmoknee, Prevent Injury and Enhance Performance (PEP) program, FootyFirst, and the Gaelic Athletic Association 15 training program).[33-36] The most widely used is the FIFA 11+, which was originally created for female soccer players aged 13-17, as a pre-game and pre-practice warm-up.[34,37] This program uses a variety of exercises, movements, and stretches aimed at reducing injury. The original research on the FIFA 11+ program concluded that although there was not a significant reduction in lower extremity injury, the overall risk of injury was reduced.[34,37] As a result, this program has been adopted by many female soccer teams worldwide.[34,37] Other research has evaluated the FIFA 11+ program as a result of the success of the program, these researchers suggest that beyond reducing the risk of injury the FIFA 11+ positively impacts performance measures (such as speed, jump height, and jump symmetry), improves dynamic postural control, and concentric knee strength.[33,38-40] Of particular interest are the movement skills within the FIFA 11+ related to locomotion (running, hoping, jumping, cutting, landing, and deceleration) and balance (one leg balance, hoping on one foot), which overlap with the fundamental movement skills in the physical literacy construct.[1,13,34] Children participating in sports that require locomotion skills involving cutting, landing, and deceleration have been identified as having an increased risk of injury.[29]

Balance skills are considered an integral part of both physical literacy assessments and injury prevention programs. Physical literacy researchers identify balance as one of the three categories of fundamental movement skills, [1,13] and injury prevention researchers suggest balance as a necessary component when designing a prevention program.[29] Recent research indicates that balance can be evaluated using nine components including functional stability limit, underlying motor systems, static stability, verticality, reactive postural control, anticipatory postural control, dynamic stability, sensory integration, and cognitive influences.[41] In a recent review of 21 tools used to assess balance in children, it was discovered that no assessments include all nine components of balance, which suggests that some balance assessments are missing important components of balance. [43] For example, reactive postural control is an important component of balance and is a primary factor in falls prevention for children, but was not included in any balance assessment.[42,43] Balance is also an important component of injury prevention programs, and has been integrated into many existing protocols.[5,34] The FIFA 11+ incorporates three components of balance; static stability, dynamic stability, and reactive postural control[34] which are assessed and enhanced through single-leg balance, lateral jumps, and partner perturbations.[34] Much like the physical literacy balance assessment protocols, the majority of published injury prevention programs do not include all nine components of balance.

The FIFA 11+ and other injury prevention programs have demonstrated success at reducing injury rates, but recent reviews cite variations between prevention programs as a limitation when comparing programs.[44-47] Herman et al [44] noted difficultly in comparing injury prevention interventions due to an inconsistency in program design, referring to variations in length and frequency of training session, and program duration. Also noted was a lack of consistency in the exercise selection to achieve similar goals. The use of eccentric hamstring curls is used in one study[48] in contrast to a combination of core strengthening and isometric hip strengthening in another,[49] to achieve the same goal of reducing hamstring injury. The between-program variation has limited researchers in their ability to compare injury prevention programs and determine the most effective means of preventing injury; however, from a clinical standpoint, having many effective means of reducing injury risk allows clinicians, athletic trainers, and other users to design individualized injury prevention programs tailored to the needs of their participants. The individualized approach may also be of benefit in physical literacy assessments as it relates to Whitehead's definition of physical literacy. Despite the between-program variation found in injury prevention programs, the National Athletic Trainers Association (NATA) has published a position statement regarding the best practices for injury prevention programs.[29] The NATA suggests that injury prevention programs should be performed during the pre-season and in-season, at least 2-3 times per week focusing on balance, strength, agility, movement technique, plyometrics, and flexibility.[29] These suggestions aid in the development of the relationship between injury prevention and physical literacy, especially by highlighting the importance of injury prevention in children.[29] Further, the authors of the NATA position statement suggest that continued participation in injury prevention programs (throughout the year, and over extended periods of time) will maintain the benefits of reduced injury rates, indicating the need for long-term participation in injury prevention methods.[29,37] These recommendations align with participation in physical activity starting early and continued throughout life. The concept of physical literacy mirrors the assertion of beginning physical activity at a young age and continuing throughout life. Assessments of physical literacy can evaluate movement competency to enhance physical activity participation in a way that is robust to injury, but re-evaluation of the outcomes of such assessments is necessary to establish a link between physical literacy and injury prevention programs.

2.4 Findings

2.4.1 Linking Physical Literacy and Injury Prevention

Fundamental textbooks in motor learning areas suggest that assessments using product measures (i.e. speed, strength, repetitions) are much more abundant than those using process measures, which is consistent within the physical literacy research.[11] The physical literacy assessments discussed above evaluate the physical performance of a child in a variety of fundamental movement skills, by evaluating performance based on speed, number of repetitions, and frequencies.[11] There are a limited number of physical literacy specific assessments developed to evaluate the process a child uses to perform these skills (i.e. technique, form, body position). Process-oriented assessments are designed to evaluate how a movement is performed, with the goal of describing the qualitative movement patterns being exhibited.[50] Some common examples of process based assessments are the Test of Gross Motor Development (TGMD-2) and the Landing Error Scoring System (LESS).[24,51] These assessments use evaluation criteria such as "Take off and land on both feet simultaneously" and "Decreased knee and hip flexion angle".[24,51] Process-oriented assessments involve outcomes that result in the optimal body position required to perform a movement, as opposed to a performance-oriented assessment that result in a time to completion or number of repetitions for a specific movement.[50] We also believe that a process-based assessment of physical literacy focuses on the individual as highlighted in Whiteheads definition of physical literacy and deemphasizes competition. A focus on the individual while deemphasizing competition allows children to grow, develop, and learn important movement skills without the perceived consequences of losing or failure. There are some disadvantages to a process-based outcome assessment, particularly the complexity of performing the assessment, the number of skills, and the time it takes to accurately assess the movement.[50] Despite these short-comings, an important difference between process-based and performance-based outcomes, is the ability of process-based outcomes to evaluate the technique of a movement skill. This distinction goes beyond simply evaluating an individual on how they move their body and may have implications in screening for injury risk factors. **Figure 2** demonstrates the relationship between process and performance assessments and the connection process-based assessments have with modifiable injury risk factors.

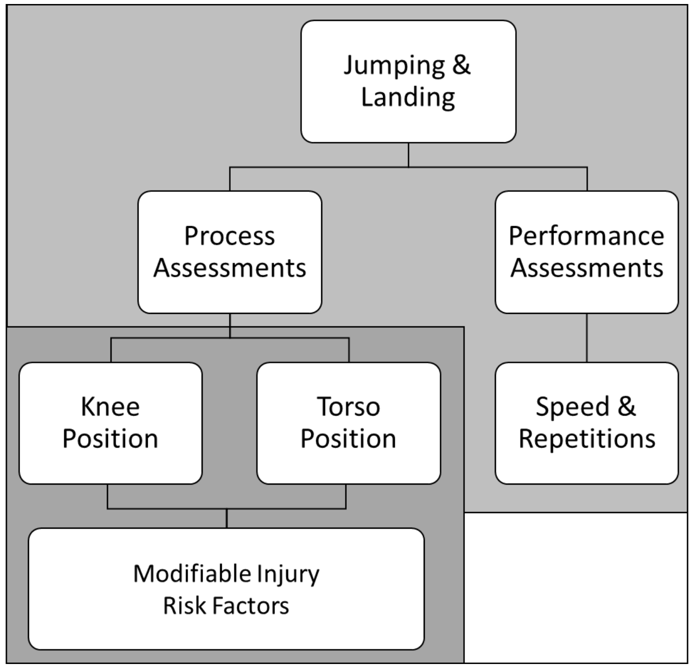

Figure 2. The relationship between process-based outcomes and injury risk factors.

The recent NATA position statement on the prevention of ACL injury suggests a series of components that are necessary to be incorporated in an injury prevention program, including feedback on movement technique.[29] This feedback highlights the importance of form and body position in reducing the risk of injury. The position statement specifically encourages teaching movement patterns that focus on body control and movement quality when implementing injury prevention training programs in children.[29] These recommendations highlight the importance of focusing on movement process, as opposed to movement performance in children. Physical literacy assessments have generally focused on performance based measures, yet the NATA position statement recommends focusing on movement technique when developing injury prevention programs with children.[29] This contrast establishes an important gap between physical literacy assessments and injury prevention programs. Physical literacy assessments have neglected any discussion about how they relate to injury prevention and reducing injury risk factors in children. Upon closer inspection, injury prevention and physical literacy are closely associated. The physical competence domain of physical literacy encompasses the fundamental movement skills of locomotion, balance, and object manipulation.[1,13] The ability to perform the fundamental movement skills at a competent level to mitigate injury risk is established through the child's body stability and balance, and movement technique, that together contribute to avoidance of compromising positions.[41] By assessing fundamental movement skills with a process-based assessment, children will be evaluated on their body position and movement quality, and movement quality has been identified as a biomechanical risk factor that can predict noncontact or indirect-contact ACL injuries.[52,53] Process-based assessment criteria that evaluate body positions identified as vulnerable to injury have the potential to screen children for modifiable injury risk factors and the child's level of physical competence. This link highlights the potential of physical literacy assessments to screen for precision of movement indicated for injury prevention, as demonstrated in **Figure 3**. By using a process-based assessment, the gap between physical literacy tools and injury prevention programs narrows. This comparison further highlights the importance of an assessment with process-based outcomes, as opposed to a performance-based assessment.

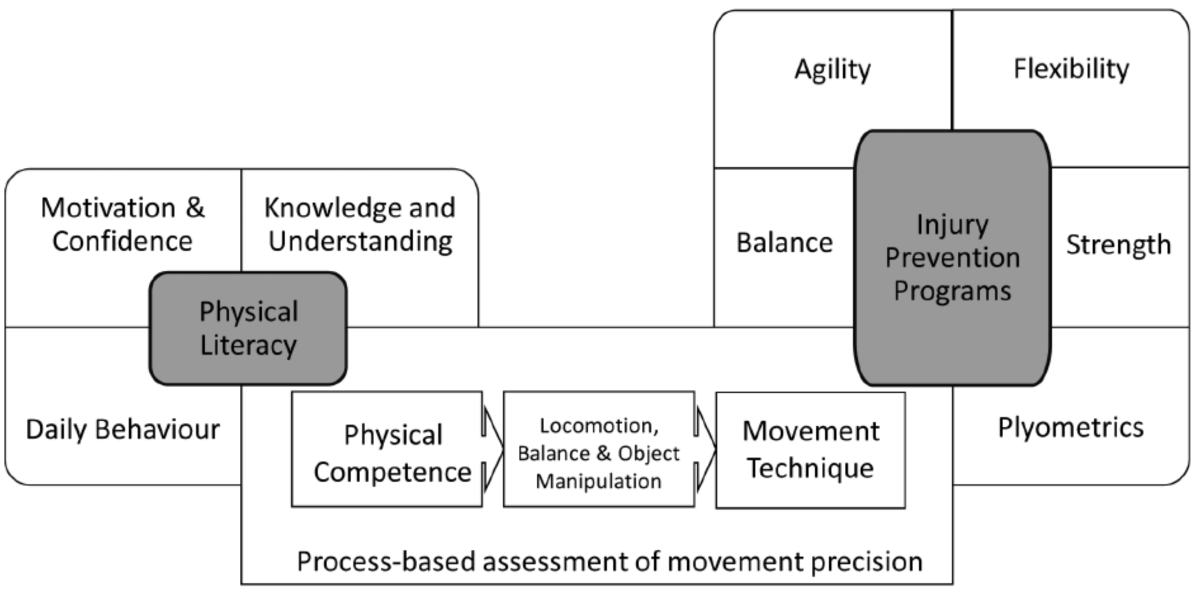

Figure 3. The connection between physical literacy, process-based assessments, and injury prevention programs

2.5 Conclusion

Physical literacy is an important concept that encourages the participation in physical activity from a young age.[1] Currently, these assessments are primarily targeted at children, and evaluate their performance in a variety of fundamental movement skills. The underlying constructs of physical literacy are linked to the framework of injury prevention programs; however, physical literacy assessments do not effectively address concerns related to injury risk.

As such, more emphasis needs to be placed on evaluating the quality and process that children use to perform these fundamental movement skills including aspects of injury prevention.

2.6 Future Research

Future research efforts should focus on establishing scientifically robust assessment tools, that use process-based outcomes to evaluate children's movement capabilities. Developing physical literacy assessments that include the evaluation of body position, form, and technique of fundamental movement skills will not only encourage participation in physical activity, but continued practice of these movements may result in children being more resistant to injury as they pursue further physical activity throughout their life.

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TRANSITION TO CHAPTER THREE

The objectives from chapter two were to present the relevant literature related to physical literacy and injury prevention, discuss the gap between these concepts, and provide theoretical framework connecting these domains. Chapter two meets the objectives and introduces the foundation for the creation of the ChildFIRST.

The next step in the development of the ChildFIRST was to investigate the best movement skills and associated evaluation criteria to assess both movement competence and injury risk in the 8-12-year-old age group. A manuscript published in *Measurement in Physical Education and Exercise Science* (doi:10.1080/1091367X.2020.1793344) in 2020 explains the use of a Delphi process used over three iterations to gain expert consensus on the ten best movements and four best evaluation criteria for each movement. The Delphi process study was not part of my PhD work and is not part of this dissertation, but it is discussed here because it describes the face and content validity for the ChildFIRST. The Delphi process occurred from 2017-2018 and formed part of two master's theses for colleagues in the Athletic Therapy Research Lab at Concordia University. See appendix one for the ChildFIRST movement skills and evaluation criteria.

The manuscript presented in chapter three was published in *Measurement in Physical Education and Exercise Science* (doi:10.1080/1091367X.2020.1781129) and describes the inter- and intra-rater reliability for the movement skills and evaluation criteria of the ChildFIRST. Together, the Delphi study and the reliability study in the upcoming chapter describe preliminary psychometric evidence for the ChildFIRST.

CHAPTER THREE:

MANUSCRIPT TWO

Assessing Movement Competence and Screening for Injury Risk in 8-12-year-Old Children: Reliability of the Child Focused Injury Risk Screening Tool (ChildFIRST)

Matthew B. Miller, MSc, CAT(C); John A. Jimenez-Garcia, BSc; Chang Ki Hong, MSc; Richard G. DeMont, PhD, CAT(C).

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The document presented in chapter three is the accepted manuscript before final copyedit that was published in *Measurement in Physical Education and Exercise Science.* Due to copyright laws the final PDF version could not be included in this thesis. Please note, the references in chapter three have been modified from the published version to match the rest of the dissertation document. No content has been modified.

3.1 Abstract

The Child Focused Injury Risk Screening Tool (ChildFIRST) is a process-based assessment including 10 movement skills with 4 associated evaluation criteria. The ChildFIRST has been validated by a group of experts to evaluate movement competence and injury risk in 8-12-year-olds. The purpose of this study is to evaluate the reliability of the ChildFIRST. Twelve college-aged subjects attended a 1-hour training session. To evaluate inter-rater reliability, the participants rated 6 videos per movement, 60 videos in total. To evaluate intra-rater reliability, the participants returned after 7 days to rate the same videos. Movement skill inter-rater reliability ranged from -0.306-0.938 ICC, intra-rater reliability ranged from -0.386-0.881 ICC. Evaluation criteria inter-rater reliability ranged from -0.04-0.835 Kα and 52-100% agreement, intra-rater reliability ranged from -0.328-0.303 Cohen's K and 45.8-98.6% agreement. The ChildFIRST demonstrates moderate-to-excellent inter-rater reliability for nine of ten movement skills, while intra-rater reliability and overall evaluation criteria reliability ranges from good-to-poor.

3.2 Introduction

Childhood obesity is one of the most serious public health challenges in Canada and across the world and the growing rate of childhood obesity is linked to an increase in sedentary behaviour.[1] Physical inactivity and sedentary behaviour are now the fourth leading cause of mortality in the world.[2] Associated with increased levels of sedentary behaviour are increased levels of obesity, cardiovascular disease, depression, and musculoskeletal injury risk (among others).[3–5] As a result of the comorbidities associated with sedentary behaviour, there is an urgent need to increase physical activity (PA) among children.[2] Sedentary lifestyles linked with (childhood) obesity are largely avoidable with the promotion of physical activity. Promoting PA can reduce sedentary behaviour, also reducing the risk of associated diseases, and mitigating the risk of musculoskeletal injury.[6,7] Recent efforts to improve physical activity participation focus on promoting PA using the concept of physical literacy (PL).[8] Physical literacy is defined as having the confidence and motivation, daily behaviour, physical competence, and knowledge and understanding to participate in PA throughout life.[8] Physical literacy programs are being implemented in schools, Young Men's Christian Association (YMCA's), and other community centres across Canada. Physical literacy assessment tools are needed to evaluate these programs; however, these tools do not yet consider risk of injury in their protocols.

There are valid and reliable assessments of physical literacy such as the Canadian Assessment of Physical Literacy 2.0 (CAPL 2.0) and Passport for Life (PFL) that evaluate each domain of physical literacy, but it is difficult to capture each aspect of physical literacy in one assessment.[9–11] There are other assessment tools that emphasize the physical competence domain of PL but many of these tools need validity and reliability evidence.[12–15] There are also tools of motor competence, not specifically identified as physical literacy tools, but that are also designed to evaluate movement from a motor competence/motor skill perspective.[16–19] It is important to emphasize physical competence (or motor competence) at younger ages because there is a strong link between physical competence, perceived physical competence, and physical activity participation, and there is an opportunity to identify children at increased risk of injury.[20,21] Tools that emphasize physical competence primarily focus on a child's movement capabilities by using product-based assessments to evaluate movement skills such as running, jumping, lunging, squatting, and various forms of balancing.[9,22,23]

Assessments of movement competence are primarily categorized as product-based or process-based.[24] Product-based assessments evaluate the outcome of a movement with the use of criteria such as speed, height, distance, and repetitions (i.e. run speed, jump distance, and number of successful catches in a row).[24] Product-based assessments give evaluators the ability to assess many children in a short time period which is advantageous in a physical education context. A disadvantage of product-based assessments is the inability to identify movement or technique errors and high-risk movements, such as knee valgus (when the knee collapses inwards, a risk factor in knee injuries), associated with musculoskeletal injury.[17,25] A recent paper examines the relationship between peak height velocity and movement competence using a product-based assessment.[26] This paper highlights the role peak height velocity plays in movement competence, indicating that after a growth spurt, performance on motor skills is decreased.[26] Research also suggests a link between peak height velocity and injury,[27,28] but within the existing literature there is no mention of the link between physical literacy and risk of injury. Product-based assessments are important tools to evaluate the performance of various movement skills, but a gap in the literature still exists between injury risk and physical literacy. The use of a process-based assessment with a focus on movement technique, body position, movement quality, and injury risk can help bridge this gap.

