PHYSICAL ACTIVITY AND HEALTH IN PRESCHOOL CHILDREN

RELATIONSHIPS BETWEEN PHYSICAL ACTIVITY AND HEALTH MEASURES IN PRESCHOOL CHILDREN

By

Leigh Gabel, B.Sc., B.A.

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Author: Leigh Gabel, B.Sc., B.A. (The University of Western Ontario)

Supervisor: Dr. Brian Timmons

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Abstract

Physical activity (PA) in preschool children (3- to 5-year olds) is characterized by short bouts of intermittent movement, generally accumulated during free play activities. Little is known about how the amount of PA or the patterns of PA accumulation are related to health in preschoolers. Ninety-six healthy preschool children (46 boys, 50 girls; 4.4 ± 0.9 years) participated in assessments of PA, body composition, health-related fitness, blood pressure, and motor proficiency. PA data were collected for 7 consecutive days using Actigraph accelerometers. PA prevalence was assessed by the amount of total and moderate-to-vigorous PA (MVPA) in min/day and as a % of wear; PA patterns were assessed by the frequency and duration of MVPA bouts and by the duration of breaks between MVPA. Younger preschoolers engaged in less PA than older preschoolers, according to measures of prevalence and patterns ($p < 0.05$). Girls participated in less PA, less frequent MVPA, and longer breaks between bouts of MVPA compared to boys ($p \leq 0.001$, for all). Health-related fitness was higher in preschoolers who engaged in more total PA, more frequent bouts of MVPA, longer bouts of MVPA, and shorter breaks between bouts of MVPA ($p < 0.05$, for all). Blood pressure was higher in preschoolers taking longer breaks between bouts of MVPA ($p < 0.05$). Motor proficiency was poorer in preschoolers who participated in shorter bouts of MVPA ($p < 0.001$). Preschoolers who met current PA recommendations of 180 min of total PA and 60 min of MVPA daily had better body composition and health-related fitness, respectively, compared to their peers who did not meet recommendations ($p < 0.05$). To the best of our knowledge, these

data are the first to provide support for new PA guidelines and to demonstrate relationships between PA and health-related fitness and blood pressure in preschoolers. Our findings indicate that PA patterns are just as important as PA prevalence in describing relationships between health measures in preschool children.

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List of Abbreviations

AUS	Australia
BMI	body mass index
BF%	body fat percentage
BP	blood pressure
CDC	Centre for Disease Control
CHMS	Canadian Health Measures Survey
DBP	diastolic blood pressure
HR	heart rate
HRR	heart rate recovery
IOTF	International Obesity Task Force
LBM	lean body mass
MP	mean power
MVPA	moderate to vigorous physical activity
NASPE	National Association for the Society of Physical Education
PA	physical activity
PDMS	Peabody Developmental Motor Scales
PP	peak power
SBP	systolic blood pressure
UK	United Kingdom
WAnT	Wingate Anaerobic Test
WC	waist circumference

Chapter 1: Literature Review

1.1 INTRODUCTION

Physical activity behaviours are established during the early years of life (Olstad & McCargar, 2009), yet little is known about the impact of physical activity on healthy growth and development during the preschool years (defined as ages 3-to 5-year olds for the purpose of this thesis). The limited evidence that exists in preschoolers suggests that physical activity, especially more intense activity, is associated with improved bone health (Janz *et al.*, 2005), motor skills (Williams *et al.*, 2008), body composition (Moore *et al.*, 1995), aerobic fitness (Alpert *et al.*, 1990), and a decrease in traditional cardiovascular risk factors (Saakslahti *et al.*, 2004). Currently, there are no Physical Activity Guidelines for Canadian children under the age of 5, and there is limited research investigating physical activity prevalence and patterns in Canadian preschoolers.

The perception that preschoolers are continuously engaged in active behaviours, thus 'active enough' (Timmons *et al.*, 2007), has reduced the attention and emphasis on the need for health-related fitness research in the early years. In fact, Canadian preschoolers are not immune to obesity trends, as significant increases in obesity prevalence have been observed in the past two decades (Canning *et al.*, 2004), and research suggests that preschool children are highly vulnerable to the early adoption of obesogenic behaviours (Reilly, 2008). Canadian data suggest that, in 2004, 21% of children between the ages of 2 and 5 years were overweight or obese (Shields, 2006). Worldwide, the high prevalence of overweight/obesity in young children has increased public concern and attention on physical activity as a modifiable influence on energy balance and body composition (Oliver *et al.*, 2007).

Physical activity can be described in terms of prevalence: the amount of physical activity (i.e., in min per day); and in terms of patterns: how that physical activity is accumulated (i.e., short bouts or long bouts). To date, no research has investigated the link between physical activity patterns and body composition in preschoolers. As with assessments of body composition, health-related fitness provides important insight into cardiovascular and metabolic health (Twisk *et al.*, 2002). Unfortunately, fitness has rarely been characterized in preschool children and there is a paucity of literature regarding the relationships between fitness and physical activity in young children. Elevated blood pressure in childhood is predictive of increased cardiovascular risk later in life (Raitakari *et al.*, 2003), yet literature describing blood pressure during the preschool years is sparse and it is not known if, or how, physical activity influences blood pressure in preschoolers. Investigations into the relationships between body composition, health-related fitness, blood pressure, and physical activity are warranted. If it can be determined that a relationship between physical activity and health exists, it becomes important to identify and target children who are not engaging in sufficient activity for optimal health. Thus, it is in the interest of preschooler health and public health policy to understand the relationships between physical activity and health measures in the early years.

1.2 PHYSICAL ACTIVITY

Physical activity (PA) is defined as any bodily movement generated by skeletal muscles that results in energy expenditure above resting levels (Caspersen *et al.*, 1985). As described by Malina (2001) and Okely et al. (2008), there are several pathways by which PA may directly or indirectly influence health. These pathways provide the justification for promoting PA in childhood:

1. *Childhood PA directly benefits childhood health (i.e., fitness, body composition, cardiovascular risk factors)*
2. *Childhood PA directly benefits adult health (i.e., bone mineral content)*
3. *Childhood PA indirectly benefits adult health by influencing childhood health (tracking of health and risk factors)*
4. *Childhood PA indirectly benefits adult health by influencing adult PA (tracking of PA)*

The focus of this thesis will be on Pathway 1 (*Childhood PA directly benefits childhood health*); however, the other pathways will be discussed where appropriate. With respect to indirect influences on health (Pathways 3 and 4), clinical manifestations of diseases and risk factors for metabolic and cardiovascular conditions often do not appear until adulthood; thus, clinical endpoints and even some risk factors are not appropriate for the classification of health during early childhood (Baranowski *et al.*, 1992). If risk factors are apparent in childhood and are predictive of future clinical manifestations, assessment is valuable; keeping in mind that the variation expected to be seen in young children is low (Baranowski *et al.*, 1992). Furthermore, it is important to determine changes in health measures and risk factors due to normal growth and maturation, so that these effects can be distinguished from the influence of PA. Likewise, where literature in preschool children is sparse, it may be necessary to first understand the relationships observed in older children and adults in order to identify the relationships between health and PA in younger children (Boreham & Riddoch, 2001).

