Influence of the relative age effect on children's scores obtained from the Canadian Assessment of Physical Literacy

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Abstract

Schools and sports governing bodies have added physical literacy in their curricula. However, until recently, there was no validated protocol to assess children's physical literacy progress. In response to this need, the Canadian Assessment of Physical Literacy (CAPL) was developed; it measures physical literacy by assessing 4 important domains (physical competence, daily behaviours, motivation and confidence, and knowledge and understanding). The relative age effect (RAE) bias is attributable to age grouping by the imposition of cut-off dates; this age grouping strategy is common in sports and schools. However, despite its objective of providing age-adjusted learning, it promotes a relative age difference that leads to a developmental advantage for children born just after the cut-off date. Analogous to the age grouping in schools and sports, the CAPL protocol uses rounded-down age bands to objectively compare children; however, this type of comparison is also known for being susceptible to the RAE bias. The purpose of this thesis was to determine whether the RAE bias was associated with the CAPL scores (i.e., the four domains individually and the overall score) and all of the physical competence domain assessments individually (anthropometrics, aerobic, strength, muscular endurance, flexibility and movement skills). Participants (n=8,233, 50.2% girls), ages 8 to 12 years, from 7 provinces were tested using the CAPL protocol. Analyses of covariance (controlling for age, testing date, body mass index *z*-scores and testing sites) revealed a significant RAE bias in boys in 2 out of the 4 domains (physical competence and knowledge and understanding domains) and in girls in 3 out of the 4 domains (physical competence, knowledge and understanding and motivation and confidence domains). However, these significant associations between domain scores and relative age yielded negligible effect sizes, thus no meaningful RAE was observed. Collectively, the results of this thesis suggest that the RAE should not affect the validity of the CAPL in accurately measuring physical literacy.

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List of Abbreviations

AB	Alberta
ADHD	Attention-Deficit/Hyperactivity Disorder
ANCOVA	Analysis of Covariance
BC	British Columbia
BMI	Body Mass Index
CAMSA	Canadian Agility and Movement Skill Assessment
CAPL	Canadian Assessment of Physical Literacy
CI	Confidence Interval
CSAPPA	Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity
CSEP	Canadian Society for Exercise Physiology
DMSP	Developmental Model of Sport Participation
FMS	Fundamental Movement Skills
HALO	Healthy Active Living and Obesity
LB	Lower Bound
MABC-2	Movement Assessment Battery for Children-2
MB	Manitoba
NS	Nova Scotia
ON	Ontario
PACER	Progressive Aerobic Cardiovascular Endurance Run
PEI	Prince Edward Island
PLAY	Physical Literacy Assessment for Youth
QC	Québec

RAE	Relative Age Effect
RBC	Royal Bank of Canada
SD	Standard Deviation
SES	Socioeconomic Status
SHAPE®	Society of Health and Physical Educators ®
UB	Upper Bound
WC	Waist Circumference
WHO	World Health Organization

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Prelude to Thesis

For the present manuscript-based thesis, I collected data in the Ottawa region, since October 2015, but was granted the use of the full CAPL–RBC Learn to Play Project's database. For this thesis, I was responsible for developing the research question, data analysis, interpretation of results and writing. This manuscript-based thesis contains one original article, presented in Part 4, for which I am the primary author. At the time of the thesis submission, the article was under peer-review in *BMC Public Health* as part of the CAPL special issue. The co-authors are listed in Part 4 (page 24) along with their contributions (page 53). All co-authors take responsibility for the content of the manuscript.

Ethics approval for the study was provided by the Children's Hospital of Eastern Ontario Research Institute (see Appendix A) and the University of Ottawa's research ethics boards, as well as the ethical review boards of the participating sites. The University of Ottawa's Research Ethics Board has also given approval, but no certificate was emitted (approval file A05-17-01).

Part 1: Introduction

Many studies have observed associations between the relative age effect (RAE) and numerous outcomes in academic and sports settings (Bisanz, Morrison, & Dunn, 1995; Musch & Grondin, 2001; Navarro, García-Rubio, & Olivares, 2015; Russell & Startup, 1986). However, to date no study has examined the RAE in the context of physical literacy, a construct that simultaneously takes into account factors in affective, cognitive, behavioural and physical domains. The present thesis-study was conducted to address this knowledge gap, and to assess the magnitude of the RAE using a comprehensive and validated physical literacy assessment protocol, the Canadian Assessment of Physical Literacy (CAPL).

The RAE bias is attributable to the grouping of children by the imposition of cut-off dates, as is done in many countries' education system and in organized sports (Musch & Grondin, 2001; Navarro et al., 2015). Despite its objective of providing age-adjusted learning and competition, it promotes a relative age difference within a cohort (a difference of up to 12 months). The systematic bias arises when relatively younger children are being explicitly compared to relatively older ones; generally, the relatively younger children are at a disadvantage. The differences in school grades attainment, sports selection and achievements between relatively older children and relatively younger ones is known as the RAE (Bisanz et al., 1995; Musch & Grondin, 2001; Wattie, Cobley, & Baker, 2008). In parallel to age grouping used in school systems and sports organizations, fitness assessments implicitly compare children using normative data that regroup children into rounded-down age bands that usually span a full year. This type of implicit comparison has also been shown to be susceptible to the RAE bias (Birch, Cummings, Oxford, & Duncan, 2016; Roberts, Boddy,

Fairclough, & Stratton, 2012; Sandercock et al., 2013; Veldhuizen, Rivard, & Cairney, 2017). Although rounded-down age bands compare children of similar chronological age, it fails to take into account biological age and length of time spent in school or in sports.

The *International Physical Literacy Association* defines physical literacy as "the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activity for life" (Whitehead, 2014). Developing and maintaining physical literacy is a worthwhile journey, as the physical literacy outcome is lifelong engagement in physical activity and the health benefits associated with being active are unequivocal. In recent years, the concept of physical literacy has gained tremendous momentum, and many countries have adopted the concept of physical literacy in their education *curricula*, and sports governing bodies have also incorporated physical literacy principals in their Long-Term Athlete Development models (Canadian Sport for Life Society, 2016; Castelli, Barcelona, & Bryant, 2015; Giblin, Collins, & Button, 2014; Lloyd et al., 2015).

However, until recently, there was no validated assessment protocol to evaluate children's progress in terms of physical literacy. In this context, the CAPL was developed and validated to address this need (Francis et al., 2016; Longmuir et al., 2015). The CAPL instrument provides an overall physical literacy score, for children between 8 and 12 years of age, by aggregating the scores obtained from the four main domains of physical literacy (physical competence, daily behaviour, motivation and confidence, and knowledge and understanding [see *Figure 1.1*]) (Francis et al., 2016; Longmuir et al., 2015).

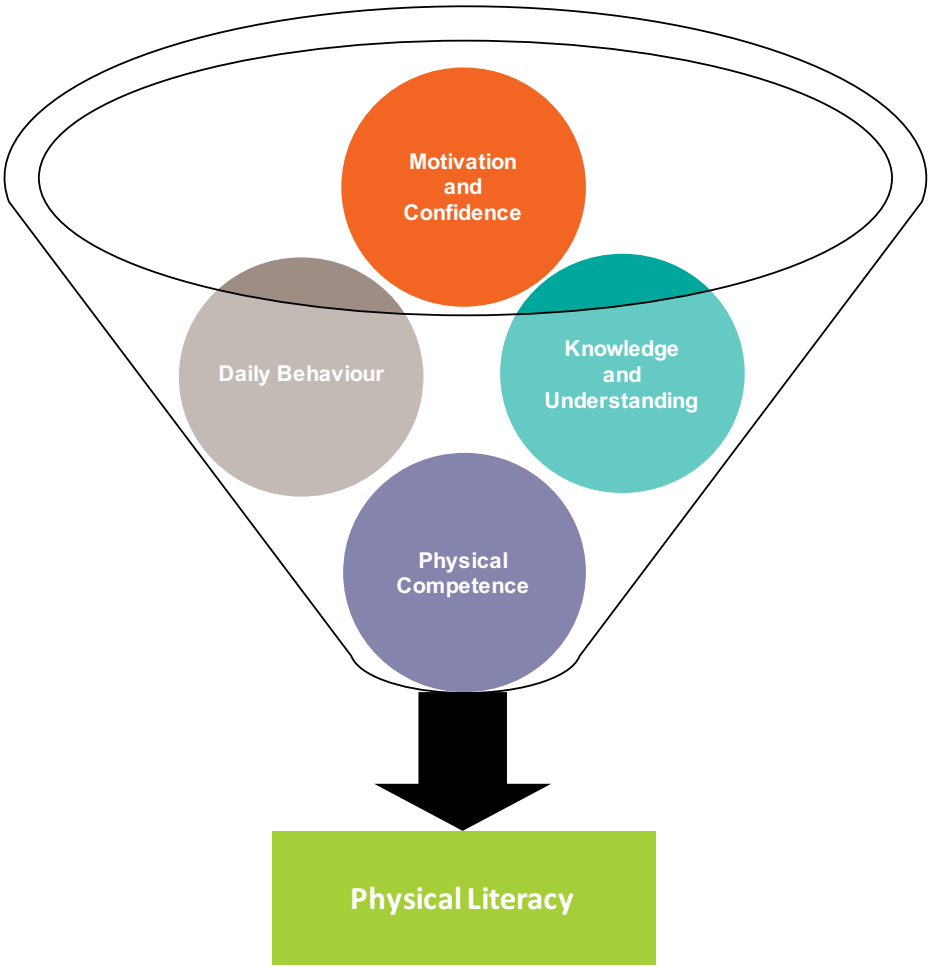

Figure 1.1. The four domains of physical literacy assessed by the Canadian Assessment of Physical Literacy (CAPL) in children (Francis et al., 2016; Longmuir et al., 2015). This figure has been adapted from the CAPL manual (Healthy Active Living and Obesity Research Group, 2013).

Physical literacy skills are being taught, acquired and practiced in schools and in organized sports. Thus, school and sports entry cut-off dates become important factors in children's acquisition of physical literacy skills, especially considering that cut-off dates are similar across many sports and education systems in many developed countries (Musch & Grondin, 2001). Also, the CAPL construct was partially informed by Canadian provincial/territorial school *curricula* and uses rounded-down age bands to compare and score children's physical literacy. Whenever

children are grouped by age and compared to one another, as it is done for the CAPL, it is reasonable to expect a RAE between children. Thus, the present study aimed to examine the patterns of association between month of birth (relative age) and physical literacy assessment scores (i.e., individual domain scores and the total CAPL scores) in children aged 8 to 12 years. We also examined the magnitude of the RAE for the different components within the physical competence domain (i.e., movement skills, aerobic capacity, strength, muscular endurance, flexibility, and body composition measurements). We hypothesized that children born earlier in the year (i.e., relatively older children) would score better on physical literacy components than those born later in the same calendar year.

Part 2: Literature Review

Physical Literacy

The mainstream understanding for the need of a more holistic approach to healthy behaviours may be central to the recent worldwide momentum gained by the concept of physical literacy. Many countries have incorporated physical literacy in their education curricula (Giblin et al., 2014). Physical literacy is an umbrella term that regroups several interconnected factors (i.e., affective, behavioural, physical and cognitive). The understanding of the term physical literacy may be relatively new in physical education but in the literature the term dates back to the late 1950s (McCloy, 1957a, 1957b). However, McCloy's work is not credited has being the seminal work for our current understanding of the umbrella concept that is physical literacy. Margaret Whitehead is the person credited with the popularization of the physical literacy concept. She developed the concept in the 1990s and introduced it in the first decade on the 21st century (Whitehead, 2001; Whitehead, 2007).

The desired outcome of physical literacy, i.e., lifelong engagement in physical activity, has been the focus of repositioning physical education for children as more inclusive and less competitive-based (Whitehead, 2010). Whitehead (2010) also underlines the intrinsic capability of each individual to develop their own physical literacy. When compared to sports, the concept of physical literacy is much less dichotomous (e.g., 'good' or 'bad'), but rather a journey that is attainable by all regardless of age or physical attributes (Whitehead, 2010). Whitehead's vision of physical literacy seems to be very much in line with the self-determination theory. The seminal work of Ryan and Deci (2000) described individuals as being "proactive and engaged" or "passive

and alienated" from their personal health and well-being as a function of social conditions in which they grow and operate. Through their research, they advanced that humans possess three innate psychological needs: competence, autonomy and relatedness; when these needs are met it results in an increased motivation and mental health (Ryan & Deci, 2000). The development of physical literacy thus aims to foster intrinsic motivation in individuals to remain active for life.

Physical literacy definitions

Numerous governmental and non-governmental institutions worldwide have adopted the physical literacy concept in their education systems. A possible explanation for the small nuances found in the definitions may be due to the different purposes the definitions were developed for. A recent overview of the available literature on physical literacy has categorised the work in 3 different themes: physical education of physical literacy, physical literacy for sport development, and assessment of physical literacy programs (Lundvall, 2015).

Physical Health Education Canada, in a position statement, defined physical literacy as (Mandigo, Francis, Lodewyk, & Lopez, 2009):

> Individuals who are physically literate move with competence in a wide variety of physical activities that benefit the development of the whole person. [They] consistently develop the motivation and ability to understand, communicate, apply, and analyze different forms of movement. They are able to demonstrate a variety of movements confidently, competently, creatively and strategically across a wide range of health-related physical activities. These skills enable individuals to make healthy, active choices throughout their life span that are both beneficial to and respectful of themselves, others, and their environment. (p. 6-7)

More recently, in 2015, a multi-agency (i.e., ParticipACTION, Canadian Sport for Life Society, the Healthy Active Living and Obesity Research Group at the Children's Hospital of Eastern Ontario, Physical Health and Education Canada, Canadian Parks and Recreation Association, and

Ontario Society of Physical Activity Promoters in Public Health) consensus statement was released in Canada to officially adopt one definition and clarify the characteristics that embody physical literacy (ParticipACTION et al., 2015). Canada joined many other countries in adopting the *International Physical Literacy Association's* definition that defines physical literacy as (ParticipACTION et al., 2015; Whitehead, 2014):

> "the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for the engagement in physical activities for life".

In 2014, the *Society of Health and Physical Educators* ® (SHAPE) America released the National Standards and Grade-Level Outcomes for K-12, which for the first time included the term physical literacy (Society of Health and Physical Educators, 2014). The 2014 document adopted a shorter version of the Mandingo and colleagues' (2009) definition, and SHAPE America defined physical literacy as (Society of Health and Physical Educators, 2014):

> "the ability to move with competence and confidence in a wide variety of physical activities in multiple environments that benefit the healthy development of the whole person".

SHAPE America positioned physical literacy as the goal of physical education in the United States. In doing so, they produced 5 specific goals for the physically literate individuals: (i) demonstrate competency in a variety of motor skills and movement patterns; (ii) apply knowledge of concepts, principles, strategies and tactics related to movement performance; (iii) demonstrate the knowledge and skills to achieve and maintain a health-enhancing level of physical activity and fitness; (iv) exhibit responsible personal and social behaviours that respects self and others; and (v) recognize the value of physical activity for health, enjoyment, challenge, self-expression and/or social interaction (Roetert & MacDonald, 2015; Society of Health and Physical Educators, 2014).