Process-based assessments evaluate how a movement is performed and describe the quality of movement.[24] Process-based assessments use evaluation criteria related to movement technique and body positioning, such as "trunk remains straight", "head in neutral alignment", and "knees and feet aligned".[24,29] Recent research, using process-based assessments, suggests that movement-oriented interventions are needed to help improve fundamental and functional movement amongst school aged children, further enhancing the relationship between process-based assessments and movement skills.[30,31] Not only are movement technique and body position essential to evaluate the quality of a movement, they are suggested as important factors in injury prevention literature.[32] A recent position statement on the prevention of anterior cruciate ligament (ACL) injuries from the National Athletic Trainers Association (NATA), indicates that movement technique and body position are key elements in injury prevention based exercise programs.[32] It is also important to note that helping children develop movement competence allows for more advanced training modalities, leading to increased resilience to injury.[33] By observing movement and using evaluation criteria related to movement quality, a process-based evaluation tool can identify errors in movement technique and high-risk body positions. The ability to identify movement errors and risky body positions is an advantage of process-based assessments because evaluators can gain more information about a child's injury risk and movement competence.[34] Children who demonstrate good movement competence are afforded more opportunities to pursue physical activity, whereas poor movement competence is considered an internal risk factor for injury.[35–37] A recent systematic review identifies the Landing Error Scoring System (LESS), a tool to evaluate injury risk factors in a jump-landing movement, as a process-based assessment.[33] Identifying the LESS as a process-based assessment gives further evidence of the link between process-based assessments and the evaluation of injury risk. A disadvantage of process-based assessments is the requirement for evaluators to observe many components of a specific movement, which can be challenging to implement in large group settings such as a physical education class.[16] Process-based assessments often use 4-5 evaluation criteria to assess complex movements involving many body segments moving at once making accurate evaluation of movement more difficult. The increased complexity of process-based assessments leads many evaluators to use video to accurately evaluate each participant.[24]

As children pursue physical activity endeavours, the exposure to physically challenging situations escalates, increasing the risk of injury.[8,9] Injury and risk of injury often limit participation in PA in childhood, contributing to life-long effects such as increased cardiovascular disease, depression, obesity, and other serious health problems.[38] Musculoskeletal injury paired with sedentary lifestyles further contributes to the public health burden, so it is essential to mitigate the risk of injury in children.[39,40] Injuries specific to the lower limb are particularly common and account for more than 60% of injuries in middle school students.[41] The connection between injury prevention programs, such as the FIFA 11+, and physical literacy assessments, such as the CAPL 2.0 and PFL, has been discussed in detail in a previous publication.[9,10,42,43] Despite the variety, physical literacy assessment tools fail to address musculoskeletal injury risk in childhood. Increasing consideration for injury prevention and screening strategies within physical literacy models should lead to improvements in physical activity participation in childhood. Our review of physical literacy and injury prevention literature indicates that it is critical for new physical literacy assessments to incorporate injury prevention and injury screening strategies, specifically in the 8-12 age, due to the increased risk of injury after the age of 12.[42,43] Physical educators, therapists, and coaches using a PL assessment integrating injury screening strategies can evaluate both movement competence and injury risk to help identify children at risk of injury before they get injured.[42] Identifying children with poor movement competence and at increased risk of injury can help inform interventions with the goal of reducing injury risk and facilitating lifelong participation in physical activity.

The research team created the Child Focused Injury Risk Screening Tool (ChildFIRST) to bridge the gap between physical literacy and injury prevention models. The aim of the ChildFIRST is to evaluate movement competence and identify lower extremity injury risk in children aged 8-12. The ChildFIRST includes 10 movement skills with four evaluation criteria associated to each movement. The ChildFIRST is intended to be conducted in a circuit and used in group settings like a physical education class or sports team. The ChildFIRST is similar to other assessment tools, such as the Test of Gross Motor Development 3rd edition (TGMD-3), CAPL, P4L, and MOBAK, because each of these assessments include a variety of movements, tested in a circuit format, intended for use in children under the age of 12.[9,10,16,19] The P4L, CAPL, and MOBAK are product-based tools, and the TGMD-3 is considered a process-based tool including 3-5 evaluation criteria for each skill.[9,10,16,19] The ChildFIRST is similar to the TGMD-3 because it has 4 evaluation criteria for each movement, but it is distinct from all of the assessment tools because it includes novel movements like the 90-degree hop and hold and single-leg sideways hop and hold. Also, the movements and evaluation criteria in the ChildFIRST have been specifically validated to evaluate movement competence and injury risk. The ChildFIRST was designed to help bridge the gap between physical literacy and injury prevention by evaluating a series of movement skills with a focus on evaluating movement technique and body positions that are associated with increased risk of injury. The research team established face and content validity of the ChildFIRST with a Delphi process (manuscript submitted), but before using this tool in a field setting, establishing reliability is required. The purpose of the present study was to evaluate the inter- and intra-rater reliability of the ChildFIRST. The *a priori* hypothesis is that each movement and each evaluation criteria will demonstrate good-to-excellent (ICC < .75) inter- and intra-rater reliability.[44]

3.3 Methods

3.3.1 Participants

The research team recruited a convenience sample of 12 college-aged participants. Five males (42%) and seven females (58%) participated, the mean age was 24.6±2.26. One participant was in the 2nd year of an athletic therapy program, two were in the 3rd year, five were in the 4th year, and four participants graduated within the last 2 months. All participants successfully passed a musculoskeletal and systemic anatomy course and have a basic knowledge of human movement and exercise. A power analysis is typically conducted *a priori* to obtain a suitable sample size required to test a specific hypothesis. In the case of reliability testing the goal is to be precise in measurement and not to have power to detect a statistical significance (Shoukri, 2004). Based on previous literature, to get an expected interclass correlation coefficient (ICC) of 0.80, with $\alpha = 0.05$ and $\beta = 0.20$, with two viewing sessions, the required sample size is at least 9 raters.[45]

3.3.2 The ChildFIRST

The ChildFIRST is a process-based assessment of movement competence and injury risk for children aged 8-12. The research team used a modified Delphi method (manuscript submitted) to create the ChildFIRST. In the Delphi tool development project, the research team surveyed a group of experts in the fields of athletic therapy/training, injury prevention, physical literacy, and motor development. The research team used the expert feedback to achieve consensus on the including of 10 movement skills and four evaluation criteria within the ChildFIRST, and to establish face and content validity. The ChildFIRST includes ten movement skills: bodyweight squat, vertical jump, single-leg sideways hop and hold, walking lunge, two-to-one-foot hop and hold, 90-degree hop and hold, leaping, horizontal jump, running, and single-leg hop. There are four evaluation criteria associated to each movement skill designed to identify specific movement errors or injury risk factors. The research team designed the ChildFIRST as an observational tool that should be conducted in settings such as a school gymnasium, soccer field, clinic, or other open area, with minimal equipment. The intended users are physical education teachers, coaches, athletic trainers/therapists, or other human movement specialists. To score the ChildFIRST, users observe children performing each movement and assign the children a score from zero to four. Each movement has four evaluation criteria that are designed to be observable movement characteristics. If the characteristic is observed, the child obtains a score of one, if the characteristic is not observed the child obtains a score of zero. The total score for each movement skill is the sum of the evaluation criteria for each specific movement, so children can achieve a possible score ranging from zero to four for each movement. Each movement skill is be demonstrated twice for the children by the evaluator, the evaluator can provide basic instructions about how to perform the movement, but the instructions cannot be directly related to the evaluation criteria (for example, evaluators cannot instruct the children to make sure their hips, knees, and ankles are aligned during the walking lunge because that is one of the evaluation criteria). After the demonstrations, the children will perform each movement skill. The child will perform; three repetitions of the bodyweight squat, vertical jump, and the horizontal jump; two repetitions on each leg of the 90-degree hop and hold, two-to-one foot hop and hold, and single-leg sideways hop and hold; and the children will perform running, walking lunge, leaping, and single-leg hop repeatedly over a 20m distance. The children will rotate through the circuit until all movements have been completed.

3.3.3 Procedures

All study procedures were approved by institutional human research ethics committee. On the first testing day, participants were trained on how to use the ChildFIRST in a one-hour training session. The evaluators are intended to be students and practitioners of physical education, physical therapy and athletic therapy, and others familiar with human movement. The training session was intended to be short and focus on how to implement the tool, and not how to identify movement errors, an element with which evaluators should be familiar. In the training session, a member of the research team described the theoretical background of the tool, gave instructions for the preparation of the tool, and instructed the participants about how to use the tool. The participants also performed practice trials in the training session and compared their scores to the researchers scores. After the training session, the participants watched 60 counter-balanced videos of children performing each movement in the ChildFIRST. The research team used six videos per movement with children of varying skill levels for a total of 60 videos. The use of video allowed evaluators to assess the exact same performance on multiple days and for multiple evaluators to judge the identical performance from the same viewing angle. Participants attended training and testing sessions individually or at maximum in groups of four to limit the amount of bias of having many evaluators in the same room with the potential of seeing the answers of others. The rating session took one hour, and the first day of testing lasted approximately two hours.

The participants returned in at least seven days to watch the videos again in another counter-balanced order, the second testing day lasted approximately one hour. The seven-day delay between testing sessions reduced the chances that participants would remember the scores they assigned to each video in the first session. All efforts were made to have participants return in seven days but due to scheduling conflicts some participants returned for the second testing session in more than seven days, with one participant returning four weeks after the first testing session. The reliability testing procedures were designed to simulate a real-life testing situation as closely as possible, for that reason the research team ensured the videos were 10-20 seconds in length, and participants were only allowed to view each video once. Short videos allow for 4-5 movements to be tested in a minute, and at least 60 videos to be evaluated in an hour. The ChildFIRST is intended to be used in a gymnasium or field setting where evaluators can test up to 30-45 children in a one hour testing session. In total, the participants participated for three hours over two testing sessions.

3.3.4 Analysis

The research team compared the scores (out of four) for each movement on the first testing day between raters to establish inter-rater reliability. The research team then compared total movement scores on the first and second testing days to establish intra-rater reliability. To establish inter- and intra-rater reliability for the total score for each movement the research team calculated the interclass correlation coefficients (ICC) using a two-way random single measures, absolute agreement, using multiple raters (ICC 2,*k* model), and a 95% confidence interval (CI). The strength of agreement using the ICC was determined by the following criteria proposed by Koo and Li: 0.00 to 0.50, poor; 0.50 to 0.75, moderate; 0.75 to 0.90, good; 0.90 to 1.00, excellent.[44] The research team performed all analysis in SPSS Version 24 (IBM Corp., Armonk, NY, USA) and Microsoft Office Excel (2016 Version).

Inter-rater reliability establishes the reliability between all raters, because this study used more than two raters (N =12) and the data is dichotomous (1 = observed, 0 = not observed), inter-rater reliability analysis of the evaluation criteria was conducted using Krippendorf's Alpha (Kα).[46] The dataset in this study is relatively small and had an irregular distribution due to the dichotomous nature. To account for the non-normal distribution, the research team calculated bootstrap confidence intervals for the Krippendorf's Alpha using 1000 bootstrap samples.[47] Bootstrapping is a procedure that conducts replications based on the actual data to more accurately estimate the amount of sampling error.[48] Krippendorf's Alpha is interpreted as: below 0.667, unreliable; 0.667 to 0.800, ability to draw tentative conclusions; 0.800 and above, can draw reliable conclusions.[47]

Intra-rater reliability establishes the reliability between the same rater over multiple testing sessions. The research team compared dichotomous scores from the same rater over two testing sessions, making 12 comparisons in total to calculate average Cohen's Kappa.[49] The research team used average Cohen's Kappa to calculate the intra-rater reliability for each evaluation criteria because average Cohen's Kappa is more robust than pooled Cohen's Kappa.[50] The research team calculated the 95% confidence interval for the Cohen's Kappa estimate because bootstrapping of a single average cannot be conducted.[50] Cohen's Kappa is interpreted as: 0 to 0.20, none; 0.21 to 0.40, fair; 0.41 to 0.60 moderate; 0.61 to 0.80, substantial; 0.81 to 1.00, almost perfect.[49] For both inter- and intra-rater reliability of the evaluation criteria the research team also calculated percentage agreement, our rationale for using multiple analysis techniques can be found in the discussion.

3.4 Results

The ChildFIRST demonstrates good-to-excellent (ICC > 0.75) inter-rater reliability for eight movement skills; bodyweight squat, vertical jump, single leg sideways hop and hold, walking lunge, 90˚ hop and hold, leaping, horizontal jump and running. The single-leg hop movement skill demonstrates moderate reliability (ICC = 0.727) and the two-to-one-foot hop and hold movement skill demonstrates poor reliability (ICC = -0.306).

The ChildFIRST demonstrates moderate-to-good (ICC > 0.50) intra-rater reliability for five movement skills; bodyweight squat, vertical jump, single leg sideways hop and hold, walking lunge, and horizontal jump. The remaining five movement skills; two-to-one-foot hop and hold, 90˚ hop and hold, leaping, running, and single-leg hop, demonstrate poor intra-rater reliability (ICC = 0.00 to 0.50). Reliability statistics and 95% confidence intervals for each movement skill are presented in Table 1. One rater was removed from the intra-rater reliability analysis because they scored all children the same for the "two-to-one foot hop and hold" movement, as a result, an ICC value could not be calculated for this rate due to having zero score variance.

Table 1. Reliability statistics for the total scores of each movement skill

	Inter-rater Reliability		Intra-rater Reliability[a]	
Movement Skill (N = 12 Raters)	ICC (2,*k*)[b]	95% CI	ICC (2,*k*)[b]	95% CI
Bodyweight Squat	0.928	0.80-0.99%	0.622	0.41-0.83%
Vertical Jump	0.938	0.83-0.99%	0.881	0.84-0.93%
Single Leg Sideways Hop and Hold	0.836	0.57-0.97%	0.689	-0.49-0.62%
Walking Lunge	0.932	0.82-0.99%	0.570	0.34-0.80%
Two-to-One Foot Hop and Hold[c]	-0.306	-1.28-0.70%	-0.386	-1.17-0.40%
90˚ Hop and Hold	0.808	0.49-0.97%	0.423	0.18-0.68%
Leaping	0.798	0.47-0.97%	0.357	-0.01-0.73%
Horizontal Jump	0.841	0.58-0.97%	0.701	0.61-0.79%
Running[c]	0.800	0.49-0.97%	0.147	-0.62-0.92%
Single Leg Hop	0.727	0.31-0.95%	-0.006	-0.55-0.54%

N, Sample Size; ICC, Interclass Correlation; CI, Confidence Interval.

[a] Intra-rater reliability scores for each skill are calculated as the average of each rater.

[b] Two-way random effects model, absolute agreement, multiple raters

[c] One rater was removed from the inter-rater reliability analysis because the rater had zero score variance in this movement skill.

The research team found that inter-rater reliability scores for individual evaluation criteria ranged from unreliable (Kα > 0.667) to reliable (Kα < 0.80). Percent agreement for individual evaluation criteria ranged from 52% to 100%. Vertical jump is the only movement skill to have an evaluation criteria (swing arms to assist movement) achieve a reliable estimate of Krippendorf's Alpha (Kα = 0.825). In contrast to the low Krippendorf's Alpha scores, all evaluation criteria achieved higher than 52% agreement, with two evaluation criteria reaching 100% agreement. Inter-rater Kα reliability statistics and bootstrap confidence intervals for each evaluation criteria are presented in table 2.