1.2.1 Assessment of Physical Activity

Accurate assessment of PA is vitally important when examining the relationships between PA and health. The strength of the relationship to a given health measure is reduced if PA is not precisely characterized; thus, it is worth reviewing the different methods of PA measurement to justify the method chosen in this thesis.

Self-reports of PA rely on the participant's ability to recall or report PA. They are notoriously inaccurate (Oliver *et al.*, 2007) and tend to overestimate the quantity of PA compared to direct measures (Adamo *et al.*, 2009). Structured activities in which preschoolers participate are easy to identify (e.g., gymnastics class, swimming lessons); however, they only make up a small proportion of a preschoolers' daily PA (Tucker, 2008). Thus, it is the unstructured activities that make up the majority of a preschoolers' daily PA that are very difficult to quantify using a questionnaire. Furthermore, in young children, it is the parents or teachers who complete such questionnaires or reports on behalf of the child. While proxy reports of PA may be useful for rank-ordering purposes, they cannot provide accurate estimates of duration and intensity of PA (Okely *et al.*, 2008).

Direct observation of PA has the advantage of capturing very detailed information about individual movement patterns. This method, however, is extremely time-consuming and not feasible in large-scale studies over long measuring periods (Oliver *et al.*, 2007). Objective methods of quantifying PA are advantageous as they avoid biases associated with proxy-reports and research bias in coding of PA intensities (Oliver *et al.*, 2007).

The doubly-labeled water method is considered the gold-standard for energy expenditure quantification; however, it is very costly and can only provide a cumulative measure over the monitoring period without providing insight into hourly or even daily variation in activity (Adamo *et al.*, 2009). Accelerometers, on the other hand, are small, non-invasive, reliable devices that are able to record frequency, duration, and intensity of everyday activities. Validation studies in children have observed high correlation between accelerometry-derived PA and direct observation analysis (Kelly *et al.*, 2004) and energy expenditure (Puyau *et al.*, 2004). Accelerometry has become a widely used and accepted measure for PA quantification and is the preferred method in young children (Trost *et al.*, 2000, 2005).

1.2.1.1 Accelerometry

Accelerometers are small (approximately the size of a matchbox), light (< 30g), and robust devices that are typically attached to a band worn around the hip. Some devices have the technology to measure motion in three planes: vertical, horizontal, and perpendicular. This thesis will focus only on devices that assess PA by measuring all motions in the vertical plane. Accelerometers are non-invasive and rarely get in the way of daily activities (Cliff *et al.*, 2009). Accelerometers can assess PA with high resolution, using short measurement intervals (e.g., every 3 sec). This is especially beneficial in young children, whose movement is characterized by short, intermittent bouts of PA (Bailey *et al.*, 1995; Baquet *et al.*, 2007; Obeid *et al.*, 2011). Vertical accelerations are sampled multiple times every sec and then converted from an analog to digital series of numbers known as 'raw counts' (Chen & Bassett, 2005). These samples are summed over user-specified intervals known as 'epochs' and stored in memory. Accelerations that fall outside the range of normal human motion are filtered out. The devices are capable of measuring PA over long periods of time (up to 20 days) and can provide high resolution assessment (Actigraph, 2010).

While accelerometers effectively capture frequency, duration, and intensity of PA and eliminate reporting biases, they are not without limitations. Accelerometers are only able to measure the motion of the limb they are attached to (e.g., hips, wrists) and they are not able to account for the increases in energy expenditure associated with walking up an incline or carrying a load (Cliff *et al.*, 2009). Furthermore, they do not accurately measure activities that occur mainly in the horizontal plane, such as skating. The majority of accelerometers are not waterproof, meaning they cannot measure energy expenditure associated with swimming and water sports. Notwithstanding these limitations, accelerometry is very well suited for PA quantification in young children (Cliff *et al.*, 2009).

1.2.1.2 Epoch Length and Wear Criteria

Traditionally, a 1 minute (min) epoch (measurement interval) has been used in accelerometry studies, meaning that accelerations are summed and averaged each min. Older accelerometry studies were limited by the technology, specifically by the amount of memory available. An epoch choice of 1 min was largely determined by the technology and then reproduced by later studies maintaining the same approach (Trost *et al.*, 2005). While a 1 min epoch may provide accurate PA estimations in older populations who engage in less sporadic activity, the intermittent nature of young children's PA requires higher resolution assessment for accuracy. Our lab confirmed findings from previous studies showing that vigorous PA in preschoolers is often misclassified as lower intensity activity when longer epochs are used (i.e., 60 sec) (Vale *et al.*, 2010; Obeid *et al.*, 2011). Compared to using a 3 sec epoch, 60, 30, and 15 sec epochs missed 78%, 66%, and 48% of daily vigorous PA, respectively (Obeid *et al.*, 2011). This occurs because within a 1 min epoch, short bouts of vigorous activity are combined with longer bouts of lower intensity or sedentary behaviour, resulting in an averaged value of lower intensity activity. This phenomenon bears relevance when monitoring PA in young populations, as it is quite common to observe short bursts of high intensity movement between longer bouts of lower intensity (Bailey *et al.*, 1995; Obeid *et al.*, 2011). In children, it is therefore recommended to use a short epoch for PA assessment (Trost *et al.*, 2005; Obeid *et al.*, 2011).