While these definitions differ slightly from one another, there is a level of consensus between them, namely the overarching goal of lifelong participation in physical activity (Corbin, 2016; Roetert & Jefferies, 2014). It should be noted that the Canadian multi-agency consensus definition may be more appropriate than positioning physical literacy as the goal of physical education since physical literacy may be developed in children in many different contexts and environments (e.g., sport, family, recreation). Canadian National, Provincial and Municipal Sporting Organizations have adopted the Canadian Sport for Life Long-Term Athlete Development Framework, which contains physical literacy in order to promote physical activity for life and it is also an approach aimed at increasing sport participation and development (Canadian Sport for Life Society, 2016; Higgs, 2010). While it is undeniable that physical education and the education system plays an important role in developing children's physical literacy, it is impossible to empirically assess which approach to physical literacy, SHAPE America or the Canadian multi-agency consensus, is more appropriate since very few have been able to measure and report on the children's progress towards their physical literacy journey (Tremblay & Lloyd, 2010).

Physical literacy assessments

The CAPL, created in 2009 by the Healthy Active Living and Obesity Research Group with support from numerous provincial and national agencies, is a comprehensive, validated and multifaceted assessment protocol that provides a thorough evaluation of children's physical literacy by assessing the four relevant domains of physical literacy (see *Figure 2.1* and Appendix B) (Francis et al., 2016; Longmuir et al., 2015). The CAPL is currently the only assessment tool that incorporates the full construct of physical literacy by combining multiple assessments within

each domain to give a comprehensive measurement of physical literacy. The CAPL protocol provides raw scores for each assessment protocol within a domain, as well as age and sex corrected overall domain scores. The domain scores are aggregated into an overall physical literacy score (Healthy Active Living and Obesity Research Group, 2013; Longmuir et al., 2015) (see Appendix B). The scoring protocol also allows for domain and total physical literacy scores to be interpreted on a progression scale, with the following four categories: "beginning", "progressing", "achieving", and "excelling" (Francis et al., 2016; Longmuir et al., 2015). Children who are "beginning" are more likely to require additional support to improve their physical literacy; children who are "progressing" are below the required level for healthy active living; children who are "achieving" are meeting the standard associated with the optimal health benefits of being active; and children who are "excelling" are above the recommended level for health benefits (Longmuir et al., 2015).

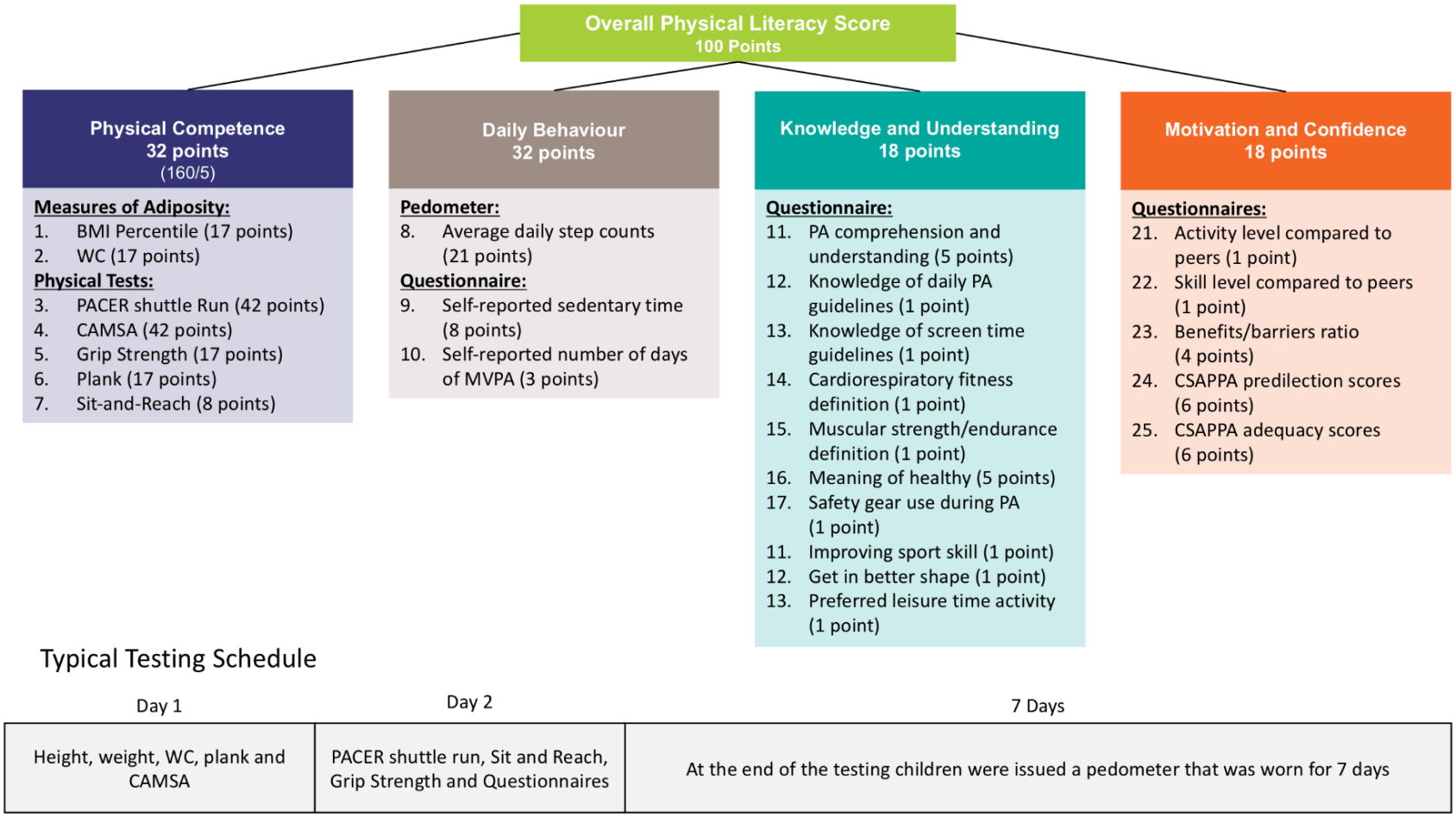

Figure 2.1. Canadian Assessment of Physical Literacy scoring system with the scoring weight for each assessment and typical testing schedule. Adapted from the CAPL Manual for Test Administration (Healthy Active Living and Obesity Research Group, 2013). Abbreviations: CAPL, Canadian Assessment of Physical Literacy; BMI, body mass index; WC, waist circumference; PACER, Progressive Aerobic Cardiovascular Endurance Run; CAMSA, Canadian Agility and Movement Skill Assessment; MVPA, moderate-to-vigorous physical activity; PA, physical activity; CSAPPA, Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity. *The "What is Most Like Me" (CSAPPA) questionnaire was developed by Dr. John Hay and is issued in the CAPL with his permission (Hay, 1992). This figure was submitted as *Additional Material 1* to *BMC Public Health* as part of the article shown in Part 4.

In Canada, three other tools exist for the assessment or monitoring of physical literacy, although their development and psychometric characteristics are not published in peer-review literature. One such assessment is the Physical Literacy Assessment for Youth (PLAY) tool. It assesses physical literacy among children aged 7 years through adulthood. The PLAY tool measures similar constructs as the CAPL (movement skills, confidence and comprehension), using either self- and proxy-reports or by a qualified staff measuring a child's performance of 18 tasks. However, the scoring system is highly subjective as the appraiser must judge the quality of movement, confidence and knowledge of the child executing the tasks. The appraiser rates their observations on a 100-mm scale where 0 to 25 mm corresponds to a rating of "initial", 26 to 50 mm is "emerging", 51 to 75 mm is "competent", and 76 to 100 mm is "proficient" (Canadian Sport for Life Society, 2013).

Another assessment is the Passport for Life, developed by Physical and Health Education Canada. Passport for Life is a formative assessment available to teachers and students in grades 3 to 12, soon to be available for kindergarten, grades 1 and 2. It assesses active participation, living skills, fitness skills and movements skills (Physical Health and Education Canada, 2013). The active participation is a questionnaire that was designed to provide insight on physical activity participation and environmental factors, and is said to detect student's future physical activity interests (Physical Health and Education Canada, 2013). The living skills section is also a self-reported reflection of the feelings, thoughts and interacting skills students need to make healthy active choices, that are both advantageous and deferential for oneself, others and the environment. Both the fitness and movement skills assessments are subjectively assessed by the teacher who measures students' performance across many tasks. Post assessment, children go through a goal setting exercise based on their results (called 'individual passport'), and results range into four

categories: “emerging”, “developing”, “acquired” and “accomplished” (Physical Health and Education Canada, 2013). Of note, the validity and the reliability of the Passport for Life assessments and tasks are untested.

The last physical literacy assessment is the Fundamental Movement Skills (FMS) assessment tool. This protocol was designed to engage and enable parents to assess their child’s (ages 5 to 12 years) motor competence not physical literacy (60 minutes Kids’ Club, 2015). The FMS protocol uses videos and images to facilitate the assessment of the 15 movement tasks, and the wording is consistent with the one used in the Passport for Life (i.e., ‘emerging’ to ‘accomplished’). The parent observes the child during the task and must choose which one of the 4 videos/pictures most accurately matches the child’s performance (60 minutes Kids’ Club, 2015). The videos offer progressions or suggestions to help the child improve their score (60 minutes Kids’ Club, 2015). This assessment is formative and can be used by anyone (60 minutes Kids’ Club, 2015). The FMS protocol was intended to be used in association with the 60 minutes Kids’ Club, an online tracker of physical activities and other daily behaviours.

These three assessment protocols are not as robust and comprehensive as the CAPL, as they do not assess all of the domains of physical literacy and mostly use subjective assessments that are not validated or reliable. Additionally, the results of studies using these other protocols would be difficult to compare with results of studies using the CAPL.

Relative Age Effect

The RAE is an area of research that has been explored by researchers from various fields (e.g., education, epidemiology and sport). Collectively, researchers have reported an association between age grouping by the imposition of an institutional cut-off date (e.g., December 31st),

common in education and sports, children's birth month and various developmental outcomes. This cohort grouping fosters an environment that provides developmental advantages for children born just after the cut-off date compared to the relatively younger children. The subtle differences in chronological age between children born in the same year (up to 12 months) is known as relative age and the consequences are known as the RAE (Musch & Grondin, 2001).

Wattie and colleagues (2008) have expressed the importance of being consistent with the terminology used when discussing the RAE bias. Often researchers have used seasons of birth bias or effect, birthdate effect and RAE bias interchangeably, which may lead to confusion and misapplication of the underlying framework (Wattie et al., 2008). While the latter two are used interchangeably, birthdate effect is often used in academic settings and RAE is mostly used in sports. They both utilize the same theoretical framework; the former, season of birth bias or effect, has its own separate area of research with a different theoretical framework that is underpinned by differences in children's prenatal, perinatal, postnatal seasonal and environmental factors (e.g., exposure to sunlight, temperature, pollution and viral diseases) and various health outcomes (Kynast-Wolf, Hammer, Müller, Kouyaté, & Becher, 2006; Martin, Foels, Clanton, & Moon, 2004; McGrath, Saha, Lieberman, & Buka, 2006; Wattie et al., 2008). Though this type of research is not without merit, it is not what is of interest here. Thus, using these terms interchangeably when discussing the RAE can be misleading. Therefore, the term RAE will be used for the present thesis when discussing the consequences associated with cohort grouping.

Initially, the RAE was observed in studies that were conducted in order to discover the determinants of academic success (Bisanz et al., 1995; Davis, Trimble, & Vincent, 1980; Diamond, 1983; Grondin, Proulx, & Zhou, 1993). These studies concluded that children born earlier in the year had greater chance of academic success compared to their younger peers, demonstrating an

association between institutional cut-off dates (relative age) and diverse academic outcomes (Bisanz et al., 1995; Davis et al., 1980; Grondin et al., 1993; Sharp, Hutchison, & Whetton, 1995). Studies also found that the RAE association persists throughout compulsory education, i.e., relatively younger children were found to be under-represented in higher ability groupings and were less likely to progress to higher education (Bell & Daniels, 1990; Lawlor, Clark, Ronalds, & Leon, 2006; McPhillips & Jordan-Black, 2009; Menet, Eakin, Stuart, & Rafferty, 2000; Sykes, Bell, & Rodeiro, 2009). Based on these studies, it would seem likely to observe an association between the CAPL's knowledge and understanding domain scores and the RAE. However, not observing a RAE in this domain in the older participants may not be surprising, considering this domain questionnaire is the same for all the participants. Thus, 12-year-old participants would be expected to answer these questions more easily than eight year olds; this should be true regardless of the relative age difference in the 12-year-old cohort.

While RAE research originally focused on associations in the school setting, it was soon applied to sports. In fact, the RAE is well established in numerous professional sports and representative youth sports, such as hockey, soccer, baseball, cricket, tennis, basketball and volleyball (Barnsley & Thompson, 1988; Cobley, Baker, Wattie, & Mckenna, 2009; Edgar & O'Donoghue, 2005; Musch & Grondin, 2001; Thompson, Barnsley, & Stebelsky, 1991). The RAE in sports has been hypothesized to be attributed to variations in children's growth and maturity within a cohort (Wattie et al., 2008). Since physical capabilities at an early age are an important determinant of success, a relative age difference has been associated with the following advantages: greater height, muscle mass, aerobic capacity, strength and speed which can lead to greater performance and success (Cobley et al., 2009; Musch & Grondin, 2001; Roberts et al., 2012; Sandercock et al., 2013). In sports where speed, strength and power are important

performance predictors, having a greater height and muscle mass (possibly due to a relative age difference) is certainly a marked advantage.

Another plausible assumption for the RAE based on growth and maturity differences relates to coaches perception of talent that is positively biased towards relatively older children who are displaying enhanced anthropometric measurements (Furley & Memmert, 2016; Wattie et al., 2008). However, the associations between RAE and anthropometric measurements have been inconsistent. Within the sport context, a number of studies have observed that relatively older children were significant taller than their younger peers (Carling, Le Gall, Reilly, & Williams, 2009; Gil et al., 2014; Hirose, 2009; Müller, Müller, & Rashner, 2016; Roczniok et al., 2013; Torres-Unda et al., 2013), while others observed no such associations (Deprez, Vaeyens, Coutts, Lenoir, & Philippaerts, 2012; Malina et al., 2005; Ulbricht, Fernandez-Fernandez, Mendez-Villanueva, & Ferrauti, 2015). Studies outside of a specific sport context examining the association between children's RAE and fitness assessments have also reported inconsistent results for anthropometric measurements. In the school setting, Sandercock and colleagues (2013) studied the association between relative age and aerobic capacity, muscular strength and power assessments, but found no association between the RAE and anthropometric measurements of children, whereas in another study in a similar context both children's height and weight were associated with the RAE (Roberts et al., 2012).

More recently, RAE studies have emerged for fitness, developmental and motor skills assessments. Even though these types of assessments are not grouping children based on a cut-off date, normative data that implicitly regroup children using rounded-down age bands that usually span a full year are generally used. Roberts and colleagues (2012) investigated the association between relative age and aerobic capacity in children ages 10 to 12 years old. Among both boys

and girls, a RAE was observed for aerobic capacity scores, after controlling for maturity, adiposity, and year of testing. In a study that focused on quantifying the RAE in three dimensions of physical performance (i.e., aerobic capacity, muscular strength and power) in a large sample of boys and girls ages 10 to 16 years, girls' overall assessments scores did not appear to be significantly affected by a RAE (Sandercock et al., 2013). In this study, the RAE in girls was only present in the muscular strength test where girls born in the first quarter of the year were stronger than those born in the last quarter of the year, after controlling for age, month of testing, family income, testing schools and height *z*-score. In contrast, boys born in the first quarter outperformed boys born in all the other quarters of the year in all of the measurements, after controlling for the same covariates (Sandercock et al., 2013). Another study conducted in the school setting investigated RAE in FMS assessments, such as measurements of balance, catching, sliding sideways, sprinting and throwing (Birch et al., 2016). The FMS tasks related to object control were associated with the RAE among both sexes, after controlling for decimal age, sex and adiposity (Birch et al., 2016). In these three studies, the relative age comparison was conducted by assigning children to quarters based on United Kingdom's school entry cut-off date of August 31st and children's birth month (Birch et al., 2016; Roberts et al., 2012; Sandercock et al., 2013).