Table 2. Inter-rater reliability for the evaluation criteria of each movement skill

Movement Skill and Evaluation Criteria (N = 12 Raters)	Percent Agreement	Krippendorf's Alpha	Bootstrapped CI[b]
Bodyweight Squat			
1. Push hips back and bend the knees until the thighs are approximately parallel with the ground	67.9%	0.173	0.05-0.29
2. Hips, knees, and ankles aligned	76.8%	0.489	0.39-0.58
3. Knees do not go too far in front of the toes	75.1%	0.103	-0.04-0.27
4. Keep the heels down all the time	92.0%	0.596	0.46-0.74
Vertical Jump			
1. Swing arms to assist the movement	92.2%	0.835	0.79-0.89
2. Knees and hips bend to land softly in a controlled fashion	73.6%	0.141	-0.00-0.28
3. Land on both feet at the same time[c]	100.0%	-	-
4. Hips, knees, and ankles aligned	70.6%	0.250	0.13-0.37
Single Leg Sideways Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	80.6%	0.188	0.03-0.34
2. Hips, knees, and ankles aligned	61.1%	0.237	0.15-0.33
3. Foot flat on the floor	71.9%	-0.004	-0.17-0.16
4. Stand up straight within three seconds after landing	63.4%	0.222	0.13-0.33
Walking Lunge			
1. Hips, knees, and ankles aligned	68.7%	0.106	-0.03-0.24
2. Upper-body straight and eyes focused in direction of travel	73.6%	0.367	0.27-0.48
3. Front knee does not go too far in front of toes	78.6%	0.201	0.05-0.35
4. No twisting nor bending back	70.6%	0.467	0.37-0.55
Two-to-One Foot Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	70.6%	0.164	0.05-0.29
2. Toes pointing forward[c]	100.0%	-	-
3. Foot flat on the floor	97.3%	0.000	-0.55-0.55
4. Hips, knees, and ankles aligned	52.0%	0.42	-0.05-0.13
90˚ Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	77.1%	0.124	-0.03-0.28
2. Hips, knees, and ankles aligned	54.2%	0.097	-0.00-0.19
3. Whole body turns together	97.2%	0.000	-0.73-0.55
4. Toes pointing forward	79.8%	0.221	0.07-0.38
Leaping			
1. Take off from one foot, land on the opposite foot	68.9%	0.347	0.25-0.45
2. Knee and hip bend to land softly in a controlled fashion	92.0%	0.241	-0.02-0.50
3. Hips, knees, and ankles aligned	53.7%	0.093	-0.00-0.19
4. Swing bent arms in opposition to legs	69.7%	0.346	0.25-0.44
Horizontal Jump			
1. Swing arms to assist the movement	95.0%	0.078	-0.29-0.45
2. Knees and hips bend to land softly in a controlled fashion	54.0%	-0.037	-0.15-0.07
3. Land on both feet at the same time	85.3%	0.539	0.42-0.64
4. Hips, knees, and ankles aligned	61.9%	0.253	0.15-0.35

Running			
1. Upper-body straight and eyes focused in direction of travel	86.6%	-0.021	-0.29-0.21
2. Swing bent arms in opposition to legs	94.7%	0.078	-0.38-0.45
3. Knee drives upward and forward to lift the foot off the ground	73.1%	0.222	0.09-0.34
4. Knee and hip bend to land softly in a controlled fashion	69.4%	0.046	-0.09-0.20
Single Leg Hop			
1. Hips, knees, and ankles aligned	58.9%	0.125	0.03-0.23
2. Take off from one foot, land on the same foot	88.8%	-0.044	-0.39- 0.24
3. Knee and hip bend to land softly in a controlled fashion	53.4%	0.078	-0.02- 0.17
4. Swing arms to assist the movement	53.2%	0.057	-0.05-0.16

N, Sample Size; CI, Confidence Interval

[a] Percent agreement calculated as the average agreement between each rater

[b] Confidence intervals were obtained from a bootstrapped sample of 1000

[c] Unable to calculate reliability coefficient due to having zero variance (i.e. 100% agreement).

The research team found that intra-rater reliability scores ranged from none (Cohen's K = 0.00 to 0.20) to fair (Cohen's K = 0.20 to 0.40). Single leg sideways hop and hold was the only movement skill to have an evaluation criteria (hips, knees, and ankles aligned) achieve fair intra-rater reliability (Cohen's K = 0.303). Several evaluation criteria achieved negative Cohen's Kappa values; possible explanations are explored in the discussion section. Percentage agreement ranged from 47.2% to 98.6%. Intra-rater reliability statistics and 95% confidence intervals for each evaluation criteria are presented in table 3.

Table 3. Intra-Rater Reliability for the Evaluation Criteria of Each Movement Skill

Movement Skill and Evaluation Criteria (N = 12 Raters)	Percent Agreement[a]	Cohen's Kappa[b]	95% CI
Bodyweight Squat			
1. Push hips back and bend the knees until the thighs are approximately parallel with the ground	70.8%	0.132	-0.02-0.28%
2. Hips, knees, and ankles aligned	48.6%	-0.328	-0.48- -0.18%
3. Knees do not go too far in front of the toes	75.0%	0.017	-0.13-0.16%
4. Keep the heels down all the time	72.2%	-0.140	-0.20- -0.09%
Vertical Jump			
1. Swing arms to assist the movement	66.6%	0.250	0.15-0.35%
2. Knees and hips bend to land softly in a controlled fashion	69.4%	0.100	-0.19-0.39%
3. Land on both feet at the same time[c]	97.2%	-	-
4. Hips, knees, and ankles aligned	62.5%	-0.060	-0.24-0.13%

Single Leg Sideways Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	81.9%	0.272	0.02-0.52%
2. Hips, knees, and ankles aligned	73.6%	0.303	0.15-0.46%
3. Foot flat on the floor	73.6%	-0.004	-0.14-0.13%
4. Stand up straight within three seconds after landing	68.0%	0.222	-0.03-0.47%
Walking Lunge			
1. Hips, knees, and ankles aligned	54.2%	-0.174	-0.31- -0.04%
2. Upper-body straight and eyes focused in direction of travel	68.1%	-0.001	-0.14-0.14%
3. Front knee does not go too far in front of toes	75.0%	-0.114	-0.18- -0.05%
4. No twisting nor bending back	77.8%	0.463	0.20-0.73%
Two-to-One Foot Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	72.2%	0.116	-0.08-0.31%
2. Toes pointing forward[c]	97.2%	-	-
3. Foot flat on the floor[c]	91.6%	-	-
4. Hips, knees, and ankles aligned	63.8%	0.108	-0.09-0.31%
90° Hop and Hold			
1. Knees and hips bend to land softly in a controlled fashion	76.3%	0.065	-0.15-0.28%
2. Hips, knees, and ankles aligned	73.6%	0.129	-0.13-0.38%
3. Whole body turns together[c]	98.6%	-	-
4. Toes pointing forward	80.5%	0.026	-0.09-0.14%
Leaping			
1. Take off from one foot, land on the opposite foot	45.8%	-0.268	-0.41- -0.12%
2. Knee and hip bend to land softly in a controlled fashion	88.8%	-0.167	-0.05-0.02%
3. Hips, knees, and ankles aligned	48.6%	-0.92	-0.21-0.02%
4. Swing bent arms in opposition to legs	56.9%	0.043	-0.11-0.20%
Horizontal Jump			
1. Swing arms to assist the movement[c]	94.4%	-	-
2. Knees and hips bend to land softly in a controlled fashion	62.5%	-0.092	-0.48- -0.18%
3. Land on both feet at the same time	65.2%	-0.206	-0.28- -0.13%
4. Hips, knees, and ankles aligned	47.2%	-0.209	-0.39-0.03%
Running			
1. Upper-body straight and eyes focused in direction of travel	91.7%	-0.017	-0.05-0.02%
2. Swing bent arms in opposition to legs	97.2%	0.048	-0.05-0.14%
3. Knee drives upward and forward to lift the foot off the ground	66.7%	-0.156	-0.25- -0.07%
4. Knee and hip bend to land softly in a controlled fashion	71.2%	0.013	-0.14-0.17%
Single Leg Hop			
1. Hips, knees, and ankles aligned	62.5%	-0.107	-0.30-0.09%
2. Take off from one foot, land on the same foot[c]	94.4%	-	-
3. Knee and hip bend to land softly in a controlled fashion	69.4%	0.072	-0.14-0.28%
4. Swing arms to assist the movement	54.1%	-0.045	-0.30-0.21%

N, Sample Size; a, alpha; CI, Confidence Interval;

[a] Percent agreement calculated as the average agreement between each rater

[b] Cohen's Kappa calculated as the average of all participants.

[c] Unable to calculate reliability coefficient due to having zero variance.

3.5 Discussion

The results of this research indicate that the ChildFIRST demonstrates good-to-excellent (ICC < 0.75 – 1.00) inter-rater reliability for eight movement skills: walking lunge, bodyweight squat, single-leg sideways hop and hold, vertical jump, horizontal jump, running, 90˚ hop and hold, and leaping. Single-leg hop demonstrates moderate reliability (ICC = .737) and two-to-one-foot hop and hold demonstrates poor reliability (ICC = -0.306). Intra-rater reliability is lower than inter-rater reliability for total movement skill scores, and range from moderate-to-good (ICC < 0.50) intra-rater reliability for five movement skills; bodyweight squat, vertical jump, single leg sideways hop and hold, walking lunge, and horizontal jump, and poor (ICC = 0.00 to 0.20) reliability for five movement skills; two-to-one-foot hop and hold, 90˚ hop and hold, leaping, running, and single-leg hop. Intra-rater reliability scores may be low because all participants did not return in exactly seven days, with two participants returning three or four weeks after the first session, and some participants may have failed to recall details of some evaluation criteria from the training session. Participants that returned in more than seven days were included in the analysis to preserve the sample size, and excluding the participants would not significantly alter the results. Due to the nature of the assessment tool, the evaluators only give dichotomous scores for each evaluation criteria, so removing the participants that did not return in seven days would not significantly change the overall reliability. Perhaps training sessions should be given at the beginning of each testing session until users become proficient with the tool. Potential users of the ChildFIRST should be aware that nine of ten movement scores demonstrate moderate-to-excellent inter-rater reliability if this tool is used for a single testing session. Only five movements demonstrate moderate-to-good intra-rater reliability so users should take caution when interpreting scores of two or more testing sessions. The poor intra-rater reliability scores indicate that the ChildFIRST cannot reliably evaluate 8-12-year-old children over multiple testing sessions in its current state. Intra-rater reliability of the ChildFIRST should improve considerably with improvements to the tool, more frequent training sessions, and additional pilot testing in the field. To enhance reliability potential, users should engage in frequent training sessions for evaluators, especially if testing is conducted on multiple days.

Although some of the movements in the ChildFIRST are similar to other physical literacy and movement competence tools,[17,19,51–53] the ChildFIRST uses process-based evaluation criteria, and includes novel movements such as the 90˚ hop and hold and the single-leg sideways hop and hold. To our knowledge, no studies have included a 90˚ hop and hold or single-leg sideways hop and hold movement in their assessments, both movements evaluate dynamic balance and the ability to control movement while jumping and landing. A common mechanism of injury in non-contact anterior cruciate ligament (ACL) tears is landing with internal or external rotation of the tibia, near full knee extension, and/or knee valgus.[54–56] The research team believes the 90˚ hop and hold movement can simulate similar mechanisms found in an ACL injury, so perhaps children who perform poorly at this movement skill may be at increased risk of injury, however, future research is needed to support this hypothesis. The ChildFIRST also includes movements such as the walking lunge and bodyweight squat which are considered basic human movements and found in many strength and conditioning programs designed for college athletes and adults.[29] Learning the bodyweight squat and walking lunge movement patterns early in life should not only improve movement competence but could help children succeed in strength and conditioning programs as they get older, enhancing sport performance and strength development.[57,58]

The poor reliability demonstrated by two-to-one-foot hop and hold movement can be explained by multiple reasons. First, the distribution of scores is not wide enough resulting in low random error, when low random error is input into the ICC formula random, a low ICC value is the result.[44] Second, this skill may be too easy for the children due to height, weight, centre of pressure/mass, and lack of effort, all potentially causing the narrow distribution of scores. Third, the evaluation criteria may be too easy to identify in the children. For example, every child achieved the criteria “toes pointing forward” and all but one evaluator scored every child as achieving the criterion “foot flat on the floor.” As discussed, a disadvantage of process-based assessments is the requirement for evaluators to observe many body segments at once. Evaluating many body segments in a short period of time makes accurate evaluation of movement more difficult, potentially having a negative effect on the reliability of the tool. Evaluators that choose to use this skill should interpret the scores of the two-to-one-foot hop and hold skill with care and consider providing training at the beginning of each rating session until the evaluators become more experienced with the tool. Improvements to the evaluation criteria, the movement descriptions, and training before each rating session may enhance the reliability. Future research should perform factor analyses on the movement skills and evaluation criteria to identify potentially redundant evaluation criteria and underlying constructs within the evaluation criteria. With more data regarding the evaluation criteria changes can be made to improve the ChildFIRST.

The evaluation criteria for the ChildFIRST are remarkably unreliable, with only "swing arms to assist the movement" in the vertical jump movement demonstrating a score that can be interpreted as reliable ($K\alpha < 0.80$).[47] While this is somewhat surprising given that these criteria were voted on and ranked by experts from around the world in a Delphi study (manuscript submitted), improvement is needed. Similar to the two-to-one foot hop and hold evaluation criteria, every child in the study achieved the criteria "toes pointing forward" from two to one-foot hop and hold, and "land on both feet at the same time" from the vertical jump. As discussed, it is possible that the criteria are too easy, this is a new tool so if training was provided prior to each rating session, evaluators may become more familiar with the testing protocol and the reliability should be enhanced, or observation may not be sensitive enough to detect an error. It is important to note that evaluation criteria like "toes pointing forward" or "land on both feet at the same time" may be too easy to perform and/or observe, but they are also important criteria for the correct execution of the movement. The goal of the ChildFIRST is to eventually be able to screen children for injury risk and evaluate movement. Evaluation criteria like "toes pointing forward" may not be important in screening for injury but because they are critical for executing the movement skill properly these evaluation criteria may still be valuable, as a result, there may be a need for balance between evaluating movement competence and screening for injury. Injury screening tools such as the Landing Error Scoring System (LESS) are designed to evaluate very specific body positions within the context of identifying injury risk, with less focus on overall skill execution.[52] The balance between evaluating movement competence and screening for injury allows for some evaluation criteria regarding the execution of the skill and incorporating injury risk assessment. For example, the evaluation criteria for the vertical jump "swings arms to assist movement" does not specifically evaluate a body position that could indicate risk of injury (such as knee valgus).[59] The evaluation criteria "swing arms to assist movement" does describe sound movement characteristics that are associated with appropriate execution of the jumping movement,[60] and could also contribute to a safe, injury free movement. It is important to evaluate both movement competence and injury risk because it is possible that despite not being identified as an individual with increased injury risk, this individual may not execute a skill properly.

Improper skill execution may also contribute to injury, although not directly linked to risky body positions, repeatedly performing a skill improperly could lead to future injury (such as overuse injuries) and this should be identified.[61] Pilot testing the ChildFIRST in larger sample sizes and various populations will help determine the utility and necessity of the evaluation criteria for assessing movement competence and injury risk.

It is interesting to note many of the evaluation criteria demonstrated very high agreement between raters, but very low reliability. For example, the evaluation criteria "swing arms to assist the movement" for horizontal jump achieved 95% agreement, and a Krippendorf's Alpha of only 0.078, the same phenomenon occurred with the Cohen's Kappa calculations. The discrepancy between percent agreement and Krippendorf's Alpha or Cohen's Kappa may be explained by the formulas for each calculation; percent agreement calculates how many times the evaluators agree on a score without accounting for random error, which can be introduced by evaluator bias/error or participant error. Krippendorf's Alpha and Cohen's Kappa calculate the ratio of observed disagreement divided by the disagreement error.[46,62] Both Krippendorf's Alpha and Cohen's Kappa include random error in their formulas which accounts for agreement by random chance, the formula for percent agreement does not account for random chance.[46,62] It is a well-known phenomenon that when percentage agreement is high, Krippendorf's Alpha and other measures of reliability are very low. The optimal percent agreement to maximize reliability is 50%, which means evaluators must disagree to increase reliability.[63] In the current research study, poor reliability scores may not be a true indication of the actual reliability of the evaluation criteria, having many raters in this study, decreases the chance that the raters are agreeing strictly by chance. The true reliability of the evaluation criteria may lie somewhere in between high percentage agreement and low Krippendorf's Alpha and Cohen's Kappa. Nonetheless, potential users of the ChildFIRST should train evaluators before every testing session, provide clear instructions to the children, and be aware that when interpreting the results of a child's score on individual evaluation criteria that the reliability may be low due to the low variation in scores and not because actual reliability is poor.

Finally, evaluation criteria such as "land on both feet at the same time" and "foot flat on the floor" are similar to items in the Landing Error Scoring System (LESS),[52] such as "One foot lands before the other foot or one foot lands heel to toe and the other foot lands toe to heel" or "The foot lands heel to toe or with a flat foot at initial contact".[52] The LESS has demonstrated its ability to identify injury risk in the collegiate population, and while there are similarities between the evaluation criteria in each tool, the evaluation criteria in the ChildFIRST are not as specific compared to the items in the LESS.[52] The lack of specificity in the wording of the evaluation criteria in the ChildFIRST allows novice evaluators to use the tool but limits the ability of the tool to identify movement errors that may lead to injury. The lack of specific wording in the ChildFIRST may also contribute to lower reliability scores, but this is intentional to make the tool more accessible to individuals without formal human movement training. Future research should correlate the evaluation criteria in the ChildFIRST with specific evaluation criteria in the LESS to determine if the specificity of the wording of the criteria affects the ability to identify injury risk.

3.5.1 Limitations

The research team did not collect clinical data as part of this research limiting our ability to demonstrate the utility of this tool. Instead, the research team focused on developing a strong reliability study to help us determine if changes are needed in the tool before pilot testing. The ICC values for intra-rater reliability are not high perhaps suggesting the need for a training session before each use of the tool, but inter-rater reliability of the total scores was excellent indicating that the data obtained could potentially inform interventions to improve movement competence and reduce injury risk. Due to the dichotomous nature of the data, there is a risk of low inter- and intra-rater reliability because of the high chance of agreement, this limits our ability to make conclusions regarding the actual reliability of the tool, but with repeated testing in multiple settings, the reliability can be confidently established. The research team acknowledges that the inconsistency in the length of time in which the participants returned as a limitation. Although there are no clear guidelines in the literature regarding the length of time that participants should return for intra-rater reliability testing, the research team acknowledges that this may have affected our results.

3.5.2 Future Research

Future research should investigate inter- and intra-rater reliability in a field setting with live evaluations, and additional reliability projects should be conducted to further establish the reliability of the ChildFIRST in these settings. Future research should also investigate the concurrent validity between the ChildFIRST and the LESS and other established injury screening tools to give preliminary evidence that the ChildFIRST can predict injury. Clinical testing of the ChildFIRST will also demonstrate the utility of the tool to distinguish between different populations (i.e. males vs females, changes throughout the age range, and compared to a control group). Finally, a long-term research goal should be to collect data on a large sample of children to establish the predictive ability of the ChildFIRST, specific cut-off points and score categories that may indicate high or low injury risk, and to gain further evidence that the ChildFIRST may be used to predict future injury.

3.5.3 Conclusions

The ChildFIRST is a process-based assessment designed to evaluate movement competence and injury risk in children aged 8-12. The ChildFIRST demonstrates moderate-to-excellent reliability (ICC = 0.50 – 1.00) for the total scores of each movement except for one (two-to-one-foot hop and hold), so this tool can be used to reliably evaluate children aged 8-12. Intra-rater reliability is good-to-moderate for five movement skills (ICC = 0.50 – 0.75), and poor (ICC = 0.00 – 0.50) for five movement skills, yet training evaluators before each session may enhance reliability for repeated testing. The evaluation criteria demonstrate high percent agreement but poor Krippendorf's Alpha and Cohen's Kappa scores, this further suggests that evaluators should be continually trained to enhance reliability. Scores on ChildFIRST can provide therapists, physical education teachers, coaches, and other stakeholders with data about movement competence in children. The ChildFIRST can provide information to aid the ongoing injury prevention efforts and help to safely promote lifelong physical activity.