The number of days and hours per day of accelerometry necessary for accurate assessment of habitual PA is an important consideration. Penpraze et al. (2006) found that in preschool children, at least 3 days of monitoring with 10 hours per day of wear was sufficient ($R > 0.60$), although 7 days maximized ($R = 0.80$) reliability. Little difference in reliability coefficients was observed using 3 or 10 hours per day of wear (Penpraze *et al.*, 2006). Likewise, including a weekend day in analysis makes no significant difference to the reliability of overall estimates of PA (Penpraze *et al.*, 2006; Sigmund *et al.*, 2007; Obeid *et al.*, 2011). Inclusion criteria in studies investigating whether PA guidelines have been met (absolute min per day) often require 10 hours of wear time for a valid day (Vale *et al.*, 2010; Beets *et al.*, 2011). When relative PA is the outcome (% of day in PA or average counts per min), common wear time inclusion criteria in the preschool literature requires at least 3 days of wear with >5 and <18 hours of monitoring per day (Williams *et al.*, 2008; Pfeiffer *et al.*, 2009; Cliff *et al.*, 2009).

1.2.1.3 Analysis of Accelerometer Data

Following the monitoring period, the data stored in the accelerometer must be uploaded, cleaned, and analyzed. Various criteria exist to clean and analyze the data, however, there is currently no consensus (Cliff *et al.*, 2009). Cleaning describes the process of screening the data and removing any periods during which the accelerometer was not worn. The accelerometer cannot be turned “off” when it is not being worn, resulting in times when the device may record movement when the participant is not wearing it. For example, if a child removes his accelerometer and hands it to his parent prior to a nap, the accelerometer will record all of the motions created by the parent while holding and moving with the device. In this case, instead of consecutive counts of '0' recorded during the non-wear time, higher counts will be captured by the accelerometer, and must be removed from the analysis. Periods of non-wear can be removed from the data (e.g., sleep, swim, naps). Cleaning can be done visually, in combination with a diary filled out by the participant or parent, indicating times when the accelerometer was worn. Other approaches include defining non-wear time as a certain number of min of consecutive '0' counts, as given the sensitive nature of the device, it is assumed that even small motions will create a value greater than zero (Cliff *et al.*, 2009). It is common to categorize 20 min of consecutive '0' counts as non-wear time, as a study in children reported 17 min as the longest period of motionless data (Esliger *et al.*, 2005). One must be cautious, however, as an accelerometer on a child who is reading or watching TV may record many minutes of consecutive '0' counts because they are actually 'motionless' during that time (Cliff *et al.*, 2009). Distinction between periods of non-wear and true motionless time (e.g., reading, watching TV) must be made for accurate PA assessment.

Raw accelerometer counts are unit-less and must be converted into a value with meaning. Accelerometer calibration studies use energy expenditure (indirect calorimetry) or direct observation to develop count thresholds, known as cut-points, which correspond to PA intensities. Numerous studies are dedicated entirely to the creation of cut-points. Cut-points for preschoolers vary significantly between studies; unfortunately, there is no standardized approach (Cliff *et al.*, 2009). Cut-points by Pate et al. (2006) were developed using a portable indirect calorimetry system in a group of 30 preschoolers during unstructured indoor and outdoor play and structured walking and running.

Correlations between VO_2 and accelerometry counts was high (r = 0.82) and was cross-validated in a subsequent analysis. Cut-points for moderate activity were defined at a VO_2 of 20mL/kg/min (discrimination between slow and brisk walking) as 420 counts/15 sec and vigorous activity at a VO_2 of 30mL/kg/min (discrimination between brisk walking and jogging) as 840 counts/15 sec (Figure 1).

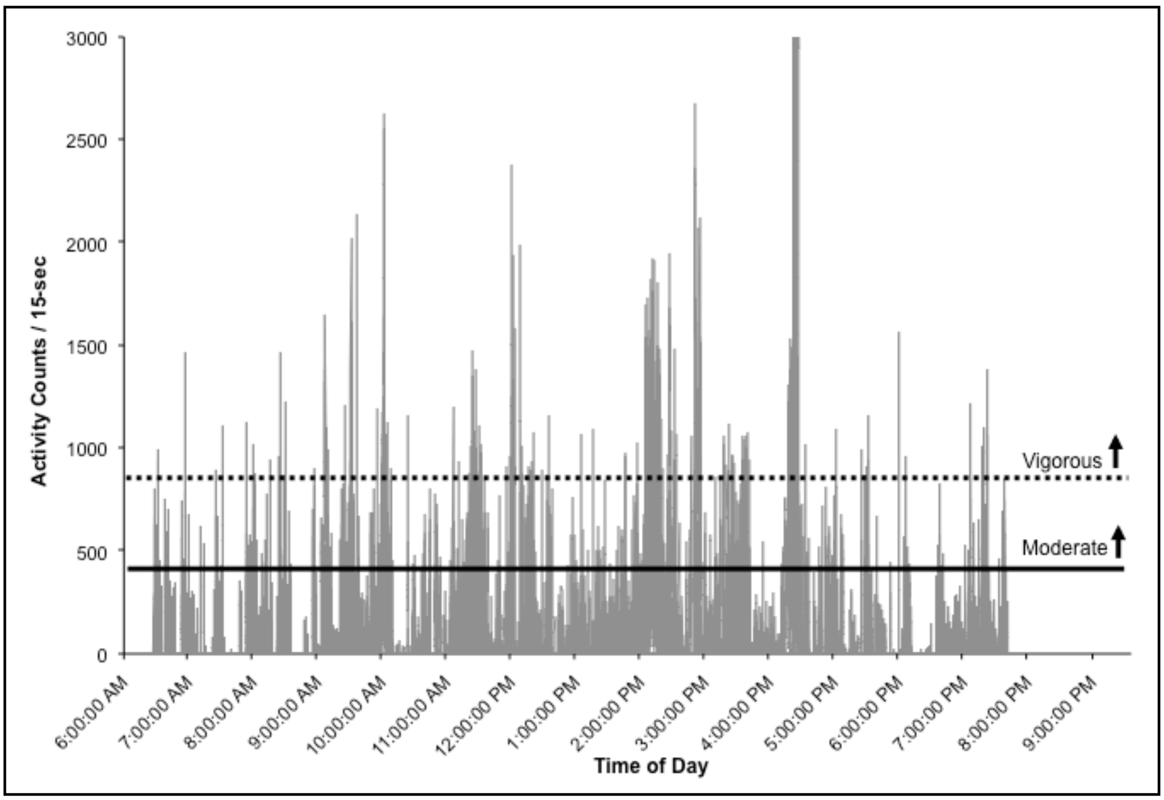

Figure 1. Example of accelerometer output using Pate et al. (2006) cut-points. Time of day is indicated on the x-axis and counts per 15 sec epoch are indicated on the y-axis. Times spent in moderate PA are indicated by the solid black line (≥420 counts/15 sec) and vigorous PA by the dotted black line (≥840 counts/15 sec).