Veldhuizen and colleagues (2015; 2017) demonstrated a different approach to observe the RAE in aerobic capacity and in a developmental deficiency assessment (Movement Assessment Battery for Children-2 [MABC-2]). Instead of using the more conventional approach for studying the RAE by comparing fitness outcome by cohort grouping (either based on a school entry or sport cut-off date), their studies used decimal age to compare the RAE within a normative data (rounded-down age bands). For the study observing the RAE in boys' aerobic capacity, the authors found no RAE association for the aerobic capacity assessment among boys between 9 and 14 years of

age (Veldhuizen et al., 2015). Whereas for the MABC-2 assessment study, they observed that the very youngest children were approximately seven times more likely than the oldest children, in the same chronological rounded-down age band, to be below the fifth percentile threshold for movement deficiencies (Veldhuizen et al., 2017). Although these two studies yielded different findings, they may be related to the normative data used to classify the tests scoring. While the normative data for the aerobic capacity test may be fairly robust, the rounded-down age bands for the MABC-2 may be too wide to accurately capture developmental deficiency in children, thus disadvantaging the youngest children within the age band. These two studies may be misclassified as RAE studies, since they clearly investigated an age effect and not the RAE as defined by Wattie and colleagues (2008).

Aside from the last two age effect studies (Veldhuizen et al., 2017; Veldhuizen et al., 2015), the first three RAE studies on fitness and FMS assessments (Birch et al., 2016; Roberts et al., 2012; Sandercock et al., 2013) suggest that the RAE in fitness and motor skill assessments goes beyond decimal age of children, since these RAE findings were associated with children's birth month in relation to a school entry cut-off date. This is of interest because the development of the CAPL was partially informed by provincial/territorial schools *curricula*. Furthermore, physical education in Canada, along with National, Provincial and Municipal Sport Organizations, have embraced the physical literacy concept, thus it is probable that children's acquisition of physical literacy is influenced by schooling (i.e., number of years of school completed) and sports cohort. Additionally, when considering that cut-off dates are similar across many sports and education systems in many developed countries (Musch & Grondin, 2001), the choice of stratifying children based on school entry cut-off date for the present observation of the RAE would make the most sense.

Based on the literature, even if it is somewhat limited, sex appears to be an important factor in the relationship between fitness and movement skills assessments and with the RAE concept. This is likely attributable to the large variability in physiological growth in youth based on sex differences in the attainment of puberty and peak height velocity (i.e., the period when maximum growth rate occurs). Peak height velocity accounts for approximately 17% of the final height of a child and occurs, on average, at age 11 and 13 in girls and boys, respectively (Abbassi, 1998; Thissen, Bock, & Wainer, 1976). The assessments in the physical competence domain of CAPL compare many of the obtained test scores to sex- and age-specific normative data. Yet, normative data for age in physical tests are based on a full calendar year and, therefore, a RAE is likely to be observed in the CAPL test scores for this domain.

Larouche et al. (2010) found no association between the RAE and physical activity participation in adults. No studies to date have investigated the RAE in daily physical activities or movement behaviours in children. However, a study published by Pierson, Addona and Yates (2014) modeled the RAE as a positive feedback loop where a relatively older child with an initially small chronological advantage has an enhanced and lasting advantage by receiving extra training, playing opportunities and coaches' attention. This positive feedback loop effect is possibly one reason behind the increased dropout rates in sports for children who are born later in the year. Therefore, the possibility of observing a RAE in physical literacy assessment is important when considering that relatively younger children may be consistently disadvantaged in physical education classes and in many sports. This in turn could affect their daily behaviour, as healthy behaviours at a young age are predictive of healthy behaviours later on in life (Chaput et al., 2014; Hjorth et al., 2014; LeBlanc et al., 2015). While we might expect relatively older children to outperform relatively younger children in the daily behaviour domain, the evidence for this is

indirect at best and mostly based on the previously reported possible causal link hypothesis of the RAE (Musch & Grondin, 2001; Roberts et al., 2012).

The RAE literature has reported an association between the relatively younger children and diagnosis rates of attention-deficit/hyperactivity disorder (ADHD) (Morrow et al., 2012). This study was conducted in British Columbia on a large sample (n= 937,943) of children between the ages of 6 and 12 years old. They concluded that 41% of boys and 77% of girls who were born later in the year (last 3 months of the year) were more likely to be diagnosed with ADHD (Morrow et al., 2012). Previous studies have reported that relatively younger children are more likely to display learning disabilities and low self-esteem (Diamond, 1983; Thompson, Barnsley, & Battle, 2004). A more recent study by Patalay and colleagues (2015) investigated the extent of the RAE on mental health and functioning, using the Strength and Difficulties Questionnaire (Goodman, Meltzer, & Bailey, 1998), in early teenagers 11-13 years of age. While the authors observed a RAE in all children, the magnitude was greatest in the younger children (11-12 years), indicating that RAE might be attenuated with age (Patalay et al., 2015). Moreover, relatively younger children were associated with increased risk of internalizing symptoms, poorer peer relationships and higher risk of mental health difficulties both at home and in school. Although there are very few RAE studies in the affective domain and the evidence is again indirect, the association between the motivation and confidence domain score and the RAE is an important one to explore. Also, while the ADHD study did report sex differences their findings, the other two studies did not.

A study conducted in the United Kingdom looked at the influence of the RAE on physical education assessment in high-school students and showed significant interactions between birth month and end-of-the-year physical education grades for students 11-14 years of age (Roberts & Fairclough, 2012). The study showed that boys and girls who were born earlier in the year attained

significantly better end-of-the-year physical education grades than their peers who were born later in the year (Roberts & Fairclough, 2012).

In summary, based on this literature review, the CAPL offers a unique opportunity to assess the RAE in a large sample of Canadian children aged 8 to 12 years. As evidenced by the previously mentioned studies, birth month is associated with achievement in many sports, academia, fitness assessments and even mental health outcomes. While there are many published studies on the topic of the RAE, this was the first study to investigate the possibility of a RAE in the context of physical literacy assessment, that takes into account affective, cognitive, behavioral and physical factors.

Thesis Objective

The main objective of this thesis was to examine, in a large sample of Canadian boys and girls aged 8 to 12 years, the association between relative age (in quarters based on school entry cut-off date and birth month [see *Table2.1*]), and physical literacy scores obtained using the CAPL. More specifically, this study investigated the possibility of a RAE bias in the CAPL scoring by addressing the following objectives:

1. To evaluate the association between relative age in quarters and the scores obtained in the four domains of physical literacy (i.e., daily behaviour, motivation and confidence, knowledge and understanding, and physical competence) as well as overall physical literacy (i.e., total CAPL score).
2. To investigate which components of the physical competence domain are most susceptible to the RAE bias.

3. To determine whether the RAE affects both sexes and all the tested ages (8 to 12 years old) similarly.

Table 2.1. Method of stratifying children by quarters based on their month of birth and the two school entry cut-off dates.

	Quarter			
	1	**2**	**3**	**4**
October 1st	Oct., Nov. and Dec.	Jan., Feb. and Mar	Apr., May and Jun.	Jul., Aug. and Sep.
December 31st	Jan., Feb. and Mar.	Apr., May and Jun.	Jul., Aug. and Sep.	Oct., Nov. and Dec.

October 1st represents Québec's school entry cut-off date and December 31st is the school entry cut-off date for Alberta, British Columbia, Manitoba, Ontario, Nova Scotia and Prince Edward Island.

Research Hypotheses

Based on available evidence on the topic, we hypothesize that:

1. On average, relatively younger children (i.e., those born the furthest away from the cut-off date) will score lower on the individual domains of CAPL and overall compared to their relatively older peers (i.e., those born closest to the cut-off date) (Birch et al., 2016; Cobley et al., 2009; Musch & Grondin, 2001; Roberts & Fairclough, 2012; Sandercock et al., 2013; Sykes et al., 2009; Thompson et al., 2004).
2. On the physical competence domain components, we expect that the magnitude of the RAE bias will vary based on the component being measured and the magnitude should be greater for muscular strength, aerobic capacity, muscular endurance, movement skills assessments and anthropometric measurements (Birch et al., 2016; Roberts et al., 2012; Sandercock et al., 2013).
3. Greater RAE will be observed in younger children (8 and 9 years old) compared with the RAE in older children (11 and 12 years old), and boys' scores in each domain and overall will be more susceptible to the RAE than girls' scores (Cobley et al., 2009).

Part 3: Methods

Figure 3.1. The 11 data collections sites for the CAPL–RBC Learn to Play Project: Victoria, British Columbia; Lethbridge, Alberta; Calgary, Alberta; Winnipeg, Manitoba; North Bay, Ontario; Windsor, Ontario; Ottawa, Ontario; Trois-Rivières, Québec; Halifax, Nova Scotia; Antigonish, Nova Scotia; and Charlottetown, Prince Edward Island.

The methods for the present study were previously validated and published (Francis et al., 2016; Longmuir et al., 2015), and a description can also be found in Part 4 (pages 29 to 36). Furthermore, the CAPL is also available online (www.capl-eclp.ca), and includes a detailed manual, training videos and other relevant information that can be accessed or downloaded, in either English or French, for free (Healthy Active Living and Obesity Research Group, 2013).

Part 4: Article

Influence of the relative age effect on children's scores obtained from the Canadian Assessment of Physical Literacy

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Influence of the relative age effect on children's scores obtained from the Canadian Assessment of Physical Literacy

Short title: Relative age effect bias and physical literacy in children

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Word count: 5,060

Abstract

Background: Acquiring an adequate level of physical literacy is important for children to remain active for life. The Canadian Assessment of Physical Literacy (CAPL) is an assessment protocol that encompasses measures of children's daily behaviours, physical competence, motivation and confidence, and knowledge and understanding. However, no studies to date have examined the relative age effect (RAE) bias in the context of physical literacy, a health indicator that simultaneously takes into account affective, cognitive, behavioural and physical domains.

Methods: The objective of this cross-sectional study was to determine whether the scores obtained in the CAPL (i.e., the four domains individually and the total CAPL score) were susceptible to the RAE bias and to examine which physical competence assessments (aerobic capacity, muscular strength, muscular endurance, flexibility or movement skills) were more susceptible to the RAE bias in children ages 8 to 12 years. Participants (n=8,233, 49.8% boys) from the RBC-CAPL Learn to Play project from seven Canadian provinces were tested using the CAPL protocol.

Results: Among boys and girls, the RAE was significantly associated with 2 and 3 out of the 4 domains scores, respectively, after controlling for covariates. However, effect sizes were negligible for the comparisons between quarters of the year and physical literacy domains and overall scores. For the main effect of the relative age, boys and girls born in the first three months of the year were taller ($F(3, 4074) = 57.0$, $p<0.001$, $f^2 = 0.04$ and $F(3, 4107) = 58.4$, $p< 0.001$, $f^2 = 0.04$, respectively) and demonstrated greater muscular strength ($F(3, 4037) = 29.2$, $p<0.001$, $f^2 = 0.02$ and $F(3,4077) = 25.1$, $p<0.001$, $f^2 = 0.02$, respectively) compared with those born later in the same year. Boys born earlier in the year were also found to be heavier than their relatively younger peers ($F(3, 4069) = 20.6$, $p<0.001$, $f^2 = 0.02$).

Conclusion: Collectively, our results suggest that the RAE bias is mainly negligible on the domains and overall CAPL scores in this large sample of children, which should not affect the validity of the CAPL in accurately measuring physical literacy.

Background

Physical literacy is a concept that has gained momentum globally and is defined by the *International Physical Literacy Association* as "the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activity for life" [1]. The goal of physical literacy (i.e., lifelong engagement in physical activity) is an attractive idea, especially when considering how critical physical activity is for children's health and well-being [2]. Many countries have adopted and included the physical literacy construct in their education system and sports governing bodies have also followed suit in their Long-Term Athlete Development programs [3-5]. In response to the need to assess physical literacy in children, the Canadian Assessment of Physical Literacy (CAPL) was recently developed and validated [6,7]. The CAPL is a comprehensive measurement tool that assesses four relevant domains of physical literacy (physical competence, daily behaviour, motivation and confidence, and knowledge and understanding), and provides an overall physical literacy score for 8 to 12 year-old children [6,7].

In sports and education systems, children are commonly grouped by age, as an administrative strategy, in order to provide age-adjusted competition and learning opportunities. However, age grouping by the imposition of a cut-off date promotes a relative age difference that often leads to developmental advantages for children who are born on the "early side" of the cut-off date. These differences are known as the relative age effect (RAE) bias [8-11]. Indeed, those who are disadvantaged by the RAE are underrepresented at the elite and professional level in many sports [10], are at greater risk of having inferior grades in school [12-15], demonstrate lower levels of self-efficacy [16], display poorer mental health coping mechanisms [17], are at increased risk

of needing special education support [18], and are at greater risk of being diagnosed with attention deficit hyperactivity disorder [19].

Studies on the RAE have also expanded to fitness, motor and developmental skills testing where children are compared to normative data that usually span a full year, or regroups a few years together. It is no surprise that an association between these types of fitness, developmental and motor skill assessments and the RAE have been found since this form of age grouping is analogous to the age grouping seen in sports and education systems [11, 20-22]. However, no study to date has examined the RAE in the context of physical literacy, a construct that simultaneously takes into account affective, cognitive, behavioural and physical measurements. The present study was conducted to address this knowledge gap, and to assess the magnitude of the RAE using a comprehensive physical literacy assessment protocol.

As it is customary with fitness and developmental assessments, the CAPL is scored by separating children into rounded-down age bands that span a minimum of a full year. Furthermore, if education systems and sports governing bodies are delivering physical literacy programs, school entry and sports cut-off dates become important factors in children's acquisition of physical literacy skills, especially considering that cut-off dates are similar across many sports and education systems in many developed countries [10].

Thus, the present study aimed to examine the patterns of association between month of birth (relative age) and physical literacy assessment scores (i.e., individual domain scores and the total CAPL scores) in children aged 8 to 12 years. We also examined the magnitude of the RAE in the different components within the physical competence domain (i.e., movement skills, aerobic capacity, strength, muscular endurance, flexibility, and body composition measurements). We

hypothesized that children born earlier in the year would score higher on physical literacy components than those born later in the same calendar year.

Methods

Participants

The CAPL RBC Learn to Play project was a cross-sectional study comprising a large number of Canadian children between 8 and 12 years of age. The aim was to recruit 12,500 children total from 11 Canadian sites: Victoria, British Columbia; Lethbridge, Alberta; Calgary, Alberta; Winnipeg, Manitoba; North Bay, Ontario; Windsor, Ontario; Ottawa, Ontario; Trois-Rivières, Québec; Halifax, Nova Scotia; Antigonish, Nova Scotia; and Charlottetown, Prince Edward Island. Although this was a convenience sample, testing sites were instructed to recruit from urban, suburban and rural areas in and around their region, while insuring a balanced representation of high, medium and low income communities. Participants were tested between February 2014 and February 2017. A parent (or legal guardian) provided written consent for participation in the study and completed a screening form indicating that their child had no known limitations for physical activity, including maximal effort exercise. Children gave assent to partake in this assessment, and the Ethical Review Boards at each participating institution also approved the protocol.