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TRANSITION TO CHAPTER FOUR

The findings from chapter three indicate that the ChildFIRST demonstrates moderate-to-excellent inter-rater reliability for nine of ten movement skills, good-to-moderate intra-rater reliability for five movement skills, and poor intra-rater reliability for five movement skills. The evaluation criteria demonstrate high percent agreement but poor Krippendorf's Alpha and Cohen's Kappa scores. The results from chapter three and the associated Delphi paper provide evidence that the ChildFIRST can be used in a cross-sectional study design.

Establishing the reliability and validity of the ChildFIRST allows the research to progress to the next step in the development of the ChildFIRST, collecting normative data. Normative data will provide users of the ChildFIRST context on how their specific children compare to a larger group of children. The following chapter describes normative data and a cross-sectional analysis for data that was collected from Fall 2019 to Winter 2021.

CHAPTER FOUR:

MANUSCRIPT THREE

The Child Focused Injury Risk Screening Tool (ChildFIRST) – Normative data for children 8-12 years old.

Matthew B. Miller, MSc, CAT(C); John A. Jimenez-Garcia, MSc; Richard G. DeMont, PhD, CAT(C).

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4.1 Abstract

Physical literacy (PL) concepts promote physical activity (PA). When children increase PA participation their injury risk also increases, but PL does not address injury prevention. The Child Focused Injury Risk Screening Tool (ChildFIRST) evaluates movement competence and injury risk in 8-12-year-old children. The ChildFIRST has 10 movements: walking lunge, bodyweight squat, single-leg sideways hop and hold, two-to-one foot hop and hold, 90-degree hop and hold, single-leg hop, leaping, running, vertical jump, and horizontal jump. Each movement has four evaluation criteria. The ChildFIRST has validity and reliability evidence but no normative data. The purpose of this study is to establish normative data and evaluate trends using the ChildFIRST in the 8-12 age group.

A cross-sectional design was used to evaluate 146 children. There were 3 participation methods: in-person, live video, or video upload. Participants viewed a demonstration of one movement then performed the movement, this continued until the child completed all movements.

All movements were normally distributed except running. There were no sex differences except for single-leg sideways hop and hold. More weekly PA was associated with higher scores on the ChildFIRST. Higher BMI was associated with lower scores on the ChildFIRST.

This is the first study to present normative data for the ChildFIRST. The ChildFIRST can distinguish between higher and lower levels of movement competence. Children who reported more weekly PA scored higher on the ChildFIRST. The normative data in this study can be used by users of the ChildFIRST to compare individual data to group scores on the ChildFIRST.

4.2 Introduction

Childhood obesity is a growing problem in Canada with reports indicating that almost 1 in every 7 children is obese.[1] There is also an upward trend in obesity as children age, 15.4% of children aged 5-9 and 23.0% of children aged 10-14 live with obesity. The obesity trend continues to adulthood with 26.8% of adults being classified as obese.[1,2] Growing levels of sedentary behaviour contribute to the increasing trend of obesity,[3] and one part of a multifactorial approach to reduce sedentary behaviour is promoting physical activity (PA) early in childhood. Unfortunately, with increased PA there is also an increased risk for musculoskeletal injury, often dissuading PA participation.[4–6] Injuries in childhood can result in the reduction of a child's current and future PA, leading to a more sedentary lifestyle.[7] Injuries that require surgical intervention such as osteochondrosis, anterior cruciate ligament (ACL) tear, or some spinal injuries, can lead to lifelong consequences like osteoarthritis.[8] Musculoskeletal injuries in childhood have the immediate consequences of pain and the recovery process, and are one of the main reasons children stop being physically active.[9] Onset of physical inactivity and a sedentary lifestyle can lead to obesity and other serious health conditions.[9] Promoting PA in children is critical to reduce the impact of sedentary behaviour, and mitigating the risk of musculoskeletal injury is a necessary consideration.

In the early 2000s, the concept of physical literacy emerged as a holistic approach to promoting positive PA habits in children.[10] Physical literacy promotes PA through 4 domains: confidence and motivation, daily behaviour, knowledge and understanding, and physical competence.[10] Physical literacy concepts have gained popularity and are being implemented in physical education programs across Canada.[11] Some physical literacy assessments, such as the Canadian Assessment of Physical Literacy (CAPL) and the Passport for Life,[13,14] evaluate all domains of physical literacy. Many others, such as the Test of Gross Motor Development-3 (TGMD-3),[15] POLYGON-FMS,[16] and the 9 Test Screening Battery,[17] focus on the physical competence domain. Measurements of physical competence generally focus on evaluating movements necessary for sport and PA, commonly referred to as fundamental movement skills (FMS).[18] Fundamental movement skills are generally classified as locomotion skills (running, skipping, jumping), balance/stability skills (single-leg balance, holding a yoga pose, doing a plank), and object manipulation skills (throwing or kicking a ball, using a tennis racquet or hockey stick).[18] Many FMS assessments are product-based and evaluate speed, repetitions, and accuracy. Fewer assessments are process-based and evaluate movement technique and body position.[19] An example of a process-based evaluation is the TGMD-3,[15] which includes performance criteria such as “arms are thrust downward during landing” for the horizontal jump, and “forward reach with the arm opposite the lead foot” for the leap skill.[15] Only recently has injury prevention been linked to physical literacy.[12] The concepts of movement technique and body position utilized in process-based assessments are also found in injury prevention literature and are considered critical elements of an injury prevention program.[20] The performance criteria in the TGMD-3 do describe body positions and movement technique, but there is no mention of risky body positions that may contribute to injury (such as knee positioning).[21] There is a need for a process-based assessment to evaluate both movement competence and to identify children at risk of injury.

In 2018, the National Athletic Trainers Association (NATA) released a position statement for the prevention of ACL injuries.[20] The position statement indicates that preventative training programs should include feedback about movement technique and quality, in combination with exercises from strength, plyometrics, agility, flexibility, and balance.[20] These exercises have characteristics best evaluated with product-based assessments, but movement technique and quality are better evaluated through a process-based criteria.[19] Process-based assessments used to evaluate movement technique can identify body positions that are associated with increased risk of injury (such as knee-valgus, lumbar spine position, and ankle positioning).[21,22] The NATA position statement recommends identifying high risk movement characteristics before the age of fifteen.[20] The Long Term Athlete Development program (used in Canada to promote the development of athletes across all ages) states that children should only start competitive sport after the age of eleven.[23] The use of a process-based assessment of movement competence and injury risk used in the 8-12-year-old population has the potential to identify children at increased risk of injury before most children begin competitive sport.

Physical literacy and injury prevention concepts overlap, but little research has explored the connection between these areas. In 2018, a literature review discussed the connection between these concepts.[12] The review summarizes several physical literacy assessments and injury prevention programs and suggests that by using a process-based assessment, concepts from physical literacy and injury prevention can be captured.[12] The review concludes by indicating that to evaluate both physical literacy and injury risk in children, emphasis should be placed on movement technique and competence when assessing FMS.[12] The Child Focused Injury Risk Screening Tool (ChildFIRST) is a process-based assessment tool created to help fill the gap between injury prevention and physical literacy concepts.[24] The aim of the ChildFIRST is to evaluate the movement skills necessary for sport and PA participation and identify injury risk in children aged 8-12.[24,25] Face and content validity of the ChildFIRST was established using a Delphi process, in which an international panel of experts in the fields of motor learning, injury prevention, athletic therapy, and physical literacy were recruited to participate.[24] After 3 rounds of questionnaires, the expert panel reached consensus on the inclusion of 10 movement skills: two-to-one foot hop and hold, running, bodyweight squat, leaping, single-leg hop, horizontal jump, single-leg sideways hop and hold, 90° hop and hold, walking lunge, and vertical jump.[24] The expert panel also reached consensus on 4 evaluation criteria associated to each movement skill.[24] The ChildFIRST demonstrates good-to-excellent inter-rater reliability for 8 of 10 movement skills; the single-leg hop demonstrates moderate inter-rater reliability, and the two-to-one foot hop and hold demonstrates poor inter-rater reliability.[25] Five movement skills demonstrate moderate-to-good intra-rater reliability while 5 movement skills demonstrate poor intra-rater reliability. [25] To date there have been no published studies describing normative data for the ChildFIRST, which makes it challenging to interpret the raw data and scores. It is important to have reference values available to effectively understand a child's movement skill and potentially provide information about injury risk. Thus, the purpose of this research study is to establish preliminary evidence that the ChildFIRST can be used to evaluate movement skill in various populations of children and establish preliminary normative values for age and sex for children aged 8-12. Additional purposes are to investigate sex differences between scores on the ChildFIRST, and to understand the associations between weekly PA habits and scores on the ChildFIRST.

4.3 Methods

4.3.1 Participants

The institutional human research ethics board approved this research (Certificate #: 30011636). A cross-sectional study design was used to evaluate 146 children (Males = 70, Females = 74, non-specified = 2) between the ages of 8-12. Two children did not identify as male or female, indicating they were 'non-specified' gender. Participants were recruited through convenience and snowball sampling from the following settings: a local volleyball club, a local soccer facility, and YMCA after school and summer day camp programs. Any child between the age of 8 and 12 were included in this study. No children were excluded from participating. Children with disabilities affecting movement skill performance were able to participate to the best of their ability but final scores were only calculated for children who performed all 10 movements without modification of the testing procedures or the skills. The demographic variables collected were age, height, weight, body mass index (BMI), PA habits (days per week), and previous injuries (Table 4).

Table 4. Demographics and Movement Skill Scores

	Males (N = 70)	Females (N = 74)	Total (N = 146[a])
	Mean ± SD	Mean ± SD	Mean ± SD
Age (years)	9.46 ± 1.07	10.00 ± 1.19	9.73 ± 1.16
Height (metres)	1.39 ± 0.11	1.45 ± 0.13	1.42 ± 0.12
Weight (kilograms)	34.9 ± 7.9	37.93 ± 9.80	36.35 ± 9.05
BMI (kg/m^2)	17.67 ± 4.25	17.83 ± 3.56	17.75 ± 3.87
PA Habits (days per week)	3.91 ± 1.68	3.61 ± 1.71	3.72 ± 1.72
Injuries (quantity)	0.30 ± 1.12	0.27 ± 0.48	0.28 ± 0.85
Bodyweight Squat	2.52 ± 1.08	2.78 ± 1.21	2.65 ± 1.14
Single Leg Hop	2.78 ± 0.98	2.74 ± 1.09	2.74 ± 1.03
Walking Lunge	2.61 ± 0.91	2.79 ± 0.91	2.69 ± 0.91
90° Hop & Hold	2.08 ± 0.85	2.21 ± 0.91	2.16 ± 0.88
Vertical Jump	2.30 ± 0.81	2.42 ± 0.82	2.38 ± 0.81
Horizontal Jump	2.87 ± 0.93	2.84 ± 0.93	2.83 ± 0.90
Running	3.42 ± 0.98	3.38 ± 0.83	3.40 ± 0.90
Single Leg Sideways Hop & Hold	2.41 ± 0.99	2.76 ± 0.86	2.57 ± 0.95
Two to One Foot Hop & Hold	2.28 ± 1.14	2.31 ± 0.78	2.31 ± 0.97
Leaping	2.20 ± 1.03	2.19 ± 0.84	2.21 ± 0.93
Total Score	25.21 ± 4.61	26.14 ± 4.90	25.65 ± 4.75

N, sample size; SD, standard deviation; BMI, body mass index, PA, physical activity; kg, kilograms; m, metres

[a] Two participants identified as non-specified gender and were removed from the M vs F analysis

4.3.2 The ChildFIRST

The ChildFIRST has been described previously, and is a valid and reliable tool to evaluate movement competence and injury risk in 8 to 12 year old children.[24,25] Briefly, the ChildFIRST includes 10 movements: bodyweight squat, vertical jump, single-leg sideways hop and hold, walking lunge, two-to-one-foot hop and hold, 90° hop and hold, leaping, horizontal jump, running, and single-leg hop. There are 4 evaluation criteria associated to each movement, each criterion is an observable characteristic of each movement. The evaluation criteria are assessed as either observed or not observed so participants can achieve a score from 0 to 4 on each movement. Participants can achieve a range of total scores from 0 to 40. The ChildFIRST is designed to be versatile allowing assessments to take place in a variety of settings

4.3.3 Procedures

Written consent was obtained from the guardians of the participants and verbal assent was obtained from the children before participating. Participants completed this research study in 3 ways; in-person, over the Zoom video conferencing platform V.5.5.2 (Zoom Inc, San Jose, California, US), or pre-recorded video. Participants that chose to participate virtually were given the option between a live assessment or submitting videos. See Appendix B for the study timeline for online participation. The online aspect of this assessment was conducted in collaboration with the Champions for Life (CFL) Foundation. The CFL foundation hosted a website, booking software, and a video submission platform for this research study.

In person: The in-person assessment occurred before and during the Covid-19 pandemic. Before the Covid-19 pandemic children were placed in groups of 4-5 and rotated through a series of 10 stations. At each station, a trained evaluator would assess 1 movement, after each group of children completed the movement at 1 station in the circuit, the group would rotate to the next movement. After each group of children completed all the movements the assessment was finished. Generally, the same process occurred for testing sessions after the onset of the pandemic, but Covid-19 precautions were taken. Five testing stations were used to reduce risk of exposure and evaluators were responsible for assessing two movements each. The testing stations were placed 2 metres apart, with 2 metres distance between the child and researcher. One child at a time would enter the testing station. When each child at each station completed the movements, they were asked to sit down. When all the children are sitting, they changed stations. See Appendix C for both testing circuit set ups.

Live Virtual Assessment: The live virtual assessment occurred on the Zoom Video Communications platform. The participants and their parents booked an appointment with an evaluator who conducted the entire assessment. The participants were asked to clear a 5-foot by 20-foot space free from any furniture, toys, or other small objects and to wear their running shoes or other footwear to prevent slipping. Each movement was demonstrated in a pre-recorded video, after which the child performed each skill. After the child completed one skill the child was shown the next video and performed the next skill accordingly, this process continued until the child completed all the movement skills. Participants were asked (with the help of their parents) to place the camera at minimum 3.5 feet away from the designated space, and at least 1.5 feet off the ground. If there was not enough space in the participants home the participants were permitted to go outside and use their yard, driveway, or other large space. See Appendix D for participant instructions.

Pre-recorded Video Assessment: Participants that selected the pre-recorded videos were directed to the video submission platform on the CFL website. On this website was a video of each movement and instructions about how to upload the video. The participants were instructed to watch each video once and then perform the movement skill. The primary investigator evaluated the participants videos after upload. Participants were given the same video set up instructions as described in the live virtual assessment.

For all participation methods the participants were instructed to watch a demonstration of the movement, provided by the evaluator (either in video format or live). Verbal instructions were not provided to the participants to avoid constraining the participants movements. No information was provided about specific evaluation criteria to allow each child to complete the task without the influence of knowing the scoring system.

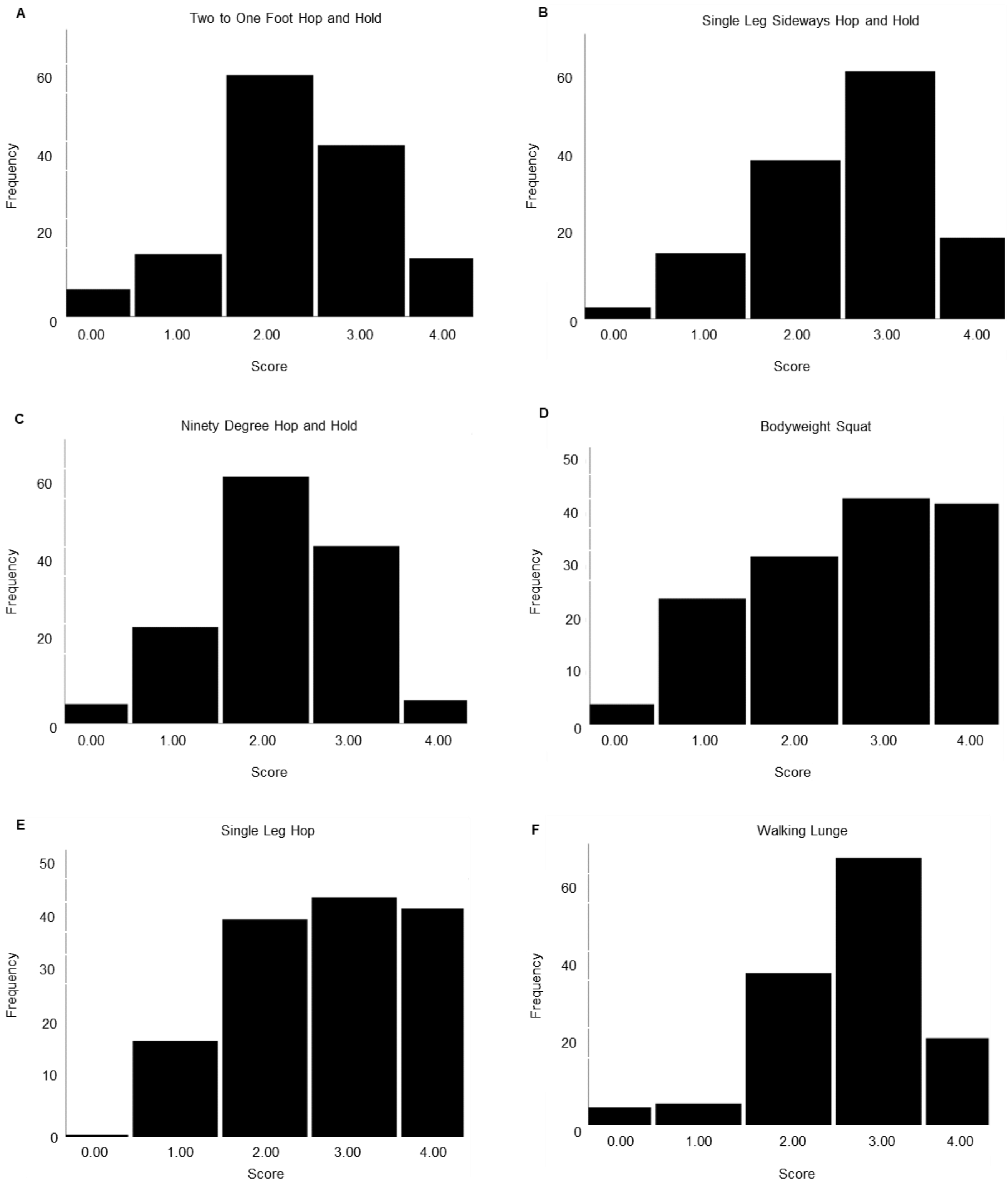
4.3.4 Data Analysis

Data analysis was conducted using Microsoft Excel (Version 2101, Redmond, Washington, US) and Statistical Package for the Social Sciences (SPSS Version 26, IMB Corp., Armonk NY, US). The distribution of the data was assessed using skewness and kurtosis and visual inspection of the histograms. Histograms were generated for the movement skills and the total score. Sex differences were evaluated using one-way ANOVAs, when the variable did not have a normal distribution the Kruskal-Wallis non-parametric test was used. Associations between demographic variables and movement skills were evaluated using Pearson Product Correlations. All missing data was coded as -999 and removed on a case wise basis.