Other calibration studies have used direct observation, whereby the examiner classifies the intensity of movement of a child that is then compared to the accelerometer data. Using the Puyau et al. cut-points (2002), validated by direct observation, moderate activity is defined as ≥ 800 counts/15 sec and vigorous activity as ≥ 2050 counts/15 sec, which is almost double the moderate and 2.5 times the vigorous cut-points defined by Pate et al. (2006). When reviewing the PA literature it is important to consider the intensity thresholds used, as different cut-points can radically alter PA outcomes. Beets et al. (2011) recently examined PA in preschoolers using four common cut-points and discovered discrepancies so drastic that moderate to vigorous activity (MVPA) ranged from 39.5 to 269.0 min per day. The lack of standardization in cut-point use makes it difficult to compare study results. Recently, prediction equations to harmonize the most common cut-points have been developed (Bornstein *et al.*, 2011), and this procedure may aid in the comparison of PA between studies.

Expressing PA in minutes per day is most convenient for conveying recommendations to the public and practitioners, and for assessing compliance with recommendations; however, this absolute expression of PA is biased by the duration that the accelerometer is worn. While accelerometers are fairly unobtrusive, it is important to keep in mind that not all participants comply with instructions to wear the accelerometer during all waking hours. Some children do not take to the device as favorably as others; thus, it is common for the accelerometer to be taken off for breaks during the day or not worn for the entire day. Expressing PA in only absolute terms (min/day) could favor the children who wore the device for the longest amount of time. Therefore, to remove wear time biases and facilitate comparisons between participants, PA can be expressed relative to the duration the accelerometer was worn (i.e., % of wear time) (Cliff *et al.*, 2009)

1.2.2 Physical Activity Prevalence and Patterns

Preschool children accumulate the majority of their daily PA through active play rather than through structured activities such as team sports (Tucker, 2008). Play has been described as the spontaneous activity in which children engage to amuse and to occupy themselves (Burdette & Whitaker, 2005). PA prevalence refers to how much PA is engaged in (i.e., amount), while PA patterns describe how that PA is accumulated (i.e., frequency, duration, and intensity). PA in young children is characterized by short, intermittent bouts of intense movement between longer bouts of lower intensity movement (Bailey *et al.*, 1995; Baquet *et al.*, 2007; Obeid *et al.*, 2011). In his seminal article, Bailey et al. (1995) observed that 95% of children's (6- to 10-year olds) high intensity activity lasted 15 sec or less. The median duration of high intensity activity was 3 sec, the smallest interval detected by their direct observation system. Further, a study in children using accelerometry and a higher resolution capability (2 sec epoch) affirmed that the duration of 95% of children's vigorous activities was 10 sec or less, with vigorous activities lasting 4.7 sec on average. Recently, these patterns were confirmed in preschool children, with 98% and 95% of vigorous and MVPA occurring in bouts of 15 sec or less, respectively (Obeid *et al.*, 2011). Besides the work of Obeid et al. (2011), PA literature in preschool children focuses only on PA prevalence. Recent work in older children has identified that how PA is accumulated (pattern) may be just as important to health as how much activity is accumulated (prevalence) (Stone *et al.*, 2009); thus, investigations into PA patterns are warranted in preschoolers.

Preschoolers spend the majority of their day in inactive or sedentary pursuits, with estimates ranging from 74% to 84% of the day (Reilly *et al.*, 2004; Fisher *et al.*, 2005; Kelly *et al.*, 2007; Vale *et al.*, 2010). This suggests that in a typical 12-14 h day, young children engage in between 2 to 4 h of PA. Estimates of daily time spent in MVPA ranges from 3 to 13% (Reilly *et al.*, 2004, 2006; Pate *et al.*, 2004; Fisher *et al.*, 2005; Kelly *et al.*, 2007; Pfeiffer *et al.*, 2009; Vale *et al.*, 2010), which equates to 25 to 110 min of MVPA, depending on the cut-points used.

1.2.2.1 Sex and Age Influences

Whether assessing PA using direct observation or objective measuring systems, consistent within the preschool literature is that boys are more active than girls (Janz *et al.*, 2001; Finn *et al.*, 2002; Pate *et al.*, 2004; Fisher *et al.*, 2005; Hinkley *et al.*, 2008; Vale *et al.*, 2010). The majority of studies also show that boys engage in more vigorous activities compared to girls (Janz *et al.*, 2001; Finn *et al.*, 2002; Janz, 2002; Saakslahti *et al.*, 2004; Pate *et al.*, 2004; Pfeiffer *et al.*, 2009; Vale *et al.*, 2010), while some studies have observed no sex differences (Temple *et al.*, 2009; Obeid *et al.*, 2011), and others observed sex differences only in older preschool children (5 years old) (Reilly *et al.*, 2004). Within the preschool age range, some have shown that vigorous activities increase with age in boys and girls (Pfeiffer *et al.*, 2009), while others have only noted this in boys (Jackson *et al.*, 2003; Reilly *et al.*, 2004). This thesis will fill an important gap in knowledge by characterizing sex and age associations with PA patterns.

1.2.3 Compliance with Physical Activity Guidelines

The purpose of evidence-based PA guidelines is to inform public health policy, health professionals, and early educators, and for knowledge translation to the general public. If a relationship between PA and health exists, it is important to be able to document what proportion of the population is obtaining the health benefits of PA and what segments need to be targeted to increase their levels of PA (Baranowski *et al.*, 1992). Current recommendations for preschoolers differ between countries. The National Association for Sport and Physical Education (NASPE) in the United States recommends that preschoolers accumulate at least 60 min of structured and 60 min of unstructured PA daily (120 min total) daily (National Association for Sport and Physical Education, 2009). Unfortunately, there was little scientific basis for the creation of these guidelines, including a lack of evidence supporting separate amounts of structured and unstructured PA. This is likely due in part to the limited evidence available to inform such recommendations. Increasingly, as more literature becomes available, PA guideline development is being informed by systematic reviews of the evidence. Examples of evidence-based guideline development include the recently released Australia (AUS) and United Kingdom (UK) guidelines which recommend that preschoolers be physically active for at least 3 hours daily (180 min), with no PA intensity specified (Australian Government Department of Health and Ageing, 2011; Department of Health, 2011). Canada does not currently have PA guidelines for children under the age of 5, although a group of researchers is working on this issue in partnership with the Canadian Society for Exercise Physiology. For children age 5 and older, however, it is recommended that 60 min of MVPA be accumulated every day (Canadian Society for Exercise Physiology, 2011). Whether these recommendations are appropriate for preschoolers is worth evaluating.