Study Protocol

Physical literacy was assessed using the CAPL protocol. Longmuir and colleagues [7] have published a detailed explanation of the CAPL protocol, including its validity. The CAPL is also available online (www.capl-eclp.ca), and includes a detailed manual, training videos and other

relevant information that can be accessed or downloaded, in either English or French, for free [23]. The CAPL instrument measures are consistent with the current definition of physical literacy by the *International Physical Literacy Association* and assesses the 4 domains of physical literacy individually (physical competence, daily behaviour, knowledge and understanding, and motivation and confidence), and provides an overall composite physical literacy score (i.e., total CAPL score) [6,7]. A Delphi expert panel process was used to inform the CAPL scoring system where the total CAPL score (maximum of 100 points) is a composite sum of the scores obtained in the 4 domains, where both the physical competence (32 points) and the daily behaviour (32 points) domains are more heavily weighted than the knowledge and understanding (18 points) and the motivation and confidence (18 points) domains (see Supplementary Material 1) [6,7]. A short explanation of each domain is provided below.

Physical Competence Domain

The aim of the physical competence domain is to test children's physical fitness, movement skills, and physical core competencies to partake in physical activities. The score for this domain is composed of objective measurements of body composition (body mass index [BMI] *z*-score [see Appendix C] [24] and waist circumference [WC] [25]), aerobic capacity (Progressive Aerobic Cardiovascular Endurance Run [PACER] shuttle run [26]), muscular strength (grip strength [25]), muscular endurance (timed plank test [27]), flexibility (sit-and-reach [25]), and movement skills performance (Canadian Agility and Movement Skill Assessment [CAMSA] see *Figure 4.1* [28]).

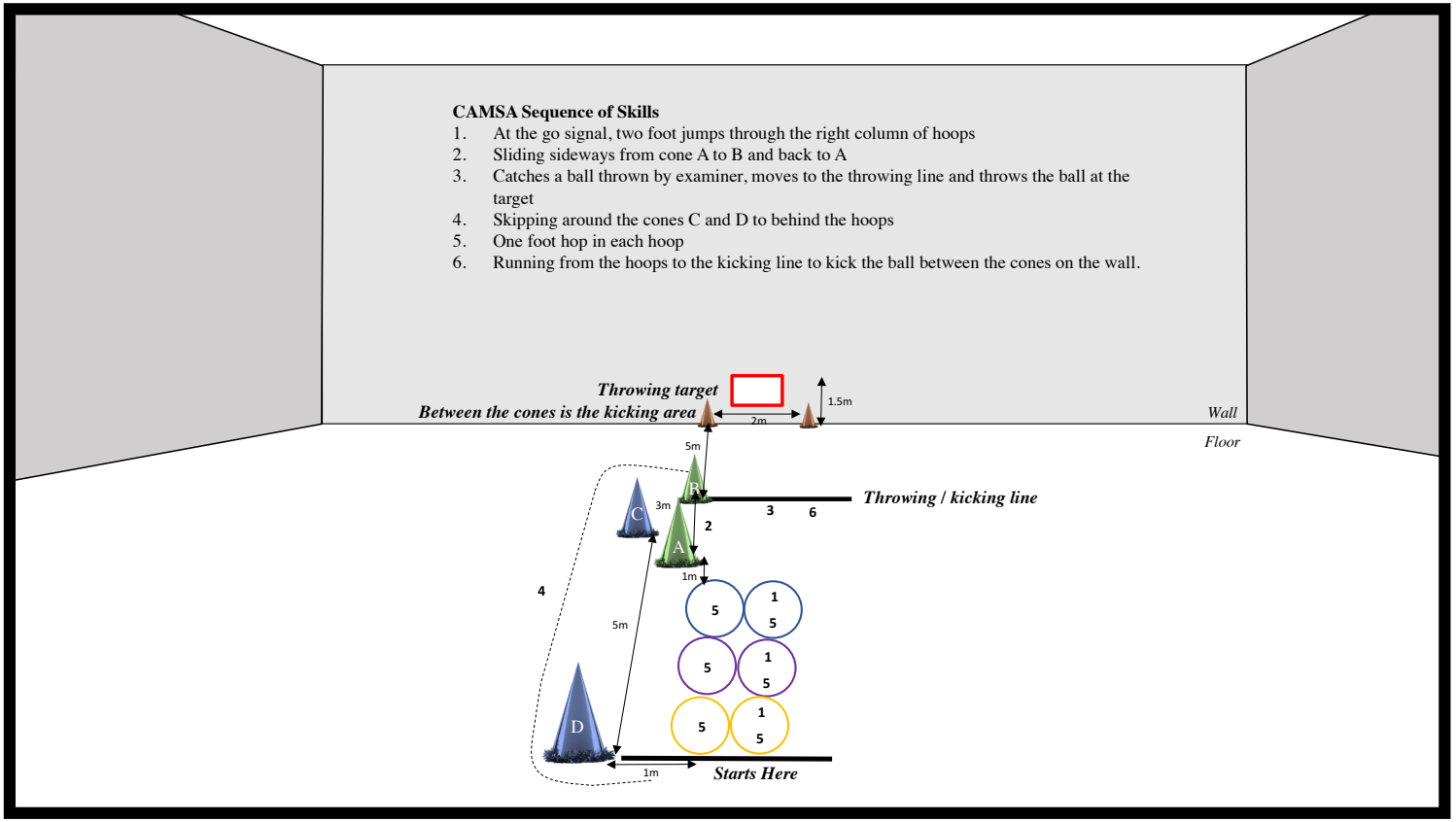

Figure 4.1. Three-dimensional rendering of the Canadian Agility and Movement Skill Assessment with the list of actions required to be performed by the participants. This rendering was adapted from the CAPL Manual and is not to scale but contains the proper measurements [23]. For this assessment, the participants were evaluated on accuracy of the skills performed and time to complete the assessment. Both time and accuracy are equally important in this assessment in order to reach maximum points. Verbal cues are provided to the participants during the assessment. Two timed/scored trials are needed for the final score, and these are corrected for the age of the participant. Equipment needed: 6 hoops (0.63 m in diameter); 6 cones (of equal size); 1 cardboard target (61 cm in width and 46 cm in height); gym floor tape; 1 soccer ball; and 1 Squelet ball or a soft ball (70 mm in diameter). This figure was submitted as *Additional Material 2.*

Daily Behaviour Domain

The daily behaviour domain contains three components, including average daily step counts measured via pedometer worn for seven consecutive days (see Appendix D), self-reported sedentary time and self-reported moderate-to-vigorous physical activity. Pedometer data criteria were established as follows: (i) step counts must be between 1,000 and 30,000 steps daily [29]; (ii) minimum wear time of 10 hours daily [30]; and (iii) at least three days of valid data that meet both aforementioned criteria [31]. The two other components were subjectively assessed via questionnaire, where children were asked to recall how many days in the past week they engaged in 60 minutes or more of moderate-to-vigorous physical activity, and to self-report their daily screen time habits.

Knowledge and Understanding Domain

The knowledge and understanding domain was assessed using a questionnaire (see Appendix E) that was designed to test aspects of healthy behaviour and the knowledge level that is expected based on Canadian physical and health education *curricula* (for grades 4, 5 and 6) across all provinces/territories [6]. The questions evaluate children's knowledge and understanding of the Canadian Physical Activity and Sedentary Behaviour guidelines for Children and Youth (www.csep.ca), related terms, definition of health, recommended safety equipment to partake in certain physical activities and sports, and understanding of movement skills [6,7].

Motivation and Confidence Domain

The motivation and confidence domain was assessed via questionnaire (see Appendix F),

and evaluated children's perceived benefits and barriers for physical activity, self-perceived activity and skill levels compared to peers, and their adequacy in and predilection for physical activity [6,7]. The questions on physical activity barriers and benefits were based on the published scales developed by Garcia and colleagues [32]. Two thirds of this domain score were attributed to children's responses to the adequacy and predilection subscales of the Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) questionnaire [33].

Analytic Sample

Figure 1 presents the sample size from the recruitment goal to the different samples sizes used in our analyses. A little over 11,000 online accounts were created for the CAPL RBC Learn to Play project, of which those outside the CAPL validated age group and the accounts missing key information were excluded. Any participants with raw scores less than quartile 1- (1.5 x the interquartile range) or greater than quartile 3 + (1.5 x the interquartile range) were deemed outliers and removed from the dataset. Age- and sex-specific *z*-scores were created and participants outside ± 5 *z*-scores were also deemed outliers and removed. Participants were also excluded from the analyses if they (or a parent) reported a medical condition or disability that would likely influence the CAPL assessment scores (n=36) (e.g., broken limb in a cast, Down syndrome, autism, and those who reported acute injury on the day of testing). For the purpose of the present paper, those with birth month missing were ineligible and removed (n=3). For all the analyses, those with incomplete scores for the dependent variable of interest were excluded. For the domain scores, it is however possible to calculate a domain score if one assessment is missing from the domain; those participants remained in the analytic samples [6,7]. Descriptive characteristics of children who were excluded did not differ from those who were included in the present analyses.

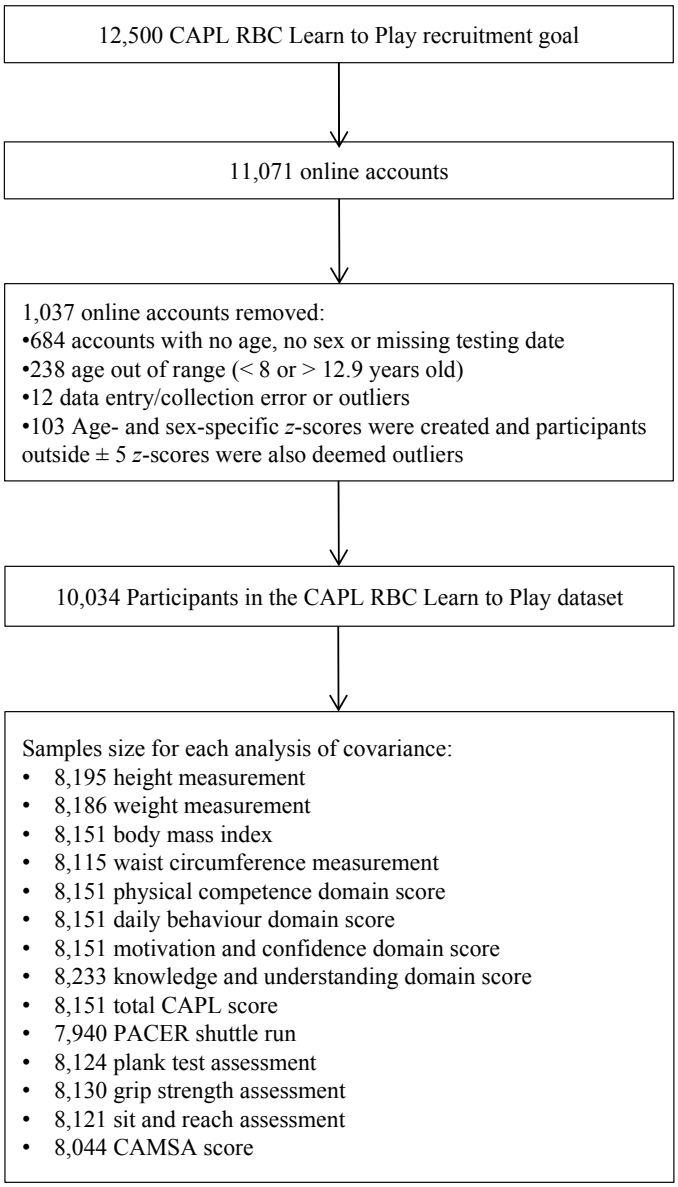

Figure 4.2. Flow diagram showing the sample sizes from initial recruitment goal to the number of participants used in these analyses. This figure was submitted as *Figure 1*.
Abbreviations: CAPL, Canadian Assessment of Physical Literacy; RBC, Royal Bank of Canada; PACER, Progressive Aerobic Cardiovascular Endurance Run; CAMSA, Canadian Agility and Movement Skill Assessment

Statistical Analysis

In the present study, the independent variable was the relative age of the children based on month of birth and school entry cut-off date. The dependent variables were the scores obtained in each individual domain of CAPL as well as the overall CAPL score. Since the physical competence domain assesses many different components that may be unequally affected by the RAE, these dependent variables were also assessed individually. Covariates used for this study included age (in whole year), the testing month, the testing sites (geographic location based on the specific testing site), and children's BMI *z*-scores (when relevant to the dependent variable). In order to examine the associations between the RAE bias and the scores obtained on physical literacy, children were stratified into quarters of the year based on their birth month and the annual school entry cut-off date of December 31st (i.e., children born in January, February and March were assigned to quarter 1; children born in April, May and June were assigned to quarter 2, etc.). All sites shared a common school entry cut-off date except for one, the Trois-Rivières site. The province of Québec school entry cut-off date is October 1st; therefore, we adjusted the quarter grouping for those participants (n=42) accordingly for all analyses of covariance (ANCOVA) (i.e., children born in October, November and December were assigned to quarter 1; children born in January, February and March were assigned to quarter 2, etc.). Data were tested for assumptions of normality, linearity and homogeneity of variance. As a result, no transformations were necessary. As expected, our sample displayed an interaction effect for sex in the relationship between relative age and performance in CAPL assessments; boys and girls were therefore analyzed separately. However, no interaction was found for age (in whole years) for the same relationship; thus, all ages were analyzed together. We performed ANCOVAs, controlling for the above mentioned covariates, with a Bonferroni post-hoc test to identify individual differences in

mean scores per quarters. An alpha level of 0.05 was set to establish statistical significance. Finally, to assess the practical or clinical significance of our findings, we calculated Cohen's f^2 [34] from the partial η^2 to interpret the effect sizes for our main effect (relative age in quarters). We interpreted the effect sizes according to Cohen's guidelines [34], i.e., $f^2 \geq 0.02$, $f^2 \geq 0.15$ and $f^2 \geq 0.35$ representing small, medium and large effect sizes, respectively. All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA).

Results

Tables 1 and 2 show the descriptive characteristics of our participants (49.8% boys). Birth months divided into quarters were not distributed evenly; almost 30% of the sample was born in the months of July, August and September. However, our sample was representative of the Canadian birth distribution [35] according to a Chi-square goodness of fit test.

Table 4.1. Descriptive characteristics overall and by sex for children 8 to 12 years of age who participated in the Canadian Assessment of Physical Literacy RBC Learn to Play study.

	All		Boys		Girls	
	n	Mean (SD) or %	n	Mean (SD) or %	n	Mean (SD) or %
Age (y)	8,233	10.6 (1.2)	4,100	10.6 (1.2)	4133	10.6 (1.2)
Height (cm)	8,195	144.1 (9.8)	4,081	144.0 (9.6)	4,114	144.3 (10.1)
Weight (kg)	8,186	40.0 (11.5)	4,076	40.0 (11.5)	4,110	40.1 (11.4)
BMI (kg/m^2)	8,151	19.0 (3.8)	4,059	18.9 (3.854)	4,092	19.0 (3.727)
WC (cm)	8,115	67.3 (10.8)	4,039	67.4 (11.0)	4,076	67.1 (10.5)
Sites (Province):	8,233	100.0	4,100	100.0	4,133	100.0
Antigonish (NS)	840	10.2	410	10.0	430	10.4
Calgary (AB)	1,126	13.7	564	13.8	562	13.6
Charlottetown (PEI)	456	5.5	230	5.6	226	5.5
Halifax (NS)	648	7.9	321	7.8	327	7.9
Lethbridge (AB)	900	10.9	444	10.8	456	11.0
North Bay (ON)	966	11.7	457	11.1	509	12.3
Ottawa (ON)	619	7.5	292	7.1	327	7.9
Trois-Rivières (QC)	42	0.5	27	0.7	15	0.4
Victoria (BC)	425	5.2	225	5.5	200	4.8
Windsor (ON)	1,108	13.5	578	14.1	530	12.8
Winnipeg (MB)	1,103	13.4	552	13.5	551	13.3

Abbreviations: SD, standard deviation; BMI, body mass index; WC, waist circumference; NS, Nova Scotia; AB, Alberta; PEI, Prince Edward Island; ON, Ontario; QC, Quebec; BC, British Columbia; MB, Manitoba.