4.4 Results

All variables were normally distributed according to skewness and kurtosis except BMI, injuries, running, and total score. Skewness and kurtosis cut-off values range from 2.00 to -2.00 (Table 2).[26] No ceiling or floor effects were found in any movement skill except for running where a ceiling effect was observed (Fig 4, H). See table 5 for skewness and kurtosis and table 6 for normative data.

Figure 4. Histograms for Movement Skill and Total Score



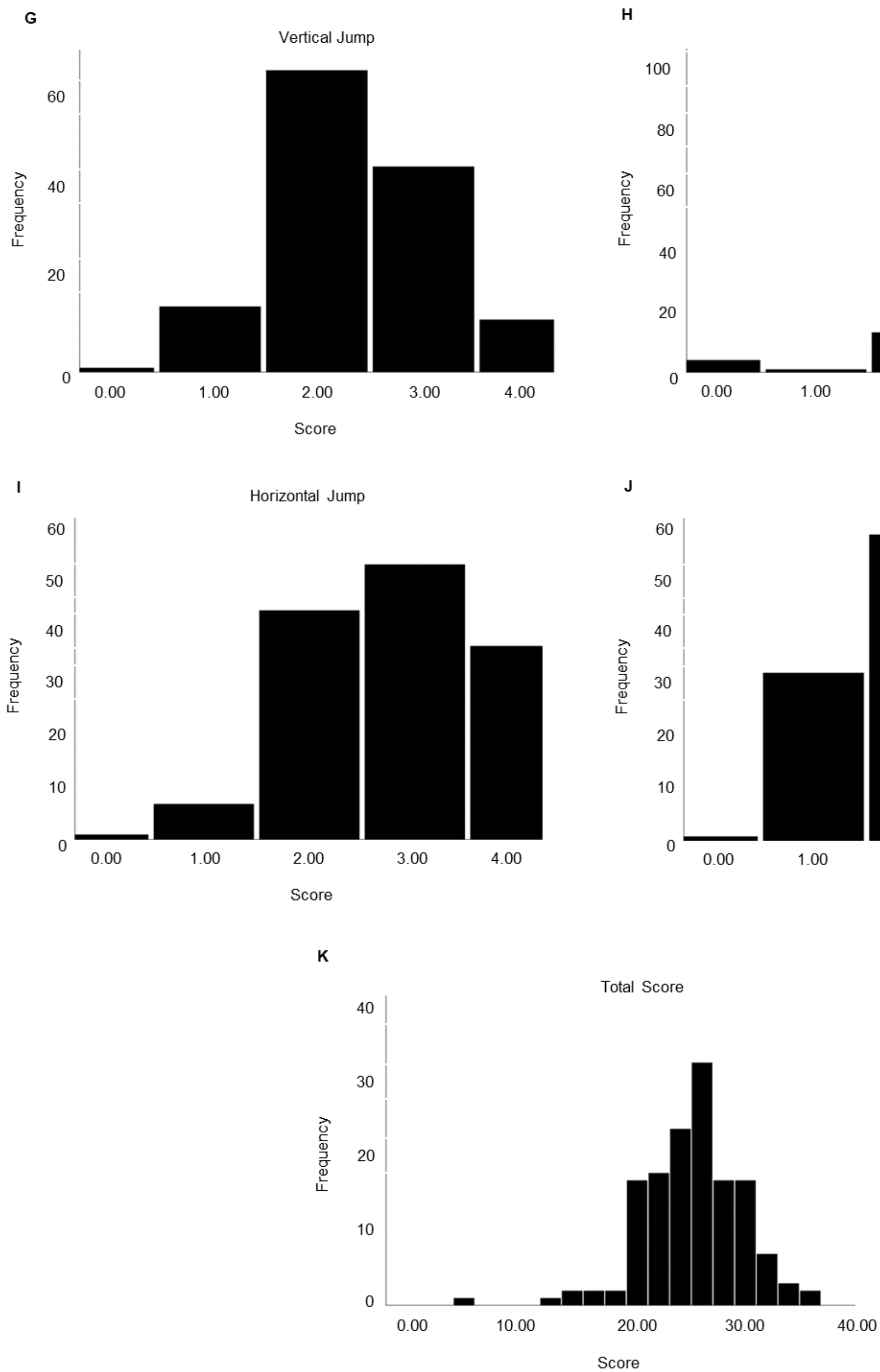

G
Vertical Jump
Frequency
Score
H
Running
Frequency
Score
I
Horizontal Jump
Frequency
Score
J
Leaping
Frequency
Score
K
Total Score
Frequency
Score

Table 5. Skewness & Kurtosis

	Mean ± SD	Skewness	Kurtosis
Age (years)	9.73 ± 1.16	0.1	-0.92
Height (metres)	1.42 ± 0.12	-0.08	-0.7
Weight (kilograms)	36.35 ± 9.05	0.94	1.63
BMI (kg/m2)	17.75 ± 3.87	0.48	5.42*
PA Habits (days per week)	3.72 ± 1.72	-0.31	-0.81
Injuries (quantity)	0.28 ± 0.85	7.82*	78.25*
Bodyweight Squat	2.65 ± 1.14	-0.42	-0.86
Single Leg Hop	2.74 ± 1.03	-0.31	-0.9
Walking Lunge	2.69 ± 0.91	-0.82	1.07
90° Hop & Hold	2.16 ± 0.88	-0.25	-0.07
Vertical Jump	2.38 ± 0.81	0.09	-0.05
Horizontal Jump	2.83 ± 0.90	-0.31	-0.43
Running	3.40 ± 0.90	-1.9	4.10*
Single Leg Sideways Hop & Hold	2.57 ± 0.95	-0.47	-0.12
Two to One Foot Hop & Hold	2.31 ± 0.97	-0.28	0.06
Leaping	2.21 ± 0.93	0.29	-0.56
Total Score	25.65 ± 4.75	-0.58	2.06*

* Value exceeds the skewness and kurtosis ranges of -2.00 and 2.00

SD, Standard Deviation; kg, kilograms; m, metres.

Table 6. Normative data by age and sex.

	8 Year Olds (N = 25)		9 Year Olds (N = 39)	
	Females (N =14)	Males (N = 11)	Females (N = 13)	Males (N = 25)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Bodyweight Squat	2.90 ± 1.10	2.69 ± 1.03	2.31 ± 1.25	2.48 ± 1.04
Single Leg Hop	2.70 ± 1.42	2.46 ± 1.05	2.69 ± 1.11	2.96 ± 1.02
Walking Lunge	2.00 ± 1.33	1.77 ± 0.93	2.54 ± 1.13	2.70 ± 0.82
90° Hop & Hold	1.80 ± 1.03	2.23 ± 0.83	2.38 ± 1.12	2.04 ± 0.82
Vertical Jump	2.40 ± 0.97	2.08 ± 0.95	2.31 ± 0.75	2.22 ± 0.67
Horizontal Jump	2.50 ± 0.85	2.62 ± 0.87	2.69 ± 0.75	2.83 ± 0.94
Running	3.20 ± 0.92	3.46 ± 0.78	3.15 ± 0.90	3.74 ± 0.45
Single Leg Sideways Hop & Hold	2.20 ± 1.03	2.23 ± 1.01	2.54 ± 0.78	2.26 ± 0.86
Two to One Foot Hop & Hold	1.90 ± 0.88	2.38 ± 1.04	2.08 ± 0.64	2.61 ± 1.12
Leaping	2.30 ± 0.67	1.92 ± 0.86	1.92 ± 0.95	2.30 ± 1.18
Total Score	23.90 ± 5.55	23.85 ± 3.98	24.38 ± 3.73	26.13 ± 3.96

	10 Year Olds (N = 38)		11 Year Olds (N = 33)		12 Year Olds (N = 9)	
	Females (N = 19)	Males (N = 19)	Females (N = 25)	Males (N = 8)	Females (N = 6)	Males (N = 3)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Bodyweight Squat	2.68 ± 1.38	2.65 ± 1.11	2.84 ± 1.14	2.38 ± 1.41	4.00 ± 0.00	2.67 ± 1.15
Single Leg Hop	2.95 ± 0.91	2.71 ± 0.69	2.60 ± 1.08	2.50 ± 1.20	3.20 ± 0.84	3.33 ± 1.15
Walking Lunge	2.89 ± 0.57	2.65 ± 0.61	3.16 ± 0.55	3.25 ± 0.71	3.20 ± 0.45	3.33 ± 0.58
90° Hop & Hold	2.16 ± 0.83	1.94 ± 0.75	2.36 ± 0.70	2.50 ± 1.07	2.60 ± 0.89	2.00 ± 1.00
Vertical Jump	2.37 ± 0.76	2.47 ± 0.62	2.40 ± 0.87	2.38 ± 0.74	3.20 ± 0.45	3.00 ± 1.00
Horizontal Jump	2.95 ± 0.97	2.82 ± 0.73	3.00 ± 0.87	3.13 ± 0.83	3.20 ± 0.84	3.33 ± 0.58
Running	3.37 ± 1.07	3.47 ± 1.07	3.48 ± 0.59	3.38 ± 0.92	4.00 ± 0.00	3.00 ± 1.00
Single Leg Sideways Hop & Hold	2.95 ± 1.08	2.29 ± 1.05	2.96 ± 0.54	2.75 ± 1.04	2.80 ± 0.84	3.67 ± 0.58
Two to One Foot Hop & Hold	2.68 ± 1.00	1.88 ± 0.99	2.28 ± 0.54	2.25 ± 1.39	2.60 ± 0.55	2.33 ± 1.53
Leaping	2.21 ± 0.85	2.41 ± 1.06	2.36 ± 0.86	2.25 ± 1.04	1.80 ± 0.84	2.33 ± 0.58
Total Score	27.21 ± 3.01	25.29 ± 4.54	27.44 ± 3.63	26.75 ± 5.52	30.60 ± 4.04	29.00 ± 5.57

Significant differences between males and females were found in the between age ($F(1,138) = 7.79$, $p = .01$), height ($F(1,131) = 7.73$, $p = .01$), weight ($F(1,127) = 4.19$, $p = .04$), and single-leg sideways hop and hold ($F(1,142) = 4.22$, $p = .03$). Females were significantly older, taller, and weighted more than males, and females performed significantly better on the single-leg sideways hop and hold movement. Two children identified as 'non-specified' gender and were removed from the sex analysis. All significance testing was conducted at $p \leq .05$ (Table 7).

Table 7. Sex differences

	Overall (N = 144)					
	Males (N = 70)		Females (N = 74)			
	Mean ± SD	95% CI	Mean ± SD	95% CI	*F* value	*p* value
Age (years)	9.46 ± 1.07	(9.20 - 9.73)	10.00 ± 1.19	(9.72 - 10.28)	7.79	0.01*
Height (metres)	1.39 ± 0.11	(1.36 - 1.42)	1.45 ± 0.13	(1.42 - 1.48)	7.73	0.01*
Weight (kilograms)	34.9 ± 7.9	(32.67 - 36.72)	37.93 ± 9.80	(35.56 - 40.30)	4.19	0.04*
BMI (kg/m^2)	17.67 ± 4.25	(16.58 - 18.77)	17.83 ± 3.56	(16.96 - 18.70)	[a]	0.94
PA Habits (days per week)	3.91 ± 1.68	(3.51 - 4.32)	3.61 ± 1.71	(3.21 - 4.01)	1.11	0.29
Injuries (quantity)	0.30 ± 1.12	(0.03 - 0.58)	0.27 ± 0.48	(0.16 - 0.38)	[a]	0.34
Bodyweight Squat	2.52 ± 1.08	(2.26 - 2.78)	2.78 ± 1.21	(2.50 - 3.06)	1.86	0.18
Single Leg Hop	2.78 ± 0.98	(2.55 - 3.02)	2.74 ± 1.09	(2.49 - 2.99)	0.07	0.79
Walking Lunge	2.61 ± 0.91	(2.39 - 2.83)	2.79 ± 0.91	(2.58 - 3.01)	1.47	0.23
90° Hop & Hold	2.08 ± 0.85	(1.88 - 2.29)	2.21 ± 0.91	(2.01 - 2.43)	0.79	0.38
Vertical Jump	2.30 ± 0.81	(2.11 - 2.50)	2.42 ± 0.82	(2.23 - 2.61)	0.78	0.38
Horizontal Jump	2.87 ± 0.93	(2.67 - 3.07)	2.84 ± 0.93	(2.62 - 3.05)	0.06	0.81
Running	3.42 ± 0.98	(3.19 - 3.66)	3.38 ± 0.83	(3.19 - 3.58)	[a]	0.35
Single Leg Sideways Hop & Hold	2.41 ± 0.99	(2.18 - 2.65)	2.76 ± 0.86	(2.56 - 2.96)	4.22	0.03*
Two to One Foot Hop & Hold	2.28 ± 1.14	(2.00 - 2.55)	2.31 ± 0.78	(2.13 - 2.50)	0.60	0.81
Leaping	2.20 ± 1.03	(1.96 - 2.46)	2.19 ± 0.84	(1.99 - 2.39)	0.00	0.93
Total Score	25.21 ± 4.61	(24.11 - 26.31)	26.14 ± 4.90	(25.01 - 27.28)	1.40	0.24

[a] Item found to be non-normal, the *p*-value presented is from a Kruskal-Wallis test
* indicates a statistically significant finding at $p < 0.05$
N, Sample Size; CI, Confidence Interval; BMI, Body Mass Index; PA, Physical Activity; kg, kilograms; m, metres

Pearson product correlations were conducted between the continuous variables (all movement skills and total score, and age, height, weight, BMI, and PA habits). Significant positive correlations were found between age and walking lunge (r(140) = .45, p = .000), vertical jump (r(140) = .20, p = .022), single-leg sideways hop & hold (r(142) = .30, p = .000), horizontal jump (r(141) = .20, p = .016), and total score (r(142) = .35, p = .000). There were also significant positive correlations between height and walking lunge (r(132) = .30, p = .001), single-leg sideways hop & hold (r(134) = .24, p = .005), and total score (r(134) = .25, p = .004). Significant positive correlations were present between weight and walking lunge (r(128) = .19, p = .031), 90 hop & hold (r(130) = .20, p = .028), and single-leg sideways hop & hold (r(130) = .24, p = .008). Significant negative correlations were found between BMI and bodyweight squat (r(127) = -.20, p = .029), and vertical jump (r(126) = -.201, p = .026) (Table 8).

Table 8. Correlations between demographic variables and movement skill scores.

	Age	Height	Weight	BMI	PA Habits
Bodyweight Squat	0.10	0.01	-0.16	-0.19*	0.07
Single Leg Hop	0.05	-0.10	-0.14	-0.95	0.27*
Walking Lunge	0.46*	0.30*	0.20*	0.29	0.11
90° Hop & Hold	0.15	0.14	0.19*	0.08	-0.15
Vertical Jump	0.20*	0.05	-0.09	-0.21*	-0.08
Horizontal Jump	0.21*	-0.08	-0.11	-0.03	0.24*
Running	0.04	0.13	0.10	-0.01	0.10
Single Leg Sideways Hop & Hold	0.30*	0.24*	0.24*	0.04	-0.02
Two to One Foot Hop & Hold	0.03	0.24*	0.17	-0.06	0.07
Leaping	0.06	-0.04	-0.02	-0.15	-0.13
Total Score	0.35*	0.25*	0.12	-0.12	0.10

BMI, body mass index; PA, physical activity
* indicates a statistically significant finding at $p < 0.05$

4.5 Discussion

The ChildFIRST is a process-based assessment tool designed to evaluate movement competence and screen for injury risk in the 8-12-year-old population. Until this study, there was no reference data available for males and females of each age between 8-12 years. The normative data described in this study can be used to assist physical education teachers, clinicians, and other stakeholders in comparing individual data from their students or clients to general scores from the ChildFIRST.