Researchers in various countries have examined if preschool children are meeting the existing PA recommendations. With respect to the NASPE recommendations of 120 min of PA daily, observations range from the majority of preschoolers not meeting (Dowda *et al.*, 2004; Benham-Deal, 2005; Cardon & De Bourdeaudhuij, 2008), to 74.3% compliance with the recommendations (Vale *et al.*, 2010). A small Canadian study found that all 30 participants met the NASPE recommendations of 120 min of PA daily (Obeid *et al.*, 2011). Likewise, no consensus has been reached with respect to the number of preschool-aged children meeting the Canadian guidelines of 60 min of MVPA daily for children 5 years and older. Telford et al. (2005) and Vale et al. (2010) found high compliance with these recommendations in preschoolers, while other have not (Reilly *et al.*, 2004; Cardon & De Bourdeaudhuij, 2008). A systematic review by Tucker (2008) estimated that only 54% of preschool children achieve 60 min of MVPA daily. Given their recent release, no study has yet examined compliance with the AUS and UK PA recommendations of 3 h of PA daily. When assessing compliance with PA guidelines, it is important to reiterate the importance and influence of cut-points. Beets et al. (2011) compared four common cut-points and found that compliance for 60 min MVPA daily ranged from 99.5% to 0.5% depending on the cut-points used. This may explain the discrepancies in the number of children meeting the guidelines between the studies noted above. Whether preschoolers are meeting PA recommendations depends on the country of residence, the guidelines investigated, and the cut-point used to define MVPA.

1.3 BODY COMPOSITION

The World Health Organization estimated that in 2010, 42 million children around the world under the age of five were overweight or obese (WHO, 2011*a*). Canadian data indicate that 15.2% and 6.3% of 2-to 5-year olds are overweight or obese, respectively (Shields, 2006). Overweight/obesity status exhibits tracking from early childhood into later childhood and adulthood (Whitaker *et al.*, 1997; Quattrin *et al.*, 2005) and a child who is overweight before the age of 6 is 4 times more likely to be overweight as an adult (Freedman *et al.*, 2005). The high prevalence of obesity among preschoolers has garnered increased public attention regarding associated health consequences.

Body composition is frequently assessed as a marker for health in children and adults. Multiple diseases have been linked to obesity in adulthood, including cardiovascular diseases, certain cancers, Type 2 diabetes, and osteoarthritis (Katzmarzyk & Janssen, 2004). Risk factors (e.g., hyperinsulinemia, impaired glucose tolerance, hypertension) for these diseases are more prevalent in children with higher adiposity (Maffeis *et al.*, 2001) and track from childhood into adulthood (Lobstein *et al.*, 2004). Children who are overweight at a young age have an increased risk of developing cardiovascular and metabolic conditions later in life (Must & Strauss, 1999; Twisk *et al.*, 2002; Baker *et al.*, 2007). Overweight and obese preschoolers have higher blood pressures than their normal weight peers (Gopinath *et al.*, 2011*a*). While little research exists examining the link between body composition and other health measures in preschoolers, the known health consequences of overweight/obesity in older children and adults highlight the necessity of interventions targeting childhood obesity.

1.3.1 Assessment of Body Composition

A wide range of methods are available to assess adiposity in children. Dual energy x-ray absorptiometry (DXA) is a full body scan that provides estimations of lean and fat mass. While providing a 'gold standard' upon which to validate anthropometric measures of adiposity, this method is expensive and therefore used mainly in a research setting. DXA also requires participants to lie still for several minutes – a request not always feasible in preschoolers (Lobstein *et al.*, 2004). Bioelectrical Impedance Analysis (BIA) is a quick and inexpensive assessment that measures the resistance of body tissues to the flow of a small electrical current (less than 1 mA). Conductivity of the electrical current is highest in blood and urine, intermediate in muscle, and low in bone and fat (Anon, 1996). BIA provides an estimate of total body water, which can be used in DXA-validated prediction equations to estimate lean and fat mass and body fat percentage (BF%) (Kriemler *et al.*, 2009).

Anthropometric measures of body composition include body mass index (BMI) and waist circumference (WC). BMI is defined as weight / height^2 (kg/m^2) and is frequently assessed due to the ease of measurement in a clinical and research setting. BMI has demonstrated high correlation with DXA total body fat ($r = 0.85$) in children and adolescents (Pietrobelli *et al.*, 1998). Furthermore, BMI has demonstrated a moderate true positive rate (0.71) and a low false positive rate (0.05) in predicting children and adolescents with a high BF% (Lazarus *et al.*, 1996). This means that while some overweight children may be incorrectly identified as normal weight using BMI, few children will be identified as overweight when they are not. Incorrect classification as overweight/obese can occur when a person has relatively high lean mass, as BMI cannot discriminate between fat and muscle mass.

WC is an indirect measure of central adiposity that is easy to assess with low cost. Although unable to discriminate between intra-abdominal and subcutaneous adipose tissue, it is, unlike BMI, able to provide information on the pattern of fat distribution. WC is a sensitive marker of cardiovascular risk (Maffeis *et al.*, 2001) and may be a better predictor of cardiovascular risk than BMI in children (Watts *et al.*, 2008) and adults (Han *et al.*, 1998). Validated against DXA, WC correctly identified a high proportion ($r = 0.84$) of children and adolescents with high trunk fat mass (Goran *et al.*, 1998; Taylor *et al.*, 2000, 2008). WC in children is typically measured at the midpoint between the last floating rib and the iliac crest (Maffeis *et al.*, 2001), although it has also been assessed at the lateral border of the iliac crest (Fernández *et al.*, 2004; Taylor *et al.*, 2011). Of these 2 measures, the midpoint between the last floating rib and the iliac crest is most highly correlated with metabolic risk in overweight children (Johnson *et al.*, 2010).