Table 4.2. Number of participants in each quarter compared with the average monthly Canadian live birth data between 2002 and 2008.

Birth Months	N	Sample (%)	Canadian Births (%)
Quarter 1	1980	24.0	23.8
Quarter 2	2097	25.5	25.5
Quarter 3	2345	28.5	26.4
Quarter 4	1811	22.0	24.3
		$\chi^2 = 0.39$; df = 3; p=0.94	

A Chi-square goodness of fit test was performed to compare our samples' birth month (in quarters) to the average Canadian births by months. The Canadian births are the averages of the percentages of Canadian live births per month between the years 2002 and 2008 [35] Quarter 1, January-March; Quarter 2, April-June; Quarter 3, July-September; Quarter 4, October-December

The *F*-test values presented in this section represent the main effect of the relative age in quarters or the covariates' contribution to the model, while the ones shown in Tables 3 and 4 are the corrected model *F*-test values. In Table 3, height of boys and girls was significantly associated with the relative age ($F(3, 4074) = 57.0$, $p<0.001$ and $F(3, 4107) = 58.4$, $p< 0.001$, respectively). Cohen's f^2 effect sizes were considered small for both boys and girls. Moreover, girls' height findings revealed a dose-response association with the RAE (quarter 1 > quarter 2 > quarter 3 > quarter 4). Girls born in quarter 4 (i.e., born between October to December) were significantly shorter than girls born in all other quarters. There was no significant difference in height between boys born in the last six months of the year (quarters 3 and 4). Similarly, weight was associated with the relative age differences ($F(3, 4069) = 20.6$, $p<0.001$ and $F(3, 4103) = 12.7$, $p< 0.0001$, in boys and girls, respectively). The effect sizes for weight were small ($f^2= 0.02$) and negligible ($f^2 = 0.01$) in boys and girls, respectively. BMI was significantly associated with the relative age in boys only ($F(3, 4052) = 5.4$, p=0.001 and $F(3,4085) = 0.9$, p=0.45 in boys and girls, respectively), but the effect size was considered negligible. Among boys and girls, the main effect of relative age was associated with the WC measurement ($F(3, 4032) = 8.7$, $p<0.001$ and $F(3,$

4069) = 3.1, p=0.03, respectively), but the effect sizes for these associations were also negligible. The covariate age was the largest contributor in the model for height, weight, BMI and WC for both sexes (data not shown).

The results for the physical competence domain revealed a significant main effect of quarter in both boys and girls ($F(3, 4051) = 11.8$, $p<0.0001$ and $F(3, 4084) = 15.7$, $p<0.0001$, respectively) but yielded negligible effect sizes in both boys and girls for the main effect of quarter. However, the covariate BMI z-score in the physical competence domain score model resulted in large effect sizes in both sexes ($f^2 = 0.44$ and $f^2 = 0.40$ in boys and girls, respectively). No RAE was observed for the daily behaviour domain scores ($F(3, 4051) = 1.4$, p=0.26 and $F(3, 4084) = 1.1$, p= 0.34 in boys and girls, respectively). Interestingly, the largest contributor in the model in boys for this domain score was the covariate BMI z-score ($F(1, 4051) = 51.4$, $p<0.001$) while in girls it was the covariate age ($F(1, 4084) = 1.1$, p= 0.34). In terms of effect sizes, the BMI z-score covariate in boys was negligible ($f^2 = 0.01$) but in the girls' model the covariate age produced a small effect size ($f^2 = 0.02$). Girls' motivation and confidence domain scores were significantly associated with the relative age ($F(3, 4084) = 2.9$, p =0.04), but the association's effect size was negligible. Among boys and girls, the knowledge and understanding domain scores were also significantly associated with relative age ($F(3, 4093) = 9.8$, $p<0.0001$ and $F(3, 4126) = 5.2$, p=0.001, respectively). Again, these main effect associations produced negligible effect sizes, while the covariate age in the association between relative age and the knowledge and understanding domain scores generated small effect sizes ($f^2 = 0.10$ and $f^2 = 0.09$ in boys and girls, respectively). Among both sexes, there was a significant main effect of birth month, in quarters, on the overall CAPL scores ($F(3, 4051) = 2.7$, p=0.04 and $F(3, 4084) = 5.8$, p=0.001 in boys and girls, respectively). The effect sizes for the associations between the overall CAPL scores and the

relative age were negligible. The covariate BMI *z*-score was the largest contributor in the model, even larger than the age covariate, for the overall CAPL scores in both boys and girls ($F(1, 4051) = 383.1$, $p<0.0001$, $f^2 = 0.09$ and $F(1, 4084) = 324.7$, $p<0.0001$, $f^2 = 0.08$, respectively).

Table 4.3. Relative age differences in scores obtained in the Canadian Assessment of Physical Literacy based on children's month of birth.

	Boys														
	Quarter 1 January to March			Quarter 2 April to June			Quarter 3 July to September			Quarter 4 October to December					
		95% CI			95% CI			95% CI			95% CI				
	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB	Mean	LB	UB	*F*-test	*p*	f^2
Height (cm)[a] (n=4,081)	146.2	145.7	146.6	144.6‡	144.1	144.9	142.9‡†	142.5	143.3	142.3‡†	141.9	142.8	563.86*	<0.001	0.04
Weight (kg)[a] (n=4,076)	42.0	41.3	42.6	39.9‡	39.3	40.5	38.9‡	38.3	39.5	38.6‡†	37.9	39.3	175.57*	<0.001	0.02
BMI (kg/m^2)[a] (n=4,059)	19.4	19.1	19.6	18.9‡	18.6	19.1	18.8‡	18.6	19.0	18.8‡	18.5	19.0	35.09*	0.001	0.004
WC (cm)[a] (n=4,039)	68.9	68.2	69.5	67.4‡	66.8	68.0	67.0‡	66.4	67.6	66.5‡	65.8	67.2	72.28*	<0.001	0.01
Physical competence domain score[b] (n=4,059)	20.6	20.3	20.8	20.1‡	19.9	20.3	19.8‡	19.6	20.0	19.6‡†	19.3	19.8	277.04*	<0.001	0.01
Daily behaviour domain score[b] (n=4,059)	18.6	18.1	19.1	18.5	18.0	18.9	18.6	18.1	19.0	19.1	18.6	19.0	12.54*	0.26	0.001
Motivation and confidence domain score[b] (n=4,059)	12.9	12.7	13.1	12.8	12.6	12.9	12.6	12.5	12.8	12.8	12.6	12.9	5.48*	0.42	0.001
Knowledge and understanding domain score[a] (n=4,100)	12.2	12.0	12.4	12.0	11.9	12.2	11.7‡†	11.5	11.8	11.6‡†	11.5	11.8	78.49*	<0.001	0.01
Total CAPL score[b] (n=4,059)	64.2	63.4	64.9	63.3	62.6	64.1	62.7‡	61.9	63.4	63.1	62.3	63.9	60.4*	0.04	0.002

	Girls														
	Quarter 1 January to March			Quarter 2 April to June			Quarter 3 July to September			Quarter 4 October to December					
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI				
		LB	UB		LB	UB		LB	UB		LB	UB	*F*-test	*p*	f^2
Height (cm)[a] (n=4,114)	146.5	146.1	147.0	144.6‡	144.2	145.1	143.7‡†	143.3	144.1	142.2‡†	141.8	142.7	629.71*	<0.001	0.04
Weight (kg)[a] (n=4,110)	41.5	40.9	42.2	40.4	39.8	41.0	39.5‡	39.0	40.1	38.9‡†	38.2	39.6	201.36*	<0.001	0.01
BMI (kg/m^2)[a] (n=4,092)	19.1	18.9	19.3	19.0	18.8	19.3	18.9	18.6	19.1	19.0	18.7	19.2	32.93*	0.45	0.001
WC (cm)[a] (n=4,076)	67.8	67.2	68.4	67.4	66.7	68.0	66.6‡	66.0	67.1	66.8	66.1	67.6	61.71*	0.03	0.002
Physical competence domain score[b] (n=4,092)	19.9	19.7	20.2	19.5‡	19.3	19.7	19.2‡	19.0	19.3	18.9‡†	18.7	19.2	276.74*	<0.001	0.01
Daily behaviour domain score[b] (n=4,092)	18.5	18.0	18.9	18.2	17.8	18.7	18.0	17.6	18.4	18.5	18.1	19.0	16.08*	0.34	0.001
Motivation and confidence domain score[b] (n=4,092)	12.5	12.3	12.6	12.3	12.1	12.4	12.2‡	12.0	12.3	12.2‡	12.0	12.3	8.72*	0.036	0.002
Knowledge and understanding domain score[a] (n=4,133)	12.4	12.2	12.6	12.2	12.0	12.3	12.2	12.1	12.4	11.9‡	11.8	12.1	72.83*	0.001	0.004
Total CAPL score[b] (n=4,092)	63.3	62.6	63.9	62.1	61.5	62.1	61.5‡	60.9	62.1	61.6‡	60.9	62.3	49.56*	0.001	0.004

An analysis of covariance was conducted controlling for multiple covariates described in each model. For the purpose of this table this symbol [‡] was used to show statistically significant differences between quarter 1 and other quarters. This symbol [†] was used to demonstrate statistically significant differences between quarter 2 and other quarters. The *F*-test is shown for the overall corrected model (*p<0.001). The last two columns, the *p-value and Cohen's* f^2 effect sizes, are presented for the main effect of the relative age by quarters. Model 1[a]: controlled for site location, age (whole years) and testing month. Model 2[b]: controlled for BMI z-score, site location, age (whole years) and testing month. Abbreviations: CI, confidence interval; LB, lower bound; UB, upper bound; BMI, body mass index; WC, waist circumference; and CAPL, Canadian Assessment of Physical Literacy.

The associations between children's relative age, in quarters, and the specific physical competence assessment protocol are presented in Table 4. Despite having a statistically significant corrected model for all the assessments, the main effect of quarters was only statistically significant for children's aerobic capacity (PACER shuttle run test), the upper body strength assessment (grip strength) and the movement skill assessment (CAMSA). Among boys and girls, the number of 20-m laps ran was associated with the relative age of children ($F(3, 3962) = 8.6$, $p<0.0001$ and $F(3,3962) = 5.8$, $p=0.001$, respectively). However, this significant main effect of relative age for the aerobic capacity assessment revealed only negligible effect sizes. While the main effect for the aerobic capacity assessment was negligible, the covariate BMI *z*-score contributed to moderate ($f^2 = 0.16$) and small ($f^2 = 0.11$) effect sizes in the model in boys and girls, respectively. The significant associations between the movement skills assessment (CAMSA) and the relative age among boys and girls ($F(3, 4003) = 11.0$, $p<0.001$ and $F(3,4025) = 15.8$, $p<0.001$, respectively) also revealed only negligible effect sizes. While negligible effect sizes were observed for both the aerobic capacity and the movement skills assessment, the significant association between upper body strength (handgrip strength) and the relative age ($F(3, 4037) = 29.2$, $p<0.001$ and $F(3,4077) = 25.1$, $p<0.001$ in both boys and girls, respectively) revealed small effect sizes in both sexes. Among boys and girls, neither the muscular endurance (timed plank) ($F(3, 4063) = 0.8$, $p=0.51$ and $F(3,4072) = 0.87$, $p=0.46$, respectively) nor the flexibility (sit-and-reach) ($F(3, 4036) = 0.7$, $p=0.53$ and $F(3,4069) = 0.4$, $p=0.43$, respectively) assessments were associated with the relative age in quarters.

Table 4.4. Relative age difference, expressed in quarters, and the scores obtained in aerobic capacity, trunk muscular endurance, upper body strength, flexibility and movement skill assessments for children 8 to 12 years participating in the Canadian Assessment of Physical Literacy.

	Boys					Girls				
	PACER (laps) (n=3,970)	Timed Plank (s) (n=4,044)	Grip Strength (kg) (n=4,045)	Sit-and-reach (cm) (n=4,044)	CAMSA (n=4,011)	PACER (laps) (n=3,970)	Timed Plank (s) (n=4,080)	Grip Strength (kg) (n=4,085)	Sit-and-reach (cm) (n=4,077)	CAMSA (n=4,033)
Quarter 1 (mean [95% CI])	28.1 [27.1-29.0]	63.5 [60.8-66.2]	36.1 [35.5-36.6]	25.4 [24.9-25.9]	32.4 [32.0-32.7]	22.1 [21.4-22.8]	62.7 [60.1-65.2]	34.1 [33.6-34.6]	31.2 [30.7-31.7]	31.4 [31.1-31.8]
Quarter 2 (mean [95% CI])	26.0 [25.1-26.9]‡	62.8 [60.2-65.3]	35.2 [34.7-35.7]	25.6 [25.2-26.1]	31.7 [31.4-32.0]‡	21.2 [20.5-21.9]	62.1 [59.6-64.6]	32.9 [32.5-33.4]‡	30.6 [30.1-31.2]	30.6 [30.3-31.0]‡
Quarter 3 (mean [95% CI])	25.2 [24.4-26.1]‡	62.1 [59.6-64.6]	33.3 [32.8-33.8]‡	25.6 [25.1-26.0]	31.4 [31.1-31.7]‡	20.2 [19.5-20.8]‡	60.2 [57.9-62.6]	32.2 [31.8-32.6]‡	31.1 [30.6-31.5]	30.3 [30.0-30.6]‡
Quarter 4 (mean [95% CI])	25.0 [24.0-25.9]‡	60.7 [57.9-63.4]	33.4 [32.9-33.9]‡	25.2 [24.7-25.6]	31.0 [30.7-31.3]‡†	20.6 [19.9-21.4]‡	60.5 [57.8-63.2]	31.3 [30.8-31.7]‡†	31.0 [30.5-31.6]	29.8 [29.5-30.2]‡†
F-test	106.38*	53.10*	237.40*	10.51*	109.38*	77.7*	56.40*	320.25*	4.34*	104.5*
p-value	<0.001	0.51	<0.001	0.53	<0.001	0.001	0.46	<0.001	0.43	<0.001
f^2	0.01	0.001	0.02	0.001	0.01	0.004	0.001	0.02	0.001	0.01

An analysis of covariance was conducted controlling for BMI z-score, site location, age (whole years) and testing month. The means that are significantly different from quarter 1are identified by this symbol [‡], while the means that are significantly different from quarter 2 are identified by this symbol [†]. Quarter 1 represents children born in January to March, quarter 2 is from April to June, etc. The *F*-test is shown for the overall corrected model (*p<0.001). The last two columns, *p*-value and Cohen's f^2, are for the main effect of relative age in quarters. The abbreviations: PACER, Progressive Aerobic Cardiovascular Endurance Run; CAMSA, Canadian Agility and Movement Skill Assessment; CI, confidence interval

Discussion

The aim of our study was to quantify the magnitude of the RAE as it relates to CAPL scores (physical literacy) in a large sample of children ages 8 to 12 years. Although we found many significant associations between the domain scores and relative age expressed in quarters, the RAE bias was negligible on the domains and overall CAPL scores. Additionally, we also observed a small relative age association among boys' and girls' height and strength measurements. Boys born in the first three months of the year were taller and heavier, and had higher handgrip strength compared to those born later in the same year. Girls born in the first six months after the school entry cut-off date were taller and had higher handgrip strength compared to their relatively younger peers born in the last six months of the year.