Overall, no ceiling or floor effects were observed for the sample group, except for the running movement. All children very well on the running skill (males scored 3.43 and females scored 3.38 out of 4.00). The running skill has a kurtosis value of 4.10 indicating this skill does not have a normal distribution. Upon inspection of the running histogram a ceiling effect was evident (Fig 4, H). These results suggest the running skill, does not adequately delineate poorly skilled versus highly skilled children in the 8-12-age-group. The results could be attributed to the running skill being too complex to evaluate with 4 evaluation criteria. A panel of experts came to consensus for the inclusion of the running skill and the associated evaluation criteria in the ChildFIRST,[24] so while the running skill is deemed to be important, modifications may be necessary to better capture the skills of the 8–12 year-old age group. Research suggests that by the age of 10, children have the cognitive and motor capabilities to master fundamental movement skill performances.[26–28] While movement skill mastery by the age of 10 is not always the case, the research cited above provides evidence to support the results of the current study that indicate children have achieved a high level of the running skill. The results of the TGMD-3 are similar, indicating that by the age of 8, 84% of children have achieved mastery of the running skill.[15] Other literature also supports this finding and indicates that children reach mastery levels of running and walking sooner than other FMS skills.[29] Although running is commonly accepted as a fundamental movement skill, the movement itself is technical in nature, and even amongst adults there are wide variations in running style.[30–32] The majority of process-based FMS assessments that include running attempt to capture the movement by using a limited number of evaluation criteria or outcomes. Researchers should consider the complexity of the running movement when designing a running based FMS evaluation. The 4 evaluation criteria used by the ChildFIRST to characterize the running movement are intended to capture the running movement in the 8-12 age group. The results of this study indicate improvements to the evaluation criteria are needed to better evaluate the running skill in the 8-12 age group.

Future research should investigate how the running skill could be modified, for example, with the addition of a change of direction or acceleration and deceleration. Deceleration paired with change of direction is known as a risk factor for ACL injury.[33] Incorporating the evaluation of deceleration into a process-based assessment could potentially help identify risky body positions that lead to injury. Running is a movement that forms the basis of many more complex skills such as dribbling (with a soccer ball or basketball for example), dodging, track and field events, and other physical activities. Fundamental movement skill evaluations should aim to evaluate more complex versions of the running skill. Research indicates that by the age of 6 children have the ability to integrate running and throwing into a smooth movement.[34] By the age of 12 many children are beginning competitive sport participation so when evaluating a child's readiness for sport increasing the complexity of some skills may more effectively evaluate a child's skill level and risk for injury.

The absence of ceiling effects (except for the running skill) indicates that the ChildFIRST can effectively measure a wide spectrum of movement skills within the 8–12-year-old population. The purpose of this study is to describe the normative data and trends within the 8-12-year-old population and not to evaluate significant differences between age groups. Generally as children age they become more proficient at movement skills.[26] Differences in skill level at various ages was not statistically tested in this paper, but it is important to discuss the trends to determine how the current data fits these age norms. The normative data described in Table 3 shows that, in general, males performed better than females on most skills at younger ages (8 and 9) and as children age there is less of a difference in skill level between sexes. By age 12, females performed as well or better on all skills compared to males. The association between age and performance is also supported by the correlation analysis with positive associations between higher movement skill and increased age. There is a general trend that as children age they perform better on all skills across sexes, however the trend towards increased skill proficiency at older ages does not hold true for all skills. For example, males peaked at age 9 for the two-to-one foot hop and hold skill and females peaked at age 10 for the same skill. For the 90° hop and hold males did not significantly improve or regress as they got older whereas females improved with age. This improvement may be attributed by increases in strength and balance because of typical growth and maturation,[35] but PA choice may also have an impact.[36,37] Interestingly, there was a trend towards a decline in males' performance on the running skill with age (albeit a minor decline), while females' performance increased with age suggesting the ceiling effect can be attributed more to the females' skill level. As both males and females aged, they achieved higher total scores (out of 40). The general trend towards increased movement competence at older ages agrees with other literature,[26,38] supporting the recommendation of starting FMS interventions early in a child's development.[26,39] When comparing age groups between sex, generally males performed better than females at the ages of 8 and 9, whereas females performed better at the ages of 10-12 compared to males. There were also positive correlations between weight, height, and movement skills, further supporting the understanding that as children age they perform better on FMS.[26,38] The ChildFIRST is designed to evaluate both movement competence and injury risk, so it is important to note that starting FMS interventions early in a child's development with a focus on injury prevention may have 2 effects; first, increasing movement competence at an early age to promote overall health and sport performance, and second, helping to reduce injury risk through identification of high risk body positions, providing feedback on movement technique, and implementing intervention strategies.

There are no significant differences between males and females on the overall score of the ChildFIRST or any of the movement skills except for the single-leg sideways hop and hold skill. Males and females have similar movement capabilities between the ages of 8-12, as described in previous research,[17,38,40] which provides support for the results of the current study. Results from both a process-based and product-based assessment tools also indicate that females are generally better at hopping skills than males,[26,41,42] supporting the finding in the current study that females performed significantly better than males in the single-leg sideways hop and hold. Previous studies have proposed a possible explanation for this sex difference, suggesting that females choose activities such as gymnastics, dance, and other activities that have a greater emphasis on locomotion skills like hopping.[36,37] The data about PA choice is not available for the current study, but general trends in the literature described above associated with activity serve as a plausible explanation for the sex differences in the single-leg sideways hop and hold skill.

Research indicates that movement quality depends on the type of PA and the amount of weekly PA.[43] While not statistically significant, weekly PA habits were positively correlated to 7 of 10 movement skills and the total score for the ChildFIRST. Two skills, the single-leg hop and horizontal jump, were significantly correlated to PA habits. Previous research also indicates that PA is a positive correlate to FMS performance,[44] supporting the results found within the current study. The correlation between higher level of PA and better movement competence suggest that the ChildFIRST can delineate between skill levels while also incorporating aspects of injury prevention into the evaluation. A possible explanation for not finding more significant correlations between PA habits and the movement skills is that the sample was not a homogenous group with regards to PA habits. Participants were recruited from multiple sites including a volleyball club, a soccer club, and some YMCA day camps. Research indicates that children participating in soccer are generally less sedentary than children who do not participate in organized sport,[45] suggesting that the participants in this study who were recruited from the soccer and volleyball club may participate in more weekly PA on average. If the soccer and volleyball groups have higher levels of PA than the YMCA group significant associations between PA and movement competence may have been lost. A subgroup analysis investigating PA differences in multiple groups is out of the scope of this normative data paper. Future research should investigate the association between PA habits and scores on the ChildFIRST because higher levels of PA are significantly associated to better performance on FMS,[44] overall health outcomes,[46,47] and fewer injuries.[48,49]

Significant positive correlations were found between weight, height, and age with various movement skills and total scores on the ChildFIRST. Height and weight increase as children grow and although there are positive associations between height and weight and higher scores on the ChildFIRST, BMI is negatively associated to scores on the ChildFIRST. There were significant negative correlations between BMI and the bodyweight squat and the vertical jump movements indicating that having a higher body mass may produce movement errors that lead to injury in these movements. The negative association between BMI and some movement skills is supported by other research signaling that children with a higher BMI perform worse on movement skills compared to children with a lower BMI.[29,50–52] The causal direction between higher BMI and poor FMS performance is unclear. Some research suggests that a child's lack of ability to perform well on FMS leads to a higher BMI,[53] whereas other research suggests that a higher BMI may lead to decreased performance on FMS.[54] Specifically in vertical translation movements (i.e. squatting and jumping) children with higher BMI may need to produce higher forces to perform these movements,[54] in turn these vertical forces lead to higher ground reaction forces which may contribute to an increased injury risk.[55] The association between higher BMI and poor movement quality is not a new finding, but the results of the current study provide further evidence of the importance of promoting PA to reduce comorbidities associated with childhood overweight and obesity, and to improve movement competence, potentially reducing injury risk.

The ChildFIRST has been shown to be a valid[26] and reliable[25] tool intended to be used by physical educators, clinicians, coaches, and other individuals with an interest in movement competence and injury risk in children. The normative data and trends from the ChildFIRST reflect what is already known about this population. The similarity in results from the ChildFIRST, the TGMD-3, and other current literature points to the utility of the ChildFIRST in accurately assessing movement competence in the 8-12 age group. The ChildFIRST is the first tool designed with the intention of assessing both movement competence and injury risk in this population. More research directed at long term injury tracking is needed to determine how well the ChildFIRST can identify children at risk of injury. Results of the study provide promising evidence of the positive association between higher weekly PA habits and better movement competence, and the negative association between higher BMI and lower scores on the ChildFIRST. Previous literature indicates a link between higher PA participation, lower BMI, and decreased injury risk.[46–49]

4.5.1 Future Research

Future research should investigate the link between decreased injury risk and higher levels of PA participation as assessed by the ChildFIRST to give support to the ChildFIRST's ability to identify children at risk of injury. Future research should also evaluate group differences (sport specialized groups, groups with differing injury history, and socioeconomic status) to further explore how a variety of populations perform on the ChildFIRST. Research efforts should also focus on gathering follow-up data regarding injuries experienced after being evaluated by the ChildFIRST; this data can help point to the ChildFIRST's ability to predict injury. Using the ChildFIRST to evaluate an intervention would also give more evidence of the utility of the ChildFIRST to measure differences in the same group of children. Some evaluation criteria in the ChildFIRST were specifically designed to identify risky body positions linked to injury so future research efforts should be directed towards exploring the relationship between the evaluation criteria, injury risk, and better scores on the ChildFIRST. Finally, with a more virtual world it is worth investigating the usefulness of virtual assessments and how they compare to in-person assessments, especially with the use of an observational tool such as the ChildFIRST that requires very little equipment.

4.5.2 Limitations

While the sample size presented here is large enough to make comparisons between sex and provide normative data, recruitment was disrupted by the Covid-19 pandemic. A strength of this study is the use of online/video to evaluate children, future projects should continue to explore the use of this type of data collection to reach more subjects across larger a geographical area. The reliability of the ChildFIRST is strong but data was collected online and in-person, potentially impacting the homogeneity of the data. Additionally, the data was collected from groups with different PA habits (soccer group vs YMCA vs volleyball). Although subset analysis of PA habits is out of the scope of this normative data project, exploring these group differences would give more context to how physical activity habits impact scores on the ChildFIRST. In this study the 'total score' variable was the only variable that fell close to, but exceeded, the 2.00 to -2.00 acceptable range of skewness and kurtosis.[26] The 'total score' histogram appears to have a normal shape and the kurtosis score is slightly above the 2.00 limit, so this variable treated as normally distributed. According to the literature, in large sample sizes (typically 50 or more) the assumption of normality for parametric tests is not necessary.[56–58] It is a strength of this study to include the skewness and kurtosis values to provide more evidence than just histograms for the normality of the data.

4.5.3 Conclusions

The ChildFIRST is a novel process-based assessment tool designed to evaluate movement competence and injury risk in 8-12-year-olds. All skills except running have normal distributions suggesting that the ChildFIRST captures a wide variety of movement skill in the 8-12 population. The results also indicate that there are no significant differences between males and females except for the single-leg sideways hop and hold skill. The children in this study also demonstrated better movement competence at older ages. The results of this study suggest that the ChildFIRST produces similar results to the TGMD-3 and the current literature, giving further support that the ChildFIRST can be used in the 8-12 age group. Enhanced movement competence is linked to better overall health outcomes, as such, movement competence should be evaluated early in a child's development. Evaluating movement competence will help guide curriculum and interventions to improve movement skill, promote physical activity participation, and identify children at risk of musculoskeletal injury. This study is the first to provide reference data and norms using the ChildFIRST. The normative data in this study can act as reference standards for the 8-12 year-old group to help inform physical education teachers, clinicians, and other stakeholders about general movement competence. This data may also be used to help identify children at increased risk for injury, but future work is needed to establish the link between scores on the ChildFIRST and high risk body positions associated to injury.

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CHAPTER FIVE:
GENERAL DISCUSSION

The projects presented within this dissertation explore the relationship between physical literacy and injury prevention to begin to fill the gap between these domains. The overarching theme of this work is to support the creation of a new assessment tool called the Child Focused Injury Risk Screening Tool (ChildFIRST). The purpose of this dissertation is, 1) to explore the link between physical literacy and injury prevention and how this link serves as the foundation for the creation of the ChildFIRST, 2) to describe preliminary reliability evidence, and 3) describe the normative data and trends in the 8-12 age group for the ChildFIRST. Chapter two addresses the first purpose of this dissertation and creates the theoretical framework for the ChildFIRST. Chapter three addresses the second purpose by describing the preliminary reliability evidence, and chapter four addresses the third purpose by exploring the normative data and sex differences. This chapter (5) provides a general discussion, additional interpretations for each previous chapter, specific recommendations for future research, and conclusions to help advance the development of the ChildFIRST.

5.1. The Connection between Physical Literacy and Injury Prevention

Chapter two describes the theoretical structure for the connection between physical literacy and injury prevention and was published in *Athletic Training & Sports Health Care.*[1] The objectives from chapter two were: 1) Present the relevant and current literature in the domains of physical literacy and injury prevention, 2) Discuss the gap in literature between physical literacy and injury prevention domains, and 3) Provide evidence and a framework for a connection between physical literacy and injury prevention domains. Chapter two met the objectives above by providing a strong review of the current physical literacy and injury prevention tools, demonstrating a gap between physical literacy and injury prevention and by discussing the framework that links these concepts.[1]

The domain of physical competence is best linked to injury prevention concepts by using a process-based evaluation of fundamental movement skills.[14] The other domains of physical literacy also link to injury prevention concepts. The first domain, confidence and motivation, help children participate in physical activity but these qualities are also linked to injury risk.[2,3]

The literature suggests that having confidence in one's own abilities is tied to a lower incidence of injuries.[4] There is a necessary balance between extreme levels of confidence, with overconfidence and a lack of confidence being linked to a higher incidence of injuries.[4] Having good levels of self-confidence are associated with more positive rehabilitation outcomes after an injury,[5] but poor self-confidence is associated to re-injury.[6] The second domain, daily behaviour, also relates to injury. Literature supports higher levels of physical activity participation result in fewer injuries in childhood.[7,8] A necessary balance is important for physical activity participation as well, not participating in physical activity at all contributes to sedentary behaviour, obesity and associated comorbidities,[9] whereas extremely high levels of physical activity can lead to injury.[10] The remaining domain of physical literacy, having the knowledge and understanding of the importance of physical activity, is not directly linked to injury. As children begin to understand how an injury will affect their physical activity, children may engage in safer physical activity habits, but research needs to be conducted to support this idea. Overall, an injury in childhood will not only affect the physical competence domain of physical literacy but it has the potential to impact other aspects of physical literacy as well. Future research should build on these ideas, for example, establishing whether physical literacy interventions designed to enhance confidence and motivation influence injury risk. More direct efforts should be placed on connecting physical literacy and injury prevention outside of the physical competence domain.

Since the publication date of chapter two, some new assessment tools have been developed. Later in 2018 the Canadian Assessment of Physical Literacy released an updated version, the CAPL 2.0, allowing evaluators to assess one particular domain of physical literacy if preferred.[11] In 2019, the third iteration of the TGMD was released including updated normative data and enhanced reliability and validity evidence.[12] The Lifelong Physical Activity Skills Battery is a process-based assessment tool designed to evaluate a series of movements that an individual could participate in at all stages of their life.[13] Extending the evaluation of fundamental movement skills past childhood is an important progression because physical activity is essential for a healthy lifestyle at all ages. The Lifelong Physical Activity Skills Battery is also composed of noteworthy evaluation criteria associated with their skills. While not explicitly categorized as a tool to identify injury risk, the authors make specific note that the 'jog' skill was designed with a focus on preventing injury.[13] Criteria such as "pelvis remains level and does not drop excessively (> 5cm drop)", "avoidance of excessive knee valgus" and "avoidance of crouch gait (i.e. does not bend knee more than 50 degrees and trunk not more than 30 degrees flexed during midstance)" are clearly directed towards identifying movement errors that lead to injury. Unfortunately, these criteria may create concerns during a live evaluation. Without appropriate training or advanced movement analysis software it is a challenge to evaluate a 5cm drop in pelvic positioning or specific joint angles in the hip and knee. These challenges are important to consider for future research and could be addressed with kinematic and kinetic analyses. The introduction of the Lifelong Physical Activity Skills Battery into the body of literature suggests that research is moving towards a more lifelong approach to assessing movement competence with more of a focus on injury prevention.

Much of the discussion surrounding the injury prevention literature relates to sport and the importance of reducing injury in athletic populations, but the concepts of physical literacy are intended to encompass all populations.[14] The impact of injury on non-athletic populations can be severe, and literature indicates that the physical and psychological effects of injury is comparable regardless of the level of physical activity participation prior to injury.[15] Physical literacy programs are increasingly being incorporated into physical education curriculums across the world,[16] as such, more importance needs to be placed on the potential injury prevention benefits that could be gained from implementing these programs. While sports and physical activity related injuries are the most common form of injury in childhood,[17,18] there are widespread advantages to schools implementing curriculums with physical literacy programs that have a focus on injury prevention. The health advantages of such a curriculum include decreased waist circumference, decreased average heart rate, decreased incidence of injury, and a decrease in time lost to injury.[19] Continued efforts should focus on promoting physical activity participation while also seeking to reduce injuries thus providing children with the opportunity to participate in physical activity throughout their life. Chapter two concludes by suggesting that physical literacy assessments fail to consider injury prevention concepts and that future assessment tools be designed to evaluate movement competence and movement technique while considering injury prevention techniques.[1]

5.2 Validity and Reliability of the Child Focused Injury Risk Screening Tool

Chapter three describes the reliability of the ChildFIRST and is paired with a publication describing the validity of the ChildFIRST, both published in *Measurement in Physical Education and Exercise Science.*[20,21] The ChildFIRST had face and content validity established by a panel of experts by using a Delphi process.[21] The objectives of Chapter three were: 1) Evaluate inter- and intra-rater reliability of the movement skills within the ChildFIRST and 2) Evaluate inter- and intra-rater reliability of the evaluation criteria within the ChildFIRST. The research study presented in Chapter three achieved the objectives set out at the beginning of this dissertation by showing that the ChildFIRST demonstrates 1) good-to-excellent (ICC > 0.75) inter-rater reliability for eight movement skills, one movement skill demonstrates moderate reliability (ICC = 0.727) and the other movement skill demonstrates poor reliability (ICC = -0.306), 2) moderate-to-good (ICC > 0.50) intra-rater reliability for five movement skills, poor (ICC = 0.00 to 0.50) intra-rater reliability for five skills, 3) inter-rater reliability of the evaluation criteria ranged from unreliable (Kα > 0.667) to reliable (Kα < 0.80), and 4) intra-rater reliability scores ranged from none (Cohen's K = 0.00 to 0.20) to fair (Cohen's K = 0.20 to 0.40).[20]

The validity of the ChildFIRST was not a project that formed part of this dissertation, but some discussion regarding the validity has merit. The use of a modified Delphi method gives strength to the validity of the ChildFIRST. Research indicates that establishing international consensus on a topic along with support from literature provides strong support for the validity of an assessment tool.[22] The results of the validity project may also help guide improvements or changes to the ChildFIRST. For example, if the data indicates there is a need to remove or replace an evaluation criterion, the data from the Delphi study can inform researchers what the next evaluation criteria should be based on consensus from the panel of experts. Further, the panel of experts was not only composed of academics, like many other Delphi method studies, but practitioners and other experts (strength and conditioning coaches, athletic therapists, and physical education teachers) were included .[21] These diverse perspectives further enhance the strength of the validity of the ChildFIRST. Future work should seek to improve the validity further by establishing an association between the ChildFIRST and 'gold standard' assessments such as kinetic, kinematic, and EMG data, and the TGMD-3 or the CAPL 2.0.[11,12]

The inter-rater reliability of the ChildFIRST is strong, indicating the tool can be used in its current form as an accurate method of conducting a cross-sectional analysis of 8-12-year-olds.