1.3.2 Classification of Overweight and Obesity

The purpose of classifying one's body composition is to predict health risks and to make comparisons between populations (Lobstein *et al.*, 2004). BF% and BMI naturally increase in the first years of life, and then gradually decline until around 6 years of age where a nadir is reached before rising again. Sex differences in body composition are observed in preschoolers, with girls possessing higher fat mass than boys (Taylor *et al.*, 2008). Because of these changes with growth, absolute values cannot be compared between children of different ages and sex. For classification of weight status using BMI, it is recommended that the 85^{th} and 95^{th} percentiles of the Centre for Disease Control (CDC) BMI percentiles be used to classify overweight and obesity, respectively (Lobstein *et al.*, 2004). This classification has been criticized, however, as the prevalence of overweight/obesity using the age-related percentiles is set at a fixed proportion of the population (Bellizzi & Dietz, 1999). Cutoffs created by the International Obesity Task Force (IOTF), which statistically link the adult BMI cutoffs of 25 and 30 kg/m^2 that correspond to childhood BMIs, are also recommended (Cole *et al.*, 2000*b*). Compared to the CDC charts, which were created using data from the United States only (Kuczmarski *et al.*, 2002), the IOTF classification system was derived using large datasets from multiple countries. Therefore, the IOTF method is often used in the research setting to compare populations world-wide. As with the example provided for compliance with PA guidelines, the prevalence of overweight/obesity significantly differs depending on which classification system is used. The IOTF system generally gives a more conservative picture of overweight/obesity status compared to the CDC method. For example, 21.5 vs. 30.2% of 2- to 5-year old Canadians are classified as overweight using the IOTF and CDC methods, respectively (Shields & Tremblay, 2010). It is not known which method is most accurate at assessing health risk; therefore, it is recommended to examine associations between BMI and health using both methods (Shields & Tremblay, 2010).

While there is no consensus on classification of overweight/obesity status using BF% and WC in children, percentiles and cut-offs have been created. Taylor et al. (2002) created BF% cutoffs using DXA that correspond to the IOTF BMI thresholds for overweight and obesity in 3- to 18-year olds. Percentiles for WC have also been developed for children as young as 2 years of age in the United States (Fernández *et al.*, 2004).

1.3.3 Relationships between Body Composition and Physical Activity

Weight gain results from a positive energy balance, when energy consumed is greater than energy expended. PA is a modifiable factor that plays an important role in overall energy balance. The relationship between body composition and PA may be bidirectional and cyclical, where low PA leads to increased overweight/obesity, which in turn leads to low PA involvement, ultimately exacerbating overweight/obesity status (Kwon *et al.*, 2011). The adult literature consistently demonstrates that obesity is negatively related with future PA (Petersen *et al.*, 2004; Ekelund *et al.*, 2008). Many cross-sectional studies have observed that overweight or obese preschoolers have lower PA levels than their normal weight peers (Davies *et al.*, 1995; Takahashi *et al.*, 1999; Janz, 2002; Trost *et al.*, 2003; Janz *et al.*, 2005; Jago *et al.*, 2005; Metallinos-Katsaras *et al.*, 2007). In longitudinal analyses, preschoolers who were more active at baseline experienced smaller gains in adiposity; whereas, less active children gained significantly more fat mass (Klesges *et al.*, 1995; Moore *et al.*, 1995). A 14-week PA and diet intervention study in 5-to 6-year olds observed post-intervention decreases in BMI, BF%, and increases in PA compared to the control group (Eliakim *et al.*, 2007). These studies highlight the significance of PA to current and future preschooler body composition and health. Dose-response relationships between PA and body composition remain undefined in preschoolers (Reilly, 2008), including the impact of PA intensity on overweight/obesity status.

1.4 HEALTH-RELATED FITNESS

"Health-related fitness" is a term used to denote characteristics that are related to the prevention of disease or the promotion of health (Caspersen *et al.*, 1985; Pate, 1991). "Skill–related fitness" is something different and refers to characteristics that indicate athletic ability, but are not known to provide additional health benefits (e.g., long jump) (Caspersen *et al.*, 1985). Tests of skill-related fitness tend to reward the athlete while penalizing the uncoordinated (Baranowski *et al.*, 1992). A person may be able to train to do well on these assessments without necessarily being 'fit'. By definition, if one were to train for a health-related fitness test, their training would result in improved health. For the purpose of this thesis, health-related fitness is considered to be reflected in aerobic fitness and short-term muscle power (anaerobic fitness).

1.4.1 Aerobic Fitness

The fitness most commonly associated with health is aerobic fitness - the ability to sustain whole-body, moderate intensity activity over extended periods of time (Boreham & Riddoch, 2001). Aerobic fitness has been studied extensively in older children and adults, and has been observed to track from childhood into adulthood (Twisk *et al.*, 2002). In adults, lower aerobic fitness has been linked to an increased risk of cardiovascular disease mortality (Lee *et al.*, 1999). Studies conducted in youth have similarly shown a protective effect of aerobic fitness on metabolic and cardiovascular health (Twisk *et al.*, 2002; Steele *et al.*, 2008). Low aerobic fitness in childhood is associated with cardiovascular disease risk factors (Hofman & Walter, 1989; Eiberg *et al.*, 2005; Anderssen *et al.*, 2007). In preschoolers, however, there is paucity of literature characterizing aerobic fitness. Furthermore, health-related fitness assessments in older children and adults cannot be assumed to be relevant to health in preschoolers. The lack of health-related fitness research in preschoolers may be in part due to the belief that this population is naturally active and, therefore, physically fit (Nguyen *et al.*, 2011).

The best measure of aerobic fitness is peak oxygen consumption (VO_{2peak}) using indirect calorimetry (Dencker *et al.*, 2010). There are several issues preventing this method from being used in preschool children, including problems resulting from children being frightened by the mouthpiece and nose clip; thus, VO_{2peak} is not commonly assessed in preschoolers. In one European study that did use this method, an average VO_{2peak} of 50 ml/kg/min was observed in children 7 years before the age of peak height velocity (approximately 5- to 7-year olds) (Rutenfranz *et al.*, 1982). Treadmill testing is preferred over cycling in young children because their relatively undeveloped knee extensors cause local fatigue and premature termination of cycling tests (Bar-Or & Rowland, 2004). Reliability studies have confirmed that children as young as 3 years are capable of walking and running on a treadmill (Nguyen *et al.*, 2011), and maximal assessments have been shown feasible in children 4 years and older (Cumming *et al.*, 1978; Wessel *et al.*, 2001; van der Cammen-van Zijp *et al.*, 2010).