Anthropometrics

Several studies in sports have hypothesised that the RAE could be attributed to physical advantages based on growth differences [9,10,36]. However, this hypothesis is not supported by all. In the sport context, a number of studies have observed that relatively older children were significantly taller than those born later in the same year [36-41], while others reported no significant associations between relative age difference and anthropometric measurements [42,43]. Studies examining the association between children's RAE and fitness or motor skills assessments outside of a specific sport context have also reported inconsistent RAE results for anthropometric measurements. For instance, Sandercock and colleagues [21] found no association between the RAE and the anthropometrics of their participants. In the present study, we did observe a RAE in children's height mainly; children born in the first six months of the year were taller than their relatively younger peers. The present study's results are consistent with a previous study [11].

However, these anthropometric advantages seen in the relatively older children did not appear to have much influence on their physical literacy scores.

Domain scores and overall CAPL scores

Sex differences were observed in the RAE, particularly evident in the motivation and confidence domain scores. Boys' scores were not significantly different based on the main effect of relative age, while girls born in the first three months of the year obtained greater scores in the motivation and confidence domain than those born in the last six months of the same year. Previous studies have shown that boys generally display greater self-efficacy and motivation, but also receive greater social support towards physical activities and sports than girls [44,45]. These sex differences in the psychosocial correlates of physical activity may be partly responsible for the lack of association between the RAE in boys' motivation and confidence scores. Another plausible explanation may be due to biological maturation and its association to physical self-concepts [46,47]. Physical self-concept is considered to be both a determinant and outcome of physical activity, with an increased positive self-concept being positively associated with daily physical activity [48]. In the present study, the adequacy component within the motivation and confidence domain was the only component that was significantly associated with the relative age in girls ($F(3, 4084) = 5.5$, $p = 0.01$, $f^2 = 0.004$). Adequacy refers to a generalized self-efficacy towards physical activity [33], and being consistently older in school and in sports cohorts may have contributed to the increased level of self-efficacy in the relatively older girls. Both biological maturation status and self-concepts, unmeasured in the present study, could have influenced children's scores on the motivation assessment.

Evidence of the RAE in the affective domain is very limited. Thompson and colleagues [16] investigated the association between the RAE of 1st grade children and self-esteem and found a positive association between relatively older children and greater self-esteem in school. Although the study was conducted in a classroom setting and in younger children, no sex difference in the relationship between self-esteem and RAE was reported [16]. More research should investigate the association between sex, biological maturation, relative age and different affective outcomes (i.e., motivation, self-efficacy, self-concept and confidence) since these factors may impact long-term physical activity participation.

Numerous studies have reported on the relationship between a child's month of birth and academic abilities. Relatively older children tend to consistently score higher on school tests than their relatively younger peers throughout their education [13,49-53]. In the present study, the RAE results on the association with the knowledge and understanding domain scores are consistent with previous studies despite the negligible effect sizes observed. It is important to note that boys born in the first six months of the year scored higher in the knowledge and understanding domain than their peers born in the last six months of the year. While in girls, those born in the first three months outscored their peers born in the last three months of the year. In contrast with a recent study [49], the present study's RAE association with the knowledge and understanding domain scores was not attenuated in older children (11 and 12 years old), even though all children completed the same questionnaire. These findings may further substantiate Boardman's [52] theory that relatively younger children may have different and unmet learning needs than their relatively older peers.

In the present study, while just short of a small effect size, a relative age difference was observed in the physical competence domain scores among both sexes. Roberts and colleagues

[11] have hypothesized that the lower physical fitness among relatively younger children may be due to less daily physical activity. If this were the case, we would have observed a RAE in the daily behaviour domain components (i.e., daily step counts and the self-reported number of days a child engages in moderate-to-vigorous physical activity per week); however, we observed no significant differences between birth months and the individual domain components or the daily behaviour domain scores. In fact, the highest daily behaviour domain score was seen in boys born in the last three months of the year. Therefore, the amount of daily physical activity does not appear to be a factor in the RAE bias; a more plausible explanation would be the maturation differences and the positive linear relationship between age and performance in this age group [11,54].

Relative age differences were statistically significant in both boys (2 out of 4 domains) and girls (3 out of 4 domains); however, these associations yielded negligible effect sizes. Thus, regarding the overall CAPL score, the observed negligible effect sizes were not surprising considering the aggregate nature of the CAPL scoring system. For the domains and the overall CAPL scores, the covariate BMI *z*-score had a greater impact than the relative age, in quarters, for the physical competence domain (large effect sizes) and overall CAPL scores (small effect sizes) in both sexes. The greater impact observed for the BMI *z*-score covariate could be partially explained by our participants' mean age and the BMI z-score acting as a proxy measure of maturation; as the World Health Organization's BMI *z*-score are age- (in years and months) and sex- specific [24]. Additionally, the covariate age had a greater impact than the relative age on the knowledge and understanding domain (small effect sizes) in both sexes and the daily behaviour domain in girls (small effect sizes).

Physical Competence fitness assessments

Among boys and girls, the strength assessment showed evidence of a RAE bias but the effect sizes were deemed small. The RAE associated with the handgrip strength test is also consistent with a previous study [21]. In this age group, rounded down age would seem to unfairly compare strength in both sexes and may be related to height and muscle mass differences. It may be worth investigating whether the handgrip strength test is associated with physical literacy or with fitness in this age group, since our results suggest that handgrip strength is highly susceptible to both the children's anthropometrics (possibly a result of biological maturation variation) and the RAE bias.

Boys born in the first quarter ran significantly more laps compared to all relatively younger peers, while in girls only the comparison between those born in the first quarter and the last six months was significant. While the effect sizes were negligible for the PACER shuttle run test, the more pronounced relative age difference in boys' aerobic capacity may be a product of the sample mean age; at 10 years, the majority of boys would be prepubescent, while there is an increased likelihood of having more variation in the biological maturation stage of girls [55-57]. The observation of a relative age difference in aerobic capacity is consistent with previous studies [11,21,54].

Among boys and girls, the CAMSA, a measure of children's movement skills, was significantly associated with the relative age difference of children. This study's results showed significant associations between the relative age and the movement skill assessment in both sexes, but the main effect of relative age showed negligible effect sizes. These significant associations are consistent with a recent study on the association between the RAE and fundamental movement skills assessments (effect sizes not reported) [20]. Our study differed from the previous study as

we did not observe sex differences in the CAMSA mean scores, however this may be due to the differences in the measurement used, the CAMSA produces an overall skill score which could be covering for sex differences in object control vs. balance tasks for example.

Even though the results for the trunk muscular endurance measurement (timed plank) were not significantly associated with the RAE, the scores did follow the expected pattern for the RAE (quarter 1 > quarter 2 > quarter 3 > quarter 4). However, the expected RAE pattern was not observed for the flexibility assessment (sit-and-reach). The scores were significantly different between boys and girls but no significant differences were observed between whole age groups in girls; younger boys (i.e. age 8 and 9) scored significantly higher than older boys (data not shown). These age and sex differences in the sit-and-reach scores are consistent with previous studies observing children's fitness [58,59].

Strengths of the present study include the large sample size and the harmonized, validated, population-specific and age- and sex-normalized protocol that measured physical literacy of children across 11 sites from the east to the west coast of Canada. Another strength of our study was the high inclusion rate (between 79 and 82% for all samples), despite needing complete assessment, domains and overall CAPL scores. Finally, we believe that this study presents a realistic observation of the RAE bias, in a physical literacy context, as not all studies exploring this bias have reported effect sizes to determine if any differences observed are in fact meaningful. However, these results need to be interpreted in light of the following limitations. First, based on our cross-sectional data, causality cannot be established. Second, the external generalizability of these findings may be limited due to the nonprobability sampling strategy, which may have produced inflated physical literacy scores. However, our sample birth distribution (in quarters) was representative of the Canadian population birth distribution [35]. Finally, having some

information on biological maturation status (e.g., measuring sitting height) would have provided some additional insight that may have helped to confirm some of the theories we advanced to explained our results.

Conclusions

Collectively, the associations between children's relative age and the CAPL domains and overall scores produced mainly negligible effect sizes, suggesting that the RAE is not an important factor to consider when assessing the physical literacy of children with the CAPL. In practice, the mean differences observed across birth months, in quarters, were not large enough to warrant an adjustment to the CAPL scores. However, we believe that it is good practice to explore possible RAE bias in new assessment protocols, specifically those that separate children into rounded-down age bands, which may or may not be appropriate for all age groups. As these age bands do not take into account length of time in school, relatively older children are likely to have greater skill development opportunities based on school entry cut-off dates than their peers born later in the year. The lack RAE findings are positive for the CAPL assessment, since the CAPL's development was partially informed by schools' *curricula*; thus, the potential for a RAE warranted exploration. This study is unique as it provides a comprehensive examination of the RAE that assessed the association in affective, cognitive, behavioural, and physical domains of physical literacy in children.

List of abbreviations

CAPL, Canadian Assessment of Physical Literacy; RAE, relative age effect; RBC, Royal Bank of Canada; BMI, body mass index; WC, waist circumference; PACER, Progressive Aerobic Cardiovascular Endurance Run; CAMSA, Canadian Agility and Movement Skill Assessment; CSEP, Canadian Society for Exercise Physiology; CSAPPA, Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity; ANCOVA, analysis of covariance; SD, standard deviation; NS, Nova Scotia; AB, Alberta; PEI, Prince Edward Island; ON, Ontario; QC, Quebec; BC, British Columbia; MB, Manitoba; CI, confidence interval; LB, lower bound; UB, upper bound.

Declarations

Ethics approval and consent to participate

Obtained from the Children's Hospital of Eastern Ontario Research Ethics Board.

Availability of data and material

The datasets used and analyzed during the current study are available from Dr. Mark S. Tremblay on reasonable request.

Competing interests

The authors declared no conflicts of interest.

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Author's Contribution

CD, MST and J-PC developed the research question and objectives. CD, JDB and J-PC led the data analysis and synthesis of results. CD wrote the manuscript. All other authors contributed to editing, reviewing and approved of the final manuscript.

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Part 5: Final Discussion

The over-arching objective of this thesis was to quantify the association between the RAE bias and the scores obtained in the CAPL. As hypothesized, sex differences were observed in the association between the children's relative age and the domains and overall CAPL scores. In boys, 2 out of the 4 domains and the overall CAPL score while in girls 3 out of the 4 domains and the overall CAPL score were significantly associated with a relative age difference. However, the associations were not clinically relevant since these associations yielded negligible effect sizes. Within the physical competence domain, three assessments were significantly associated with a relative age difference among both sexes, i.e., movement skills, aerobic capacity and muscular strength. Nevertheless, the public health relevance of these weak associations is also questionable. Among boys and girls, anthropometric measurements were significantly associated with children's relative age but again the clinical relevance of these associations is questionable and was likely mainly the result of a large sample size. Furthermore, the positive associations between relatively older children and advantageous anthropometrics measurements did not appear to translate into any substantial advantages when it comes to physical literacy scores.

The present thesis was the first to investigate the RAE bias in the context of physical literacy assessment. In doing so, this thesis/study is unique in the RAE literature, as it simultaneously compares the magnitude of the RAE in affective, physical, behavioural and cognitive factors. Previous studies have isolated most of these domains, except the behavioural domain, painting perhaps an incomplete picture of the full implication that the RAE may have. Moreover, while our findings cannot be generalized to the Canadian population, our sample was more heterogeneous than many of the studies that observed a RAE bias. This may also help to

explain some the negligible and small effect sizes we observed. Furthermore, the present study presents a realistic observation of the RAE bias, in a physical literacy context, as not all studies exploring this bias have reported effect sizes to determine if any differences observed are in fact meaningful or not.

Finding no association between the daily behaviour domain scores and the RAE may seem counterintuitive; however, those findings are novel and may help to inform future interventions. Observing no RAE in objectively-measured step counts and self-reported physical activity and sedentary behaviours goes against the hypothesis that the RAE bias is likely attributable to extra practice on the part of the relatively older children (Musch & Grondin, 2001; Pierson et al., 2014; Roberts et al., 2012). However, these findings are cross-sectional and longitudinal studies will be needed to confirm these findings. However, longitudinal studies using the CAPL construct are limited as the assessments are only validated for children between 8 to 12 years of age. Thus, it would be desirable to expand and adapt the CAPL protocol to younger children, adolescents, and young adults to identify those who require more help in their physical literacy journey. Expanding the age range for the CAPL is also important as physical literacy continues to gain momentum and recognition worldwide. It is expected that physical literacy will become the 'gold standard' of physical education and sports development programs in the future (Roetert & MacDonald, 2015). While other physical literacy assessments do cover a wider age range, they are not validated, the assessments are more subjective, and do not cover all of the physical literacy domains.

A more likely explanation of the RAE (than the extra practice hypothesis) is related to cognitive growth; however, this hypothesis has received hardly any attention (Wattie et al., 2008). Martin and colleagues (2004) advanced that the development of the frontal lobe was highly correlated with chronological age, similarly to biological maturation. The frontal lobe

encompasses the prefrontal and primary motor cortexes which are responsible for controlling attention and impulses to remain on task, forming concepts, manipulating ideas, engaging in behaviours for delayed gratification or future goals and voluntary gross motor activities (Diamond, 2000; Wattie et al., 2008). All of these cognitive functions are certainly important for learning and skilled motor performance required in many sports. Sex differences in the RAE may also be rationalized by this cognitive growth theory, as boys do not reach full frontal lobe maturity until late adolescence. In girls it happens one to two years earlier, corresponding with their earlier puberty onset (Giedd et al., 1999). Moreover, for the present thesis it was hypothesized that the magnitude of the RAE would be attenuated with age; however, we observed no such differences in the tested ages. The cognitive growth and maturity theory may be a reasonable explanation for not finding any age differences in the pattern of association between children's CAPL scores and relative age. In the future, if the CAPL protocol is expanded for adolescents, revisiting the RAE bias could provide further insights to this theory.

The cognitive growth and maturity theory is supported by Cobley and colleagues' (2009) findings in their meta-analysis of the RAE in sports, as they did not observe a linear relationship between the RAE risk and skills or age category. While they observed a RAE in older cohorts, at the elite level the RAE decreased below that of youth cohorts, and at adult age (recreation sport for adults [>18 years]) the RAE also decreased below that of adolescents. These findings would seem to support the theory that post biological and frontal lobe maturation, relative age advantages become diminished, since adults are on equal footing developmentally (Lefevre, Beunen, Steens, Claessens, & Renson, 1990). However, since talent identification in sports happens much earlier (often during prepubescent years), relatively younger children have a greater risk of dropout due to the disadvantageous selection and attainment, thus rarely attained that developmentally equal

footing stage (Delorme, Chalabaev, & Raspaud, 2011; Helsen, Van Winckel, & Starkes, 1998; Lemez, Baker, Horton, Wattie, & Weir, 2014).

A possible solution to the RAE in sports would be to delay talent identification and selection to post maturation (i.e., 16 years old). This of course is unlikely to happen and would not be possible for all sports, though in many sports athletes do peak in their late twenties or early thirties (e.g., hockey, soccer and basketball). Studies have reported that 8 to 12 years of dedicated training are needed for an athlete to reach elite level, often referred as the '10-year or 10,000 hours rule' (Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Römer, 1993; Helsen, Starkes, & Hodges, 1998; Hodges & Starkes, 1996; Ward, Hodges, Williams, & Starkes, 2004). Furthermore, to support the theory that delaying talent identification would be beneficial to sports organizations, studies observing sport specialization in young athletes have found an association between intensive sport specialization at an early age and increased psychological and psychosocial stress, increased risk of injury and drop out during adolescent years (Baker & Côté, 2003; Bean, Fortier, Post & Chima, 2014; Gould, 2010; Helsen, Starkes, et al., 1998; Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2012; Law, Côté, & Ericsson, 2007; McFadden, Bean, Fortier & Post, 2016; Moesch, Elbe, Hauge, & Wikman, 2011; Soberlak & Côté, 2003; Wall & Côté, 2007). Therefore, delayed selection could be a solution to reducing the likelihood of the RAE in sports and in the process potentially widen the pool of potential athletes and reduce the dropout rates. In the meantime, measuring and monitoring biological maturity of children in addition to using physical literacy assessments, such as the CAPL protocol, could provide a more accurate picture of potential talents in children and may help to reduce the association between physical attributes and coaches' perception of giftedness.