Improvements to the intra-rater reliability of the movement skills and evaluation criteria would be beneficial for the ChildFIRST. Without stronger intra-rater reliability, it becomes difficult to interpret results of pre-post study designs or randomized control trials. The strength of the data would come into question, as a result intra-rater reliability specifically should be improved. Recommendations to improve the reliability are outlined in the discussion of chapter three specifically; there were a few participants who completed their second testing session more than one week after the first testing session, which may have influenced the results.

Establishing reliability evidence for the evaluation criteria is difficult due to the dichotomous nature of the data. There is an extensive discussion in Chapter three regarding the correct methodology and the difficulties in analyzing reliability using dichotomous data. A 2020 review included 23 studies that evaluated the movement skill reliability in each TGMD variant (TGMD 1,2 and 3), a tool that also has dichotomous evaluation criteria.[23] The systematic review makes no mention of the reliability for the evaluation criteria of the TGMD, implying reliability for the criteria was not calculated.[23] The ChildFIRST does have reliability for the evaluation criteria, and although poor for some items, it is a strength to present this data. Dichotomous evaluation criteria in the rating of movement skills are used to indicate the absence or presence of a particular characteristic. This scoring method is useful for quick but informative ratings in settings with many participants. Some limitations to dichotomous scoring systems are discussed in section 5.4 “Limitations”.

A discussion surrounding Cronbach’s Alpha is required to explain why this reliability measure was not calculated for the ChildFIRST. Many scales and assessments use internal consistency evaluated with Cronbach’s Alpha to accompany traditional reliability data such as interrater reliability. Internal consistency describes how well the items in a test measure the same construct or concept.[24] Internal consistency is important for assessments that measure the same construct, for example, do all the questions of a particular questionnaire consistently measure a specific trait such as anxiety. It is difficult to apply this concept to the ChildFIRST because each movement skill is distinct, and although they share similar evaluation criteria, the movements are different and are not intended to be consistent with each other. It would not be advantageous for the single leg sideways hop and hold skill to consistently measure the same concept as the bodyweight squat because the goal is different between these two skills. The literature does not support using Cronbach’s Alpha if there are multiple concepts or constructs.[24] The ChildFIRST has 10 constructs (movement skills) and four evaluation criteria that should be highly correlated to each movement. If the movement skills demonstrated high internal consistency it would call into question the effectiveness of the ChildFIRST because the goal is to capture a wide variety of movements aimed at identifying risky movement patterns.

Another method to understand more about the interconnectedness of the evaluation criteria and movement skills is an exploratory factor analysis.[25] The exploratory factor analysis is a correlational based analysis that groups items together based on theoretical factors,[26] in this case the theoretical factors are the movement skills. It is important to note that nine of ten movement skills have the evaluation criteria "hips, knees, and ankles aligned" and eight movement skills have the evaluation criteria "knees and hip bend softly to land in a controlled manner". It is possible that if the child does not have their hips, knees, and ankles aligned in one skill, they do not have their hips, knees, and ankles aligned in some (or all) of the other skills with the same criteria. The EFA can give researchers evidence about the importance and redundancy of the criteria. If the evidence suggests, this data can be used to enhance or potentially change the evaluation criteria, improving the ChildFIRST as a whole. A minimum sample size required to conduct a factor analysis is generally 10 subjects per item, and with 40 items in the ChildFIRST, 400 subjects would be required to conduct this analysis.[26,27] When more data are added to the normative data sample an exploratory factor analysis should be conducted to explore the structure of the ChildFIRST and potentially make data driven changes to the tool.

Chapter three concludes by suggesting continuous training for the evaluators using the ChildFIRST to ensure reliability stays high prior to each testing session. Although there are some skills and evaluation criteria that demonstrate poor reliability, the ChildFIRST can be used in its current form to reliability evaluate children in cross-sectional study designs. Researchers can use the ChildFIRST in other study designs, but should be aware of the importance of repeated training sessions for evaluators if a pre-post or test-retest study design is used. Overall, the ChildFIRST can be used to provide reliable data to physical educators, clinicians, coaches, and other stakeholders about movement competence in the 8-12-year-old population.[20]

5.3 Normative Data for the Child Focused Injury Risk Screening Tool

The objectives of Chapter four were to: 1) Investigate normative data and trends for scores on the ChildFIRST in a group of 8-12-year-old children and 2) evaluate differences between age, sex, height, weight, body mass index (BMI), and physical activity habits, in scores on the ChildFIRST. The research study presented in Chapter four achieved the objectives set out at the beginning of this dissertation by showing that: 1) all skills except for running were normally distributed, and 2) older children performed better in general than younger children and there were no differences between males and females except for the single leg sideways hop and hold skill. The results of chapter four also demonstrated a positive association between higher levels of physical activity and better scores on the ChildFIRST, and a negative association between higher BMI and scores on the ChildFIRST.

Chapter four describes the findings from a large data set and provides normative data for ChildFIRST using a sample of 8-12 year-old children. Normative data allows other users to compare the results of their own data to a larger dataset. This data can help inform interventions aimed at improving movement competence and injury risk. As more normative data is collected the data set will become more robust, allowing more users to confidently create interventions targeted at the children who perform worse than the "average" as indicated by the data set. A larger data set will promote increased use of the ChildFIRST, further contributing to the normative data. Significant efforts should be aimed at collecting more normative data amongst several populations such as, socioeconomic status, various provinces, differing sport populations, and various countries.

A challenge of creating a novel assessment tool such as the ChildFIRST is the difficulty in comparing results to other assessment tools. There are no other tools with a focus on physical literacy that are designed to evaluate both movement competence and injury risk. There are other process-based assessment tools such as the TGMD-3 that also utilize evaluation criteria related to technique and body position.[12] Both the TGMD and the ChildFIRST use "take off on one foot, land on the opposite foot" as evaluation criteria for the leaping skill and "arms move in opposition to the legs" for the running skill. These two examples are directly linked to the successful performance of the movement skill, but they do not provide any information regarding body positioning that may lead to injury. The ChildFIRST is distinct from the TGMD in that it includes evaluation criteria in several movements that are specifically meant to identify risky body positions, such as a knee valgus.[28] Incorporating evaluation criteria specifically aimed at identifying risky body positions related to injury is what sets the ChildFIRST apart from other assessment tools and is the key component in linking physical literacy and injury prevention concepts.

The results of chapter four indicate that children with higher BMI perform more poorly on some of the ChildFIRST movements and that children who participate in more physical activity per week perform better on the ChildFIRST. Both BMI and physical activity participation are linked to injury risk, but when the ChildFIRST was designed, the evaluation criteria were intended to be the mechanism for which the ChildFIRST identifies injury risk. Specific evaluation criteria such as “hips, knees, and ankles aligned” and “knees and hips bend to land softy in a controlled fashion” were designed to identify children who are at increased risk for injury. If a child does not achieve these criteria it is possible they exhibit characteristics that could lead to injury. Physical activity habits and BMI being linked to performance on the ChildFIRST gives preliminary evidence that scores on the ChildFIRST could be associated to injury. Future research needs to study the relationship between specific evaluation criteria and scores on the ChildFIRST further and explore how the movement skills and evaluation criteria link to injury risk.

Understanding the relationship between injury risk and the ChildFIRST is a challenge. A good first step would be to collect follow up data about any injuries that were experienced by the children who participated in the normative data study. Collecting this data would allow researchers to make associations between scores on the movement skills and evaluation criteria, and the severity, type, and location of injuries experienced. Prospective data about injuries sustained after participating would require a long follow up period to allow for a large enough sample of injuries to make meaningful comparisons. Another good step to connect injury and the ChildFIRST would be to establish the relationship between movement scores and specific evaluation criteria, and biomechanical data using kinematic, kinetic, and sEMG analysis. Biomechanical data can help inform researchers about how children who exhibit risky body positions (such as a knee valgus) score on the ChildFIRST. With this data researchers can begin to understand how the ChildFIRST may predict injury. For example, if a child performs the bodyweight squat and fails to achieve the “hips, knees, and ankles aligned” criteria it may indicate the child is at an increased risk for injury. This evaluation criteria is designed to evaluate lower limb positioning/alignment, including knee valgus.[15] By comparing scores on the ChildFIRST to kinematic data, a possible connection could be made between a child exhibiting a knee valgus position during the bodyweight squat in a laboratory setting and the same child not achieving the “hips, knees, and ankles aligned” criteria. With this data researchers may be able to determine that a child who does not achieve this criterion demonstrates movement characteristics associated with increased injury risk, warranting an intervention. Corrective exercises known to reduce knee valgus could be prescribed (by a rehabilitation professional such as an athletic therapist) to the child, in turn potentially reducing the child’s risk for injury. The same discussion could apply to other evaluation criteria potentially linked to injury risk, such as “knees and hips bend to land softly in a controlled fashion”. Failure to achieve this criterion may indicate the child is not absorbing their landing, resulting in large ground reaction forces affecting their lower limb. Laboratory comparisons could be made between this criterion and measures such as force plate data, providing evidence that a child who does not achieve this criterion is at increased risk for injury. Feedback on how to properly absorb their landing could be given, potentially reducing their injury risk. This type of future research uncovers the potential the ChildFIRST may have to identify children at increased injury risk.

5.4 Limitations

It needs to be stated that the Covid-19 pandemic affected the data collection of the final project of this dissertation. In the winter of 2019 plans were made to collect data from eight YMCAs in the Montreal area, while this largescale data collection did not occur, the research team made significant efforts to transition online and with the help of the Champions for Life Foundation the project was still a success. The data collected about weekly physical activity does not have significant substance, the participants were asked to indicate how many times their children participates in physical activity throughout the week. Nowhere were the participants asked to indicate the type or quantity of physical activity. While this is a limitation, it is promising that despite the quality of the data, there were still significant findings related to weekly physical activity levels. It is important to note that the ChildFIRST was developed to assess typically developing children.

The movements and evaluation criteria are not designed to evaluate children that display cognitive, physical, neurological, or other forms of developmental differences. These children can participate in the evaluation (to avoid exclusion), but the scores are not interpretable with the current dataset. Future research should seek to understand if the ChildFIRST could be used to evaluate movement and injury risk in these populations. The ChildFIRST is limited in considering how the systems of the body (neurological, visual, auditory etc.) interact and contribute to individual differences in movement. As children mature these systems contribute in differing ways to a child's movement quality, but the ChildFIRST only focuses on assessing the physical attributes a child displays during movement.

Using a dichotomous scale to evaluate a criterion such as "hips, knees, and ankles aligned" could create a limitation by reducing precision when evaluating this complex body position. A dichotomous score reduces fidelity of the criteria to be achieved, so evaluators cannot indicate partial success. A 7-point rating scale has been discussed as a way to improve reliability;[51] it would provide more options for evaluators when observing complex body positions. There is a tradeoff however, a 7-point rating scale does provide evaluators the opportunity for a broader evaluation of a movement skill. The use of a 7-points to evaluate "hips, knees, and ankles aligned" or "keep heels down all the time" would not improve the information about how a child performs a movement, but it would improve the reliability and give evaluators the opportunity to indicate partial achievement of a criteria. Symonds discusses the importance of avoiding coarseness in a rating scale (as found in a dichotomous scale), indicating that giving more options to the evaluators allows for a more representative rating.[51] Symonds suggests that more response options will enhance reliability to a point, indicating that a anything more than a 10-point scale may be too 'fine' a scale, reducing reliability.[51] Future research should investigate ways to improve the reliability of the ChildFIRST and investigate if changing the rating system should be implemented while preserving the meaning of the overall tool. It is important to note, the ChildFIRST was modeled after other tools that also use dichotomous rating scales such as the TGMD-3 and the Landing Error Scoring System.[38, 52] The TGMD-3 and the LESS are well established tools providing evidence of the usefulness of a dichotomous rating system, but there is merit to the discussion about how effective a dichotomous scale is when evaluating specific joint positions or complex movements. Using two rating options does allow for a faster evaluation placing less stress on the evaluators by allowing them to quickly assess a child's movement when there are many children in a group. Increasing the number of scoring criteria would subsequently increase the time it takes to complete the ChildFIRST. The goal was to create a tool that could easily be implemented in a physical education setting and conducted in a reasonable time. There is a tradeoff when assessing movement in a field setting compared to a laboratory setting. While field based tools are designed to be as accurate as possible, laboratory tests occur in a controlled environment often with more available technology. This situational difference usually results in less accurate field based tools. The issues around the dichotomous nature of the evaluation criterion can be partially answered by conducting concurrent validity testing to determine how closely the ChildFIRST evaluates movement compared to laboratory measures.

The use of dichotomous ratings also limits interpretation of scores for a specific movement and the total score of the ChildFIRST. For example, a child that achieves the first and third evaluation criteria of a particular movement and a child that achieves the second and fourth criteria on the same movement would both score the same value (two). One evaluation criterion may be more important and provide information about injury risk whereas the other evaluation criterion does not. With the current data there is no way to distinguish between a child that scores a two with different evaluation criteria. With more information about the importance of the evaluation criteria the rating scale could be ordinal in nature, allowing for stronger interpretations of the scores both on a specific movement and for the total score. The use of an exploratory factor analysis (EFA) could help researchers improve this limitation through determination of the importance of specific evaluation criteria. The use of an EFA is discussed in the future research section.

5.5 Recommendations for Future Research

This thesis brought a novel and comprehensive approach to connecting the domains of physical literacy and injury prevention. The development of a new process-based assessment tool called the Child Focused Injury Risk Screening Tool (ChildFIRST) helps to link physical literacy and injury prevention. The findings described in this document lay the groundwork for future research in the following areas:

1. Continue to collect data from various populations to enhance the normative data. With enhanced datasets the normative data can give physical educators, clinicians, and other stakeholders more information about their specific children and how they relate to the normative sample. A larger dataset will encourage more users from across Canada and

the world, leading to widespread evaluation of the movement competence and injury risk of children. A larger data set will also allow researchers to conduct an exploratory factor analysis which can help inform decisions about changing the ChildFIRST.

2. Conduct an EFA when the normative dataset becomes large enough (400 subjects). The current evaluation criteria give us valuable information about body positions associated to increased injury risk in a field setting. Data from an EFA can help researchers make important decisions regarding the importance of specific evaluation criteria and help identify redundant criteria that may need to be changed. The data from the EFA as well as the additional future research projects can help inform meaningful changes to the ChildFIRST to improve the tool.
3. Establish concurrent validity between the ChildFIRST and gold standard assessments such as kinematic data, kinetic data, EMG data, and the TGMD-3 or the CAPL 2.0. The use of kinematic data can help inform researchers about what body positions are optimal for each movement in the ChildFIRST and what body positions lead to injury. This information can help refine the evaluation criteria within the ChildFIRST to make them more meaningful regarding the prediction of injury. Kinetic data can help inform researchers to the ground reaction forces and other forces that children experience when participating in the ChildFIRST and can help researchers identify children who may be at increased risk of injury because of their ground reaction forces during the ChildFIRST movements. EMG data can help inform researchers about the musculature used by children who score high compared to children who score low on the ChildFIRST. Electromyographic data can be very valuable in both identifying highly skilled versus not skilled children and to inform intervention strategies based on enhancing muscle activity in the appropriate musculature.
4. Collect prospective data regarding injuries sustained in participants after being evaluated by the ChildFIRST. This data can help researchers understand the ChildFIRST's ability to predict injury and help to identify important evaluation criteria that help the ChildFIRST predict injury. With data about the ChildFIRST's ability to predict injury users can identify children who exhibit high risk for injury and design interventions to decrease their injury risk. This can help children continue to participate in physical activity throughout their life.

The above indicated directions are the suggested next steps for research on the ChildFIRST. Some long-term goals would be to determine score thresholds for children who are at no risk, medium risk, or high risk for injury. Another goal is to develop interventions based on the ChildFIRST results to enhance both physical literacy and injury risk within the 8-12 year-old population. The link between scores on the ChildFIRST and injury needs to be explored further. The overarching goal of the ChildFIRST is to enable children to participate in physical activity safely and confidently, now and throughout their life.

5.6 Conclusions

The overall contributions of this dissertation are novel and important because prior to the publication of the papers contained in this thesis and the development of the ChildFIRST there was only speculative expert opinion describing the connection between physical literacy and injury prevention. The ChildFIRST is the first tool to merge these two concepts and start to bridge the gap between these areas. The results described in this dissertation provide evidence that the ChildFIRST: 1) is a valid and reliable tool to assess movement competence and injury risk in the 8-12-year-old population, 2) can distinguish between higher and lower movement skill, 3) demonstrate associations between higher levels of physical activity participation and higher score on the ChildFIRST, 4) demonstrate associations between higher BMI and lower scores on the ChildFIRST, and 5) provide results that align with the current body of research. These results give credibility to the ChildFIRST and give a strong direction towards future research aimed at establishing the tool's ability to predict injury.