One of the most common treadmill tests of aerobic fitness is the Bruce Protocol. The Bruce Protocol is an incremental, maximal treadmill test that has high reproducibility and has been used worldwide on children as young as 4 years old (Cumming *et al.*, 1978; Wessel *et al.*, 2001; van der Cammen-van Zijp *et al.*, 2010). Earlier studies conducted this maximal assessment without allowing children to hold onto the handrails, as holding on reduces the metabolic costs of work (Cumming *et al.*, 1978). More recently, studies in preschoolers have permitted holding onto handrails to alleviate possible balance problems in preschoolers (van der Cammen-van Zijp *et al.*, 2010). Time until exhaustion is used to assess fitness, with normative data available for children 4 years and older for both holding and not holding the handrails (Cumming *et al.*, 1978; Wessel *et al.*, 2001; van der Cammen-van Zijp *et al.*, 2010). In 4- to 5-year old children using handrails for support, mean duration until exhaustion was 10.2 ± 1.5 min. No study to date has published normative values for children younger than 4 years of age. In children, it is important to consider age-related differences in efficiency of walking and running, where younger children are less efficient than their older peers (Cumming *et al.*, 1978). Further, fitness assessed using only endurance time should be used with caution in young children, as two children of the same age and size may have different abilities to walk and run (i.e., motor skills) resulting in different endurance times that may not be reflective of different energy metabolism (i.e., VO_{2peak}) (Cumming *et al.*, 1978). Anecdotally, the success of this protocol has hinged on the motivation of the child to continue until exhaustion as well as the skill of the researcher in dealing with young children (Cumming *et al.*, 1978). Assessments using the Bruce Protocol found that 4- to 5-year old girls exercised for a longer duration until exhaustion compared to the boys (Lenk *et al.*, 1998; van der Cammen-van Zijp *et al.*, 2010), while others have observed the opposite (Cumming *et al.*, 1978; Wessel *et al.*, 2001).

Conducting maximal assessments is very challenging in a young population; thus, submaximal treadmill assessments are often used in their place, with heart rate (HR) as a surrogate measure of aerobic fitness (Alpert *et al.*, 1990; Gutin *et al.*, 1990; Shea *et al.*, 1994). It is assumed that a higher workload at a specified HR (e.g., 170 bpm) indicates enhanced fitness. However, this method ignores variables that might result in lower performance, such as poor motor coordination and size differences, which are not necessarily reflective of a lower VO_{2peak}. Thus, other methods to assess aerobic fitness in preschoolers will be discussed below.

1.4.1.1 Heart Rate Recovery

Heart rate recovery (HRR) following exercise is an accepted proxy of aerobic fitness in adults (Darr *et al.*, 1988) and is correlated with VO_{2peak} (Wang *et al.*, 2006). Attenuated HRR at 1 and 2 min following exercise is a cardiovascular risk factor and an independent predictor of mortality in healthy adults (Cole *et al.*, 1999, 2000*a*) and those with cardiovascular disease (Vivekananthan *et al.*, 2003). While health in young children cannot be judged by mortality statistics, risk factors can be assessed, recognizing that risk factors may only contribute to part of an eventual mortality or clinical manifestation (Boreham & Riddoch, 2001). It is possible that HRR in young children may be useful in predicting future health. Recently, HRR demonstrated an inverse association with metabolic risk factors in healthy children and adolescents (Lin *et al.*, 2008). HRR was slower in children (mean age 13.5 years) with higher BMI and lower exercise endurance (Singh *et al.*, 2008). Relationships between HRR and other health measures have not been examined in preschool children.

HR responses during exercise are controlled by the autonomic nervous system, with increases in HR mediated by an increase in sympathetic activity and concurrent parasympathetic withdrawal. HRR following exercise results from an interaction of parasympathetic reactivation and sympathetic withdrawal (Arai *et al.*, 1989; Pierpont & Voth, 2004). In a study investigating the physiology of HRR in healthy adults, athletes, and those with chronic heart conditions, vagal reactivation was the main determinant of HRR in all three groups (Imai *et al.*, 1994), suggesting that attenuated HRR following exercise is evidence of impaired parasympathetic reactivity. Adults with higher aerobic fitness recover faster from exercise than their less fit peers (Darr *et al.*, 1988). This observation has been explained by training induced changes in the balance between sympathetic and parasympathetic activation and withdrawal (Savin *et al.*, 1982).

HRR is faster in children compared to adults (Baraldi *et al.*, 1991). Increased parasympathetic activity in children, paired with a decreased contribution of sympathetic activity compared to adults, may account for children's faster recovery (Ohuchi *et al.*, 2000). Sex differences in HRR following maximal exercise have also been observed in children (Cumming *et al.*, 1978; Pels *et al.*, 1981; Washington *et al.*, 1988; Wessel *et al.*, 2001). A small study in 4- to 5-year olds observed a HRR of 81 bpm (boys) and 60 bpm (girls) following 2 min of recovery from the Bruce Protocol, with no differences at 5 min post exercise (Wessel *et al.*, 2001). Cumming et al. (1978) observed a HRR of 79 and 71 bpm in boys and girls, respectively, following the same maximal protocol and a 2 min recovery in 4-to 5-year olds. Recently, Nguyen et al. (2011) confirmed the reliability of HRR from submaximal exercise in a group of 3- to 5-year olds. No study has characterized HRR following maximal exercise in children under 4 years of age.

1.4.2 Short-term Muscle Power

Brief, high intensity activity is important for the development of muscle and bone mass (Armstrong & van Mechelen, 2008 Ch. 27). Correspondingly, PA patterns in children are characterized by short bouts of intense movement (Obeid *et al.*, 2011). It is not known if assessments of short-term muscle power are related to health in young children, or if they purely measure "skill–related fitness". However, given the intermittent nature of preschoolers' PA, the determination of short-term muscle power bears relevance to young children's movement patterns.

The Wingate Anerobic Test (WAnT) is a common laboratory assessment of anaerobic fitness. The WAnT is a 30 sec all-out sprint test on a cycle ergometer against a constant braking force, designed to provide measures of short-term muscle power. The applied braking force is proportional to body mass and induces noticeable fatigue within just a few seconds (Bar-Or, 1987). Power is a product of force and velocity, which can be calculated for the WAnT by multiplying the braking force by the total distance traveled (pedal revolutions × distance per revolution) divided by the duration of the test.