Côté and Fraser-Thomas (2007) have proposed the Developmental Model of Sport

Participation (DMSP), focusing on the development of children aged 7 to 18 years in sports. The DMSP is different from the Long-Term Athlete Development framework; while sport governing bodies apply and develop their own Long-Term Athlete Development frameworks, the DMSP is not sport specific (Bridge & Toms, 2013; Côté & Fraser-Thomas, 2007). It contains three pathways for children's sport participation: (i) elite performance through early specialization in a single sport; (ii) elite performance through the sampling of multiple sports; and (iii) recreational participation through sampling of multiple sports. Pathways within the DMSP contain various phases of development that follow a child entry into sport participation (Côté & Fraser-Thomas, 2007). The two elite pathways each contain different proportions of deliberate play and practice activities throughout an individual's sporting development while recreational participation is centered on deliberate play (Côté & Fraser-Thomas, 2007). Children who specialize before the age of 12 years are categorized into the early specialization while those who specialize in their teen years are considered to be in the pathway of elite performance through the sampling of multiple sports. This latter pathway is characterized by a progressive narrowing of the sport focus (Côté, Baker & Abernethy, 2007; Côté & Fraser-Thomas, 2007).

The DMSP model has been supported by studies that have found a positive association between children's increased sport sampling and higher level of competition in the late teen years (Baker & Côté, 2003; Bridge & Toms, 2013; Lidor & Lavyan, 2002; Vaeyens, Güllich, Warr, & Philippaerts, 2009). However, these findings are not consistent across the literature; for some sports, it is suggested that early specialization may be beneficial (Baker, 2003; Côté, Lidor & Hackfort, 2009; Law, Côté & Ericsson, 2007). Moreover, a review by Bean and colleagues (2014) has suggested that the motivational climates are different between those who specialize early (i.e., disempowering) and those who sample and specialize later (i.e., empowering). These findings,

while limited, do seem to support delaying sport specialization in children since the negative motivational climate may be associated with increased psychological and psychosocial stress and drop out during adolescent years (Bean et al., 2014). The relationship between the RAE and those who specialize early vs. those who sampled sports and specialized later is unknown and may be worth exploring in future studies. Additionally, for the CAPL, it may be advantageous to gather more specific information on children's sport participation that would provide further context to the motivation and confidence domain scores.

The main limitations of the present study were discussed in the article (Part 4, pages 50 and 51). However, another limitation that deserves careful consideration is the lack of information on the socioeconomic status (SES) of children, including factors such as parental level of education, household income and family structure. Studies have demonstrated an association between SES with a broad array of health outcomes (including physical activity participation) in children (Bradley & Corwyn, 2002; Ford et al., 1991; Seabra et al., 2013; Sirin, 2005). Therefore, it is not implausible that SES would be a factor in children's acquisition of physical literacy, and this aspect should be investigated in order to inform future physical literacy interventions.

In conclusion, this study was much needed as it confirmed the validity of the CAPL in accurately measuring children's physical literacy. More importantly, these results suggest that excelling in physical literacy is not related to a single factor, such as birth month, place of residence, age, month of testing or BMI but rather a range of interactions. The implications for scientists is fairly simple in theory but much more challenging to apply in practice. The time for a reductionist approach to investigate health outcomes and behaviours is long past, and researchers should carefully consider a research design the takes into account multiple interactions and moderation effects. This range of influences is likely the reason why no one theory was supported

as the primary cause of the RAE. Evidently there is still much to be learned when it comes to the RAE, including understanding the domains in which the RAE operates, the magnitude of the impact and the underlying causes of the RAE bias. It should be noted that it is good practice to investigate systematic biases, such as the RAE, in new assessment protocols and assuming that the RAE is a non-issue is not a valid approach in science. The present findings should be regarded as being positive, in that not all assessment protocols are affected by the RAE; thus, when comparing children coaches, teachers and pedagogy professionals should strive to use assessment protocols that have been validated and shown to be unaffected by systematic biases when comparing children between them. Continuing to raise awareness about possible systematic biases among professionals, who play a critical role in empowering children to remain active for life is an important endeavour. In the end, the goal is simply to advance our understanding and promotion of health and wellness where children live, play and learn.

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Appendices

Appendix A – CHEO's Research Ethics Board Annual Renewal Approval

RESEARCH INSTITUTE
INSTITUT DE RECHERCHE

Research Ethics Board
2016 Annual Renewal (Delegated)

Principal Investigator: Dr. Mark Tremblay
REB Protocol No: 13/202X
Romeo File No: 20130481
Project Title: CHEOREB# 13/202X - CAPL-RBC Learn to Play Project
Primary Affiliation: HALO\HALO
Protocol Status: Active
Approval Date: December 5, 2016
Approval Valid Until: December 15, 2017
Annual Renewal Submission Deadline: November 15, 2017

Documents Reviewed & Approved:

Document Name	Comments	Version Date
Assent Form	Child Assent form ENG - CAPL-RBC project	2015/11/11
Consent Form	Parent Consent Form ENG - CAPL-RBC project	2015/11/11
French Assent Form	Child Assent form FR - CAPL-RBC project	2014/11/03
French Consent Form	Parent Consent form FR - CAPL-RBC project	2014/11/03
Protocol	Protocol - CAPL-RBC Project	2015/11/09

This is to notify you that the CHEO REB has granted approval to the renewal for the above named research study for a period of one year. The renewal was reviewed and approved by the Chair or a delegate of the Chair. Decisions made by the Chair under delegated review are ratified by the full Board at its subsequent meeting.

Approval is granted with the understanding that the investigator agrees to comply with the following requirements:

1. The investigator must conduct the study in compliance with the protocol and any additional conditions set out by the Board.

2. Investigators must submit an annual renewal report to the REB 30 days prior to the expiration date stated on the final approval letter.
3. The investigator must not implement any deviation from, or changes to, the protocol without the approval of the REB except where necessary to eliminate an immediate hazard to the research subject, or when the change involves only logistical or administrative aspects of the study (e.g., change of telephone number or research staff). As soon as possible, however, the implemented deviation or change, the reasons for it and, if appropriate, the proposed protocol amendment(s) should be submitted to the Board for review.
4. The investigator must, prior to use, submit to the Board changes to the study documentation, e.g., changes to the informed consent letters, recruitment materials.
5. Investigators must provide the Board with French version of the consent form, unless a waiver has been granted. An interpreter should be offered to participants as required or at the request of the participant throughout the course of research.
6. For clinical drug or device trials, investigators must promptly report to the REB all adverse events that are both serious and unexpected (SAEs) or unexpected and untoward occurrences (including the loss or theft of study data and other such privacy breaches.
7. For SAE reports on clinical drug trials, the investigator must also comply with the hospital-wide Policy regarding, Procedures for Considering Medical Error in the Differential Diagnosis of Severe Adverse Events (SAE) Associated with the Drugs Administered in a Clinical Trial .
8. Investigators must promptly report to the REB any new information regarding the safety of research subjects (e.g., changes to the product monograph or investigator's brochure of drug trials). Where available, any reports produced by the Data Safety Monitoring Board should also be promptly submitted to the REB.
9. Investigators must notify the REB of any study closures (closed to accrual, temporary, premature or permanent).
10. Investigators must submit a final report at the conclusion of the study.

If you have any questions, pertaining to this letter, please contact the Research Ethics Board Office at (613) 737-7600, ext. 3350 or 2128.

Regards,

Dr. Franco Momoli, Ph.D.
Interim Chair, CHEO Research Ethics Board
401 Smyth Road, Ottawa, ON K1H 8L1
Tel: (613) 737-7600 ext. 6012 | Fax/Téléc: (613) 738-4875 | fmomoli@uottawa.ca

RESEARCH INSTITUTE
INSTITUT DE RECHERCHE

Research Ethics Board
2016 Annual Renewal (Delegated)

Principal Investigator: Dr. Mark Tremblay
REB Protocol No: 13/226X
Romeo File No: 20130520
Project Title: CHEOREB# 13/226X - Canadian Assessment of Physical Literacy Research Database
Primary Affiliation: HALO\HALO
Protocol Status: Active
Approval Date: December 16, 2016
Approval Valid Until: January 15, 2018
Annual Renewal Submission Deadline: December 15, 2017

Documents Reviewed & Approved:

Document Name	Comments	Version Date
Protocol	CAPL Database Protocol	

This is to notify you that the CHEO REB has granted approval to the renewal for the above named research study for a period of one year. The renewal was reviewed and approved by the Chair or a delegate of the Chair. Decisions made by the Chair under delegated review are ratified by the full Board at its subsequent meeting.

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Appendix B – CAPL's scoring system

Copied from: CAPL Manual for Test Administration with permission from Mark Tremblay (Francis, 2016; *Healthy Active Living and Obesity Research Group*, 2013 Longmuir et al., 2015)

Overall **Score**

Interpretation of Child's Overall Score and Domain Scores:

	Beginning	Progressing	Achieving	Excelling
Physical Literacy Overall (max 100)	< 43.8	43.8 to 63.8	> 63.8 to 74.0	> 74.0
8	< 39.2	39.2 to 61.5	> 61.5 to 72.6	>72.6
9	< 47.3	47.3 to 63.7	> 63.7 to 72.0	> 72.0
10	< 41.2	41.2 to 61.6	> 61.6 to 71.7	>71.7
11	< 44.8	44.8 to 66.7	> 66.7 to 77.6	> 77.6
12	< 41.3	41.3 to 64.0	> 64.0 to 75.3	> 75.3
Physical Competence (max 32)	< 14.1	14.1 to 21.5	> 21.6 to 25.3	> 25.3
8	< 12.3	12.3 to 18.5	> 18.5 to 21.7	> 21.7
9	< 13.8	13.8 to 19.8	> 19.8 to 22.7	> 22.7
10	< 14.0	14.0 to 20.5	> 20.5 to 23.7	>23.7
11	< 16.0	16.0 to 23.4	> 23.4 to 27.1	> 27.1
12	< 16.6	16.6 to 24.7	> 24.7 to 27.1	> 27.1
Daily Physical Activity Behaviour (max 32)	< 7.5	7.5 to 19.2	> 19.3 to 25.2	> 25.2
8	<10.1	10.1 to 21.7	> 21.7 to 27.7	> 27.7
9	< 8.6	8.6 to 20.3	> 20.3 to 26.1	> 26.1
10	< 6.3	6.3 to 18.0	> 18.0 to 23.9	> 23.9
11	< 7.9	7.9 to 19.7	> 19.7 to 25.6	> 25.6
12	< 7.0	7.0 to 18.1	> 18.1 to 23.7	> 23.7
Knowledge and Understanding (max 18)	< 6.8	6.8 to 11.5	> 11.6 to 14.1	> 14.1
8	<7.7	7.7 to 10.8	> 10.8 to 12.3	> 12.3
9	< 6.5	6.5 to 11.0	> 11.0 to 13.3	> 13.3
10	< 6.7	6.7 to 11.6	> 11.6 to 14.1	> 14.1
11	< 7.1	7.1 to 12.2	> 12.2 to 14.7	> 14.7
12	< 7.2	7.2 to 12.3	> 12.3 to 14.8	> 14.8
Motivation and Confidence (max 18)	< 8.1	8.1 to 13.7	> 13.8 to 16.6	> 16.6
8	<7.4	7.4 to 12.4	> 12.4 to 15.0	> 15.0
9	< 8.5	8.5 to 13.7	> 13.7 to 16.4	> 16.4
10	< 7.6	7.6 to 13.7	> 13.7 to 16.8	> 16.8
11	< 8.4	8.4 to 13.9	> 13.9 to 16.6	> 16.6
12	< 8.1	8.1 to 13.9	> 13.9 to 16.8	> 16.8

Physical Literacy **Scoring**

CAPL total score

Daily behaviour (range 0 to 32)	+	Physical competence (range 5.2 to 32)	+	Motivation and confidence (range -1.5 to 18)	+	Knowledge and understanding (range -0.63 to 18)	+	Total CAPL score (range 3.07 to 100)

Calculating the Daily Behaviour Domain Score

The component scores for both the physical activity behaviour (measured with pedometer step counts) and the sedentary time (based on self-report) are summed. Physical activity behaviour is assigned a heavier weight than sedentary time and the weekly physical activity question because the direct measurement of activity over 7 days by pedometer is a more objective measure than the questionnaire measures. Sedentary time is assigned a higher weighting than the weekly physical activity question because daily physical activity level is also represented primarily by the pedometer step counts.

The daily behaviour domain score is calculated as follows:

Pedometer steps component score (range 0 to 21)	+	Total screen time component score (range 0 to 8)	+	Weekly time spent in MVPA component score (range 0 to 3)	=	Daily behaviour (range 0 to 32)		

Calculating the Physical Competence Domain Score

The aggregate physical competence domain score is calculated as follows:

Body composition aggregate score (range 8 to 34)	+	Musculo-skeletal fitness aggregate score (range 6 to 42)	+	PACER score (range 10.5 to 42)	+	Overall obstacle course score (range 1.5 to 42)	=	Physical competence domain score (range 26 to 160)/5 = (range 5.2 to 32)

Calculating the Knowledge & Understanding Domain Score

The score for each of these 10 questions is summed to give a possible maximum total score of 18 for the knowledge and understanding domain.