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Note: The references in this list are the reference list for chapter's one and five combined. The references for chapter two, three, and four are found at the end of each chapter to limit the number of changes from the accepted/submitted PDF version.

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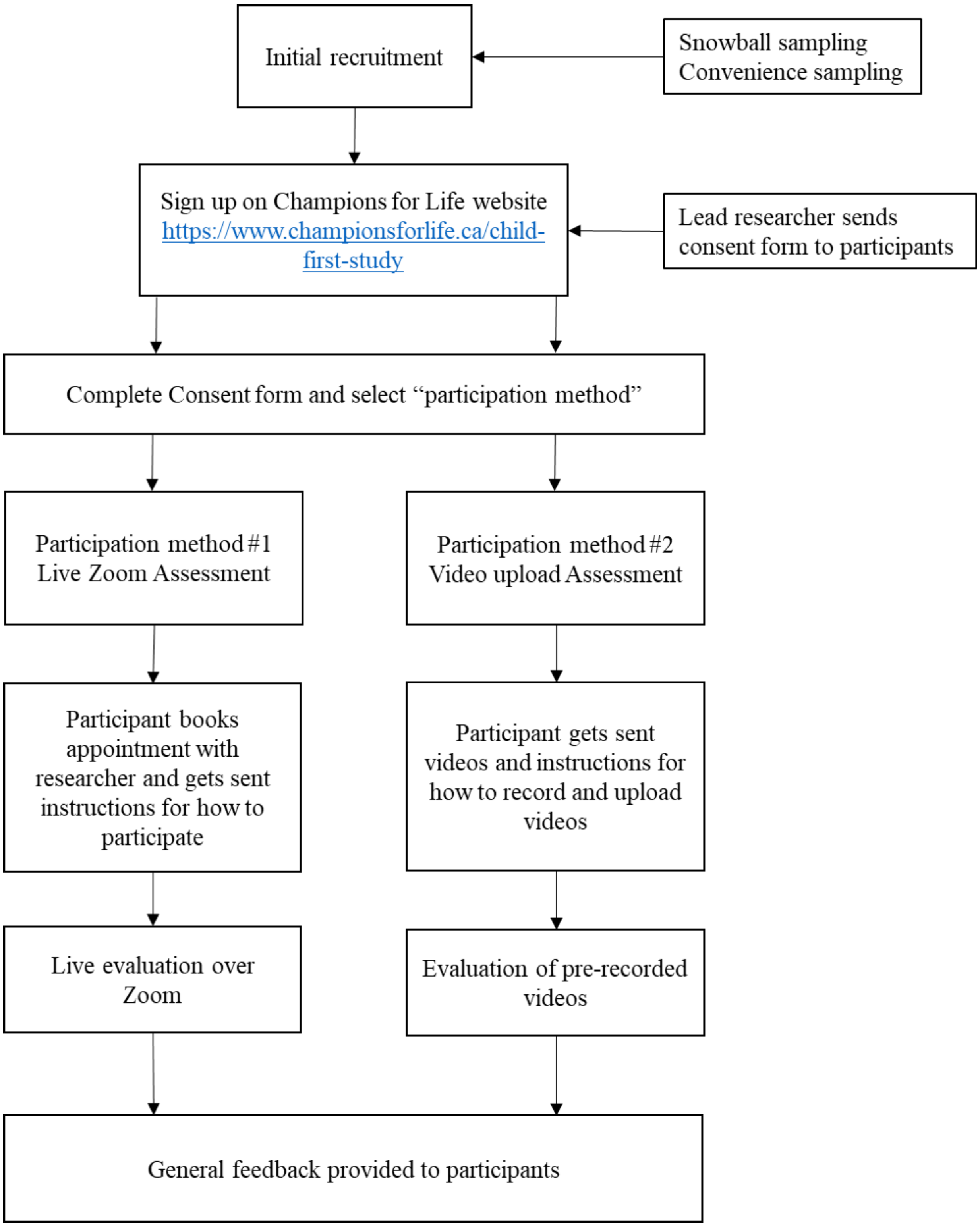
APPENDIX A

The ChildFIRST

Movement Skill	Evaluation Criteria
Bodyweight Squat	1. Push hips back and bend the knees until the thighs are approximately parallel with the ground 2. Hips, knees, and ankles aligned 3. Knees do not go too far in front of the toes 4. Keep the heels down all the time
Vertical Jump	1. Swing arms to assist the movement 2. Knees and hips bend to land softly in a controlled fashion 3. Land on both feet at the same timec 4. Hips, knees, and ankles aligned
Single Leg Sideways Hop and Hold	1. Knees and hips bend to land softly in a controlled fashion 2. Hips, knees, and ankles aligned 3. Foot flat on the floor 4. Stand up straight within three seconds after landing
Walking Lunge	1. Hips, knees, and ankles aligned 2. Upper-body straight and eyes focused in direction of travel 3. Front knee does not go too far in front of toes 4. No twisting nor bending back
Two-to-One Foot Hop and Hold	1. Knees and hips bend to land softly in a controlled fashion 2. Toes pointing forwardc 3. Foot flat on the floor 4. Hips, knees, and ankles aligned
90˚ Hop and Hold	1. Knees and hips bend to land softly in a controlled fashion 2. Hips, knees, and ankles aligned 3. Whole body turns together 4. Toes pointing forward
Leaping	1. Take off from one foot, land on the opposite foot 2. Knee and hip bend to land softly in a controlled fashion 3. Hips, knees, and ankles aligned 4. Swing bent arms in opposition to legs
Horizontal Jump	1. Swing arms to assist the movement 2. Knees and hips bend to land softly in a controlled fashion 3. Land on both feet at the same time 4. Hips, knees, and ankles aligned
Running	1. Upper-body straight and eyes focused in direction of travel 2. Swing bent arms in opposition to legs 3. Knee drives upward and forward to lift the foot off the ground 4. Knee and hip bend to land softly in a controlled fashion
Single Leg Hop	1. Hips, knees, and ankles aligned 2. Take off from one foot, land on the same foot 3. Knee and hip bend to land softly in a controlled fashion 4. Swing arms to assist the movement

APPENDIX B

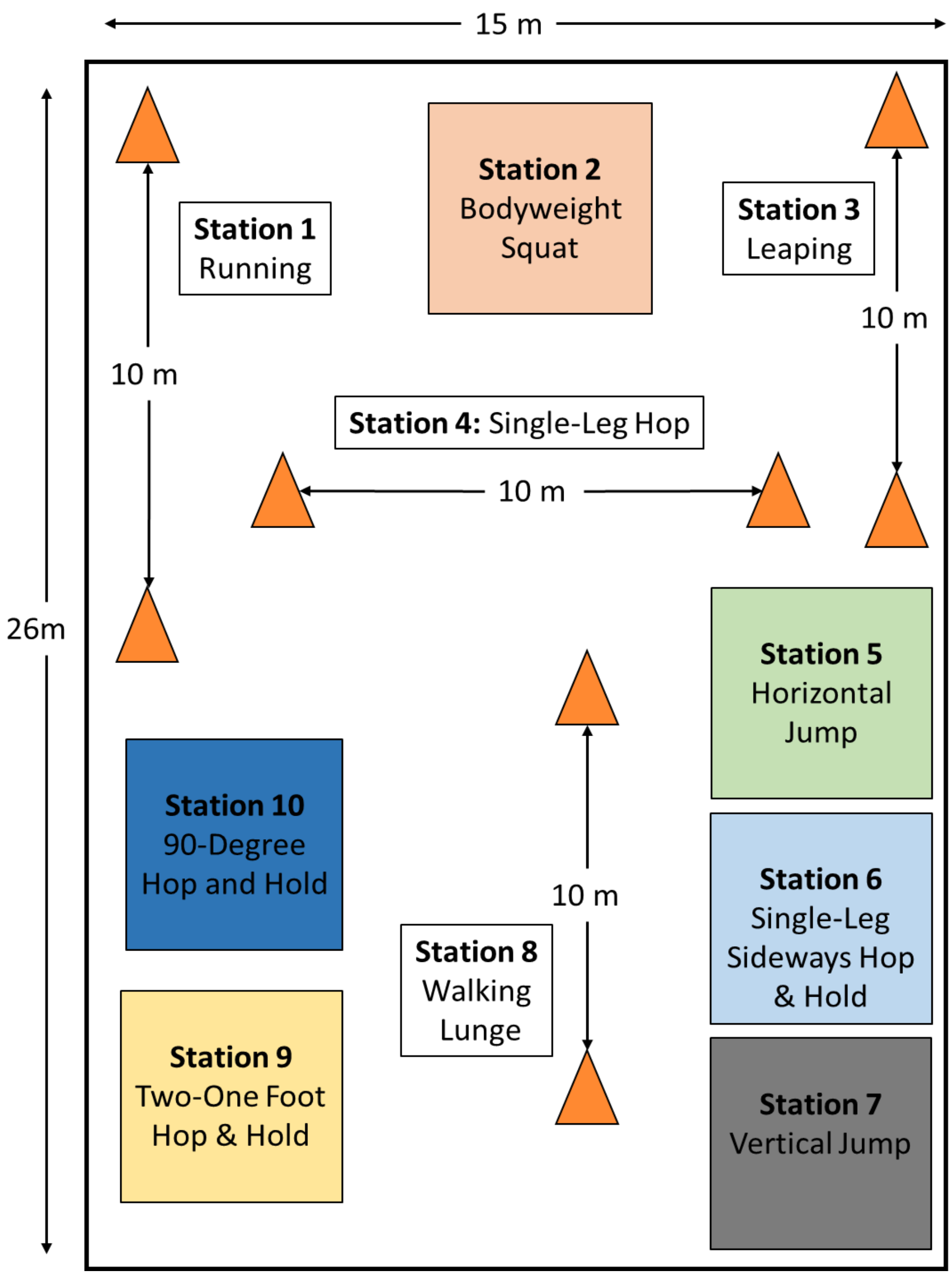
Study Timeline for Online Participation



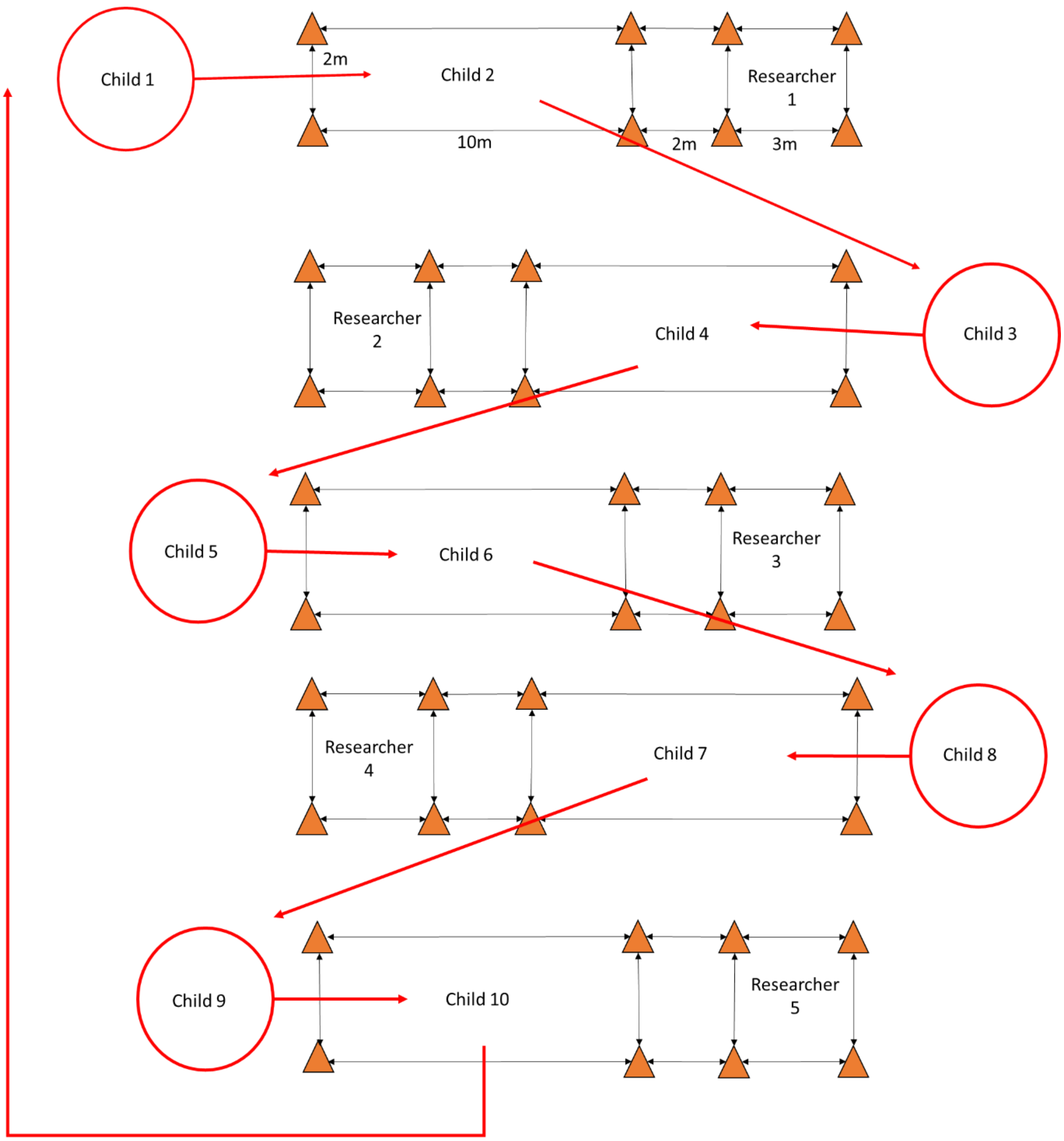
APPENDIX C

Testing Circuit

Testing Circuit before Covid-19: A member of the research team was assigned to each station and was responsible for evaluating one movement. the participants rotated through a series of 10 stations. At each station, a trained evaluator would assess 1 specific movement, after each group of 2 to 4 children completes the movement at one station in the circuit, the group would rotate to the next movement. The evaluator stayed at each circuit After each group of children completed all the movements the assessment was complete. See appendix C for the testing circuit.



Testing Circuit with Covid-19 precautions: A member of the research team will stand within the researcher area indicated below. They will remain in the researcher area for the duration of the data collection. The researcher at each station will be responsible for evaluating two movements. The children will only enter the testing area when being evaluated. All other children will wait behind the testing area inside a hula hoop at an appropriate distance (indicated with the red circle below). Each testing station is 2m apart, with 2m between the child and researcher. When all children have completed the movements in all the stations they will be asked to sit down. When all the children are sitting, they will change stations



APPENDIX D

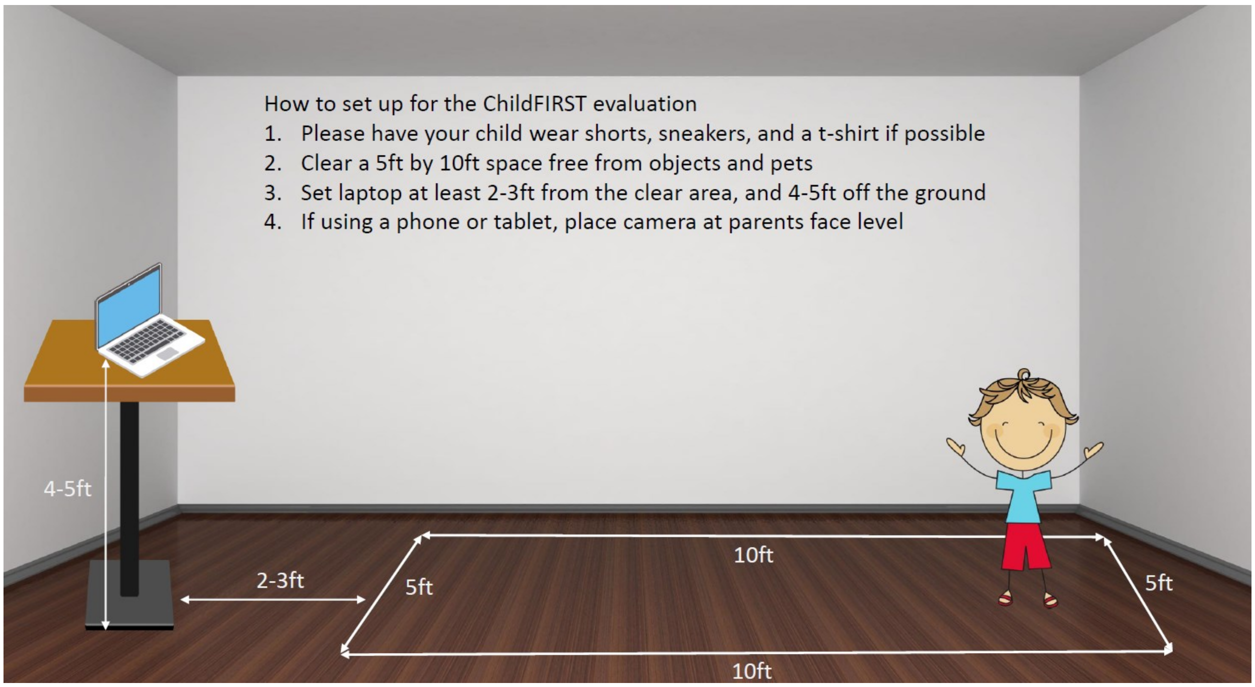
Directions for Participation in ChildFIRST Research Study.

Thank you for completing the consent form and agreeing to participate in our study!

Please follow the directions below:

1) If possible please have your child wear shorts and a t-shirt. If the weather permits and the child is under parental supervision we encourage you to move outside.

2) If moving outside is not possible find a clear area using the dimensions in the picture below.



3) It is highly recommended to use a smartphone (iphone/android etc) to join the zoom meeting. At your assessment time, join the zoom meeting at the following link:

   https://concordia-ca.zoom.us/j/93271813938

4) If it is possible, using a Laptop or another device (not the phone being using for zoom), bring up this video https://www.youtube.com/watch?v=QNxStOxUA5A&feature=youtu.be

*****Please no coaching*****