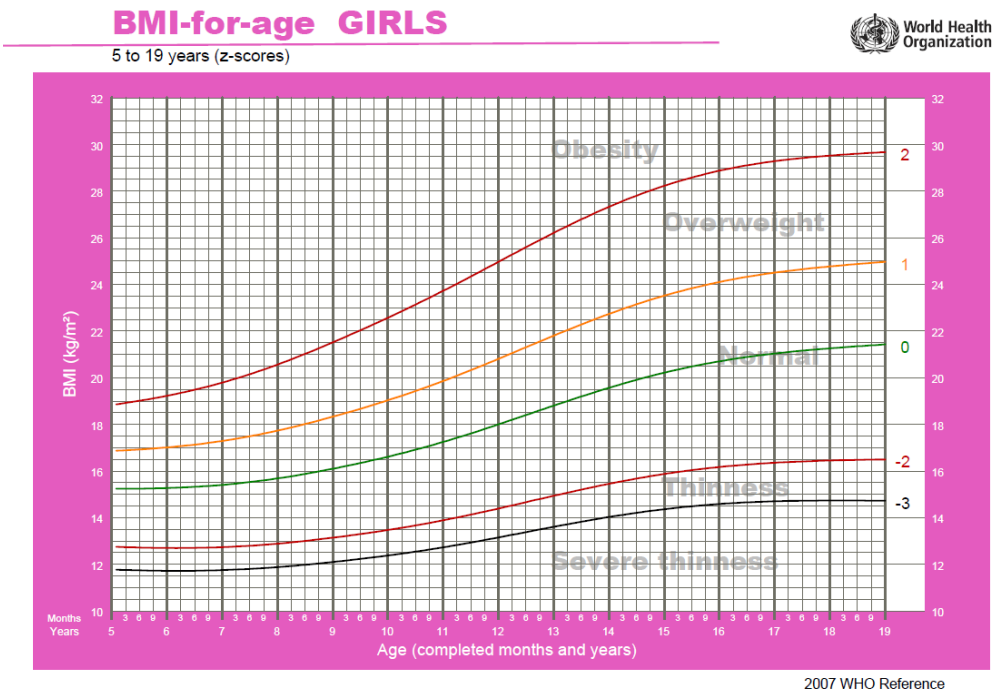
Q1 range 0 to 1	+	Q6 range 0-1	+	Q7 range 0-1	+	Q8 range 0-1	+	Q9 range 0-5	+	Q10 (0-5)	+	Q11 (0-1)	+	Q12 (-0.63-1)	+	Q13 (0-1)	+	Q14 (0-1)
										=								
Knowledge and understanding domain score (range -0.63 to 18)																		

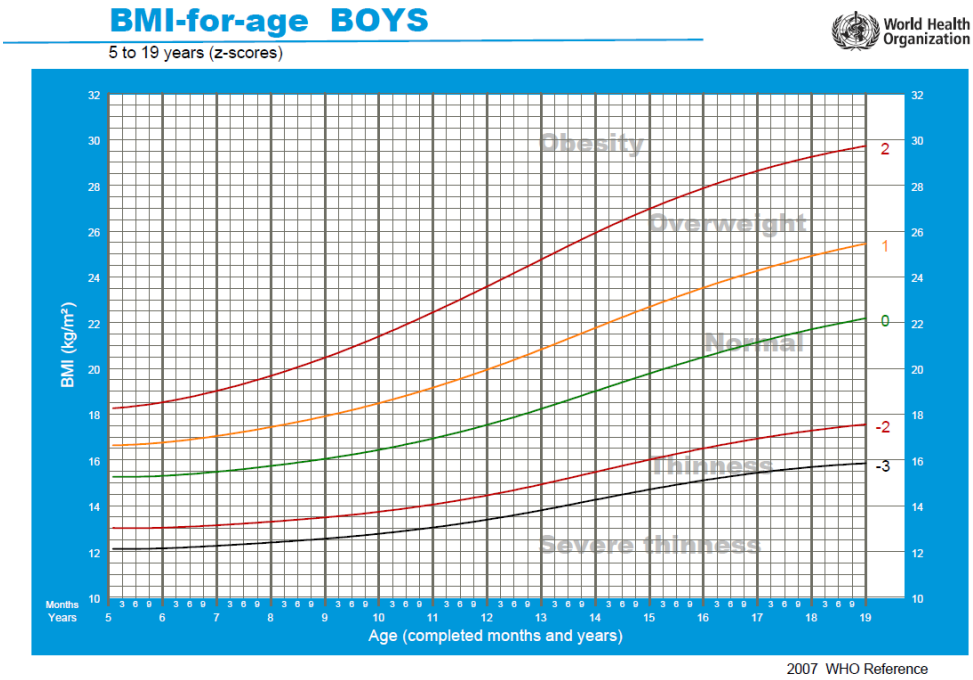
Calculating the Motivation & Confidence Domain Score

CSAPPA* adequacy score (range 1.5 to 6)	+	CSAPPA* predilection score (range 1.5 to 6)	+	Benefits: Barriers ratio (range -4.7 to 4)	+	Q4 (range 0.1 to 1)	+	Q5 (range 0.1 to 1)	=	Motivation & Confidence domain score (range -1.5 to 18)

* The "What's Most Like Me" (CSAPPA) questionnaire was developed by Dr. John Hay and is used in the Canadian Assessment of Physical Literacy with his permission. No reproduction, alteration or publication of the "What's Most Like Me" questions is permitted without express written permission from Dr. John Hay, Brock University, St. Catharines, Ontario, Canada.

Appendix C – World Health Organization age- and sex-specific BMI z-scores charts





(de Onis et al., 2007)

Appendix D – Pedometer tracking log sheet

Copied from: CAPL Manual for Test Administration permission from Mark Tremblay
(Francis, 2016; *Healthy Active Living and Obesity Research Group*, 2013 Longmuir et al., 2015)

Pedometer **Tracking Log**

Practice day!	Time on: am/pm	Time off: am/pm	# of steps taken:	Was the pedometer worn all day? ☐ Yes, I never took it off ☐ No, how many hours missing:____

Day	Date	Wake up time in the morning	Bed time in the evening	# of steps taken	Was the pedometer worn all day?
1					☐ Yes, I never took it off ☐ No, how many hours missing:____
2					☐ Yes, I never took it off ☐ No, how many hours missing:____
3					☐ Yes, I never took it off ☐ No, how many hours missing:____
4					☐ Yes, I never took it off ☐ No, how many hours missing:____
5					☐ Yes, I never took it off ☐ No, how many hours missing:____
6					☐ Yes, I never took it off ☐ No, how many hours missing:____
7					☐ Yes, I never took it off ☐ No, how many hours missing:____

Appendix E – CAPL Questionnaire

Copied from: CAPL Manual for Test Administration permission from Mark Tremblay (Francis, 2016; *Healthy Active Living and Obesity Research Group*, 2013 Longmuir et al., 2015)

Physical Activity Questionnaire
(Canadian Assessment of Physical Literacy)

What school grade are you in: (please circle one)

1 2 3 4 5 6 7 8

Are you a: (please circle one) boy girl

What month is your birthday: (please circle one)

Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec

How old are you: (please circle one)

5 6 7 8 9 10 11 12 13 14 15

In this project, when we talk about physical activity, we mean when you are moving around, playing or exercising. Physical activity is any activity that makes your heart beat faster or makes you get out of breath some of the time.

Why are we asking you these questions? We want to know what kids like you think about physical activity, sports and exercise.

Please remember:

- There are no right or wrong answers. We only want to know what you think.
- If you do not know an answer, please write your best guess.
- There is no time limit, so please take all the time you need.

1. **How many minutes each day should you and other children do physical activities that make your heart beat faster and make you breathe faster, like walking fast or running? Count the time you should be active at school and also the time you should be active at home or in your neighbourhood.**

   a) 10 minutes
   b) 20 minutes
   c) 30 minutes
   d) 60 minutes or 1 hour

2. **Kids say there are many different reasons that they like to be active or play sports. Being active is anything that you do when you are moving, exercising or not sitting still. Below are some reasons that other kids have told us why they like to be active. For each reason, tell us what you think. If you think it is a good reason then you would "Agree a little" or "Agree a lot". If you do not think it's a good reason, then you would "Disagree a little" or "Disagree a lot". If you are not sure or you don't think the reason is good or bad then you are "in between".**

A reason that I might be active is because when I am active. . .	Disagree a lot	Disagree a little	In between	Agree a little	Agree a lot
...I look better	1	2	3	4	5
...I have more energy	1	2	3	4	5
...I feel happier	1	2	3	4	5
...I have fun	1	2	3	4	5
...I make more friends	1	2	3	4	5
...I get stronger	1	2	3	4	5
...I like myself more	1	2	3	4	5
...I get in better shape	1	2	3	4	5
...I feel healthier	1	2	3	4	5

3. **Kids say there are also reasons that make it hard for them to be active. For each reason, tell us what you think. If you think it is a good reason then you would "Agree a little" or "Agree a lot". If you do not think it's a good reason, then you would "Disagree a little" or "Disagree a lot". If you are not sure or you don't think the reason is good or bad then you are "in between".**

I might not be active if. . .	**Disagree a lot**	**Disagree a little**	**In between**	**Agree a little**	**Agree a lot**
...I didn't have enough time to be active	1	2	3	4	5
...I have too many chores to do	1	2	3	4	5
...I didn't have a good place to be active	1	2	3	4	5
...If the weather was too bad	1	2	3	4	5
...I didn't have the right clothes/shoes	1	2	3	4	5
...I didn't know how to do the activity	1	2	3	4	5
...I didn't have the right equipment	1	2	3	4	5
...I had too much homework	1	2	3	4	5
...I didn't have anyone to be active with	1	2	3	4	5
...I didn't like to be active	1	2	3	4	5

4. **Compared to other kids your age, how active are you? (circle one number)**

A lot less active — Same — A lot more active

1 2 3 4 5 6 7 8 9 10

5. **Compared to other kids your age, how good are you at sports or skills? (circle one number)**

Others are better — Same — I'm a lot better

1 2 3 4 5 6 7 8 9 10

6. **Sometimes children watch television, play video games or play on the computer or on a smart phone. What is the most time that children should look at a screen each day? Do not count the time that you have to look at a screen to do your homework.**

   a) 30 minutes
   b) 60 minutes or 1 hour
   c) 2 hours
   d) 4 hours

7. **There are many different kinds of fitness. One type is called endurance fitness or aerobic fitness or cardiorespiratory fitness. Cardiorespiratory fitness means... (circle the right answer)**

   a) How well the muscles can push, pull or stretch.
   b) How well the heart can pump blood and the lungs can provide oxygen.
   c) Having a healthy weight for our height.
   d) Our ability to do sports that we like.

8. **Muscular strength or muscular endurance means... (circle the right answer)**

   a) How well the muscles can push, pull or stretch.
   b) How well the heart can pump blood and the lungs can provide oxygen.
   c) Having a healthy weight for our height.
   d) Our ability to do sports that we like.

9. **Draw a line to all the words you think describe what "Healthy" means.**

Being skinny **Looking good**

Healthy

Eating well **Feeling good**

Not being sick

10. This story about Sally is missing some words. Fill in the missing words below. Each word can only be used to fill one blank space in the story.

Fun	Endurance	Good	Pulse	Strength

Sally tries to be active every day. Running every day is good for her heart and lungs. Sally thinks that physical activity is _____ and is also _____ for her. At her sport team's practice she does more running to improve her _____. The team also does exercises like push-ups and sit-ups that increase her _____. After exercising, she checks her heart rate which is also called a _____.

11. Circle each activity that you do. If you <u>always</u> or <u>almost always</u> wear safety gear (like helmet or shin pads) when you do the activity, add a check mark inside the circle.

Snowmobiling

Swinging

Baseball

Sledding

Monkey Bars

Skipping

Swimming

Inline Skating

Skiing

Biking

Ice Skating

12. If you wanted to GET BETTER AT A SPORT SKILL like kicking and catching a ball, what would be the best thing to do? (circle one answer)

a) Read a book about kicking and catching a ball
b) Wait until you get older
c) Try exercising or being active a lot more
d) Watch a video, take a lesson or have a coach teach you how to kick and catch

13. If you wanted to IMPROVE YOUR FITNESS, what would be the best thing to do? (circle one answer)

a) Read a book about improving your fitness
b) Wait until you get older
c) Try exercising or being active a lot more
d) Watch a video, take a lesson or have a coach teach you how to improve your fitness

14. If you were allowed to pick what you do after school, which activity would you pick? (circle only one activity)

Play video/computer games	Go to my sports team's practice
Read	Walk my dog
Do homework	Chat with friends online
Play outside with my friends	Watch television

When answering the following questions (questions 15-21), please tell us about what you did LAST WEEK.

15. On a school day, how many hours did you watch TV?

☐ I did not watch TV on school days

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

16. On a school day, how many hours did you play video or computer games or use a computer for something that was not school work?

☐ I did not play video/computer games or use a computer other than for school work on school days

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

17. On a weekend day, how many hours did you watch TV?

☐ I did not watch TV on weekend days

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

18. On a weekend day, how many hours did you play video or computer games or use a computer for something that was not school work?

☐ I did not play video/computer games or use a computer other than for school work on weekend days

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

19. During the past week (7 days), on how many days were you physically active for a total of at least 60 minutes per day? (all the time you spent in activities that increased your heart rate and made you breathe hard)

a) 0 days
b) 1 day
c) 2 days
d) 3 days
e) 4 days
f) 5 days
g) 6 days
h) 7 days

20. On a school day how many hours did you spend sitting down doing non-screen based activities (e.g. reading a book, doing homework, sitting and talking to friends, drawing, etc.). Do not count the time that you sit at school.

☐ I did not spend time sitting down in non-screen based activities (e.g. reading a book, doing homework, sitting and talking to friends, drawing, etc.) on school days

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

21. On a weekend day how many hours did you spend sitting down doing non-screen based activities (e.g. reading a book, doing homework, sitting and talking to friends, drawing, etc.). Do not count the time that you sit at school.

☐ I did not spend time sitting down in non-screen based activities (e.g. reading a book, doing homework, sitting and talking to friends, drawing, etc.) on a weekend day

☐ Less than 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

Thank you for your help!

Appendix F – CAPL's "What is most like me" questionnaire

Copied from: CAPL Manual for Test Administration permission from Mark Tremblay
(Francis, 2016; Hay, 1992; *Healthy Active Living and Obesity Research Group*, 2013 Longmuir et al., 2015)

What's Most **Like Me**

For the rest of the questions you have to read 2 sentences and then circle the sentence you think is **MORE LIKE YOU**.

Try the following **SAMPLE QUESTION:**

Some kids have one nose on their face!	**BUT**	Other kids have three noses on their face!

That shouldn't be too hard for you to decide! Once you have circled the sentence that is more like you, then you have to decide if it is **REALLY TRUE** for you or **SORT OF TRUE** for you.

Here is another sample question for you to try. Remember, first circle the sentence that is more like you and then put a check in the correct box if it is really true or only sort of true for you. THERE ARE NO RIGHT OR WRONG ANSWERS, JUST WHAT IS **MOST LIKE YOU**.

SAMPLE QUESTION #2:

Some kids like to play with computers		**BUT**	Other kids don't like playing with computers
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me ☐ SORT OF TRUE for me

Now you are ready to start filling in this form. Take your time and do the whole form carefully.
If you have any questions, just ask! If you think you are ready you can start now.

BE SURE TO FILL IN EACH PAGE!

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What's most like me

Some kids can't wait to play active games after school	**BUT**	Other kids would rather do something else after school	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids don't like playing active games	**BUT**	Other kids really like playing active games	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids don't have much fun playing sports	**BUT**	Other kids have a good time playing sports	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids are good at active games	**BUT**	Other kids find active games hard to play	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids don't like playing sports	**BUT**	Other kids really enjoy playing sports	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids always hurt themselves when they play sports	**BUT**	Other kids never hurt themselves playing sports	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids like to play active games outside	**BUT**	Other kids would rather read or play video games	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me	☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids are among the last to be chosen for active games.		**BUT**	Other kids are usually picked to play first.	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids do well in most sports		**BUT**	Other kids feel they aren't good at sports	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for mee	☐ SORT OF TRUE for me

Some kids learn to play active games easily		**BUT**	Other kids find it hard learning to play active games	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for mee	☐ SORT OF TRUE for me

Some kids think they are the best at sports		**BUT**	Other kids think they aren't good at sports	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids find games in physical education hard to play		**BUT**	Other kids are good at games in physical education	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids like to watch games being played outside		**BUT**	Other kids would rather play active games outside	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids like to take it easy during recess		**BUT**	Other kids would rather play active games at recess	
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me	☐ SORT OF TRUE for me

Some kids aren't good enough for sports teams		**BUT**	Other kids do well on sports teams
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me ☐ SORT OF TRUE for me

Some kids like to read or play quiet games		**BUT**	Other kids like to play active games
☐ REALLY TRUE for mee	☐ SORT OF TRUE for me		☐ REALLY TRUE for me ☐ SORT OF TRUE for me

Some kids like to play active games outside on weekends		**BUT**	Other kids like to relax and watch TV on weekends
☐ REALLY TRUE for me	☐ SORT OF TRUE for me		☐ REALLY TRUE for me ☐ SORT OF TRUE for me

Thank you for your help!