Two indices of power are typically measured: peak power (PP), the highest mechanical power output during the test, taken as an instantaneous value or as an average of the first 3 or 5 sec; and mean power (MP), the average power output throughout the entire test. PP reflects local muscle ability to produce high power in a short time, while MP reflects the local muscular endurance of the legs (Bar-Or, 1987). The test is highly reproducible and correlated with other field and laboratory anaerobic assessments in children and adolescents (Bar-Or, 1987). Until recently, the WAnT had not been performed in children under the age of five. As young children typically accumulate intense activity in bouts of 15 sec or less, a 10 sec modified WAnT was developed (Nguyen *et al.*, 2011). Subsequently, the feasibility and reliability of the modified WAnT was confirmed in a group of 30 preschoolers (Nguyen *et al.*, 2011). Studies using the WAnT in pubertal children have observed higher power output in boys compared to girls, along with an independent positive relationship between age and power output (Armstrong, 2001). These maturation-related findings are in agreement with evidence suggesting that the degree of motor unit activation is higher following puberty (Armstrong, 2001). It is not known how short-term muscle power relates to age and sex during the preschool years.

1.4.3 Relationships between Fitness and Physical Activity

As mentioned previously, there is a paucity of literature examining fitness in preschoolers; thus, little is known about the relationships between fitness and PA in preschoolers. In studies conducted in older children, significant yet weak positive relationships have been observed between PA and VO_{2peak} (r = 0.11 to 0.32) (Dencker *et al.*, 2006; Butte *et al.*, 2007). Similarly, in field studies, children who performed best on the fitness assessment (1.6 km distance run) were also more active (Pate *et al.*, 1990). An intervention study in preschoolers found that HR at three submaximal workloads was significantly reduced after 8 weeks of aerobic activities, indicating improved fitness in the intervention group (Alpert *et al.*, 1990). This suggests that fitness can be enhanced by PA in children as young as 3 years of age. Recently, Burgi et al. (2011) found that aerobic fitness, as assessed by the number of stages completed in a 20-m shuttle run test, was significantly related to total PA and MVPA in 4- to 6-year olds. Furthermore, vigorous PA was predictive of aerobic fitness 9 months later (Bürgi *et al.*, 2011). No study to date has examined the relationships between PA and HRR or short-term muscle power in preschoolers. Given the role PA may play in the development of aerobic fitness and short-term muscle power, and the influence of fitness on cardiovascular and metabolic health, investigation of these relationships is relevant to preschooler health.

1.5 BLOOD PRESSURE

Cardiovascular disease is the leading cause of death worldwide (WHO, 2011*b*). High blood pressure (BP) is the most important cardiovascular disease risk factor, contributing to an estimated one-half of cases of coronary heart disease and stroke (Whitworth, 2003; Lawes *et al.*, 2008). Signs of atherosclerosis (fatty streaks and fibrous plaques in aortic and coronary arteries) are visible even during childhood (Holman *et al.*, 1958); the Bogalusa Heart Study observed that the development of atherosclerosis in young people was related to elevated BP ($r = 0.55$) (Berenson *et al.*, 1998). There is increased clustering of other cardiovascular risk factors (i.e., high triglycerides, low HDL cholesterol, hyperinsulinemia, central adiposity) in children with elevated BP (Sinaiko *et al.*, 2002). Furthermore, BP in childhood demonstrates tracking into adulthood (Chen & Wang, 2008), and is associated with cardiovascular risk later in life (Raitakari *et al.*, 2003). The Cardiovascular Risk in Young Finns Study found that elevated BP in childhood was related to increased arterial stiffness in adulthood (Juonala *et al.*, 2005). Management of elevated BP in childhood may help to reduce the global disease burden caused by hypertension (Labarthe, 1999).

1.5.1 Assessment and Classification of Blood Pressure

Systolic blood presure (SBP) is the highest pressure within the systemic arteries during ventricular contraction. Diastolic blood pressure (DBP) is the lowest pressure within the systemic arteries during ventricular relaxation. Both SBP and DBP increase during childhood, as BP is related to height (Malina *et al.*, 2004). Traditionally, BP is measured by auscultation using a sphygmomanometer and a stethoscope over the brachial artery. SBP is defined by the onset of Korotkoff sounds, ‘tapping’, while DBP is indicated by the disappearance of Korotkoff sounds (Anon, 2004). Increasingly, automated oscillometric devices are being used in place of auscultation. The advantage of the automated system is the minimal training required for proficiency, removal of observer bias, and a potential reduction in ‘white-coat hypertension’ (rise in BP associated with the presence of a health care professional) (Myers & Valdivieso, 2003). Oscillometric devices function by measuring mean arterial pressure and subsequently calculating SBP and DBP using algorithms. The algorithms used differ between devices and do not always match BP values using auscultation (Butani & Morgenstern, 2003).

Oscillometric measurements in children tend to underestimate BP by approximately 1 – 4 mmHg (Wong *et al.*, 2006).

To account for normal growth and development, BP, in children including preschoolers, is classified by sex, height, and age using tables provided in the fourth report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (Anon, 2004). Normal BP is defined as a SBP and DBP percentile less than the 90th percentile; prehypertension as greater than or equal to the 90th but less than the 95th percentile; and hypertension as greater than or equal to the 95th percentile. As individual day-to-day BP variation is large, measurements on multiple occasions are required for a diagnosis of hypertension.

1.5.2 Relationships between Physical Activity and Blood Pressure

While PA is effective at reducing BP in adults (Mora *et al.*, 2007), there is a paucity of literature examining relationships between BP and PA in childhood. Recent studies in pre-pubertal children found that increases in PA were concurrent with reductions in SBP and DBP (Gopinath *et al.*, 2011*b*). Other studies propose that PA is effective in reducing BP in hypertensive youth, while normotensive individuals gain little benefit (Strong *et al.*, 2005). While older studies have observed an inverse relationship between BP and aerobic fitness in preschoolers (Gutin *et al.*, 1990; Shea *et al.*, 1994), it is not known how PA relates to BP in this young age group. PA may indirectly affect BP through energy balance and body composition, as preschoolers with higher BMIs have elevated SBP and DBP (Simonetti *et al.*, 2011; Gopinath *et al.*, 2011*a*). For the first time, this thesis will characterize the relationship between BP and PA in preschoolers.

1.6 Motor Skill Proficiency

The preschool period is termed the 'Golden Age of Motor Development' (Parizkova, 1996) and is characterized by further development of locomotor (running, jumping, galloping), stability and balance (static and dynamic), and object-control (throwing, kicking, catching) skills introduced in the toddler period (Parizkova, 1996). Improvement in these skills and activities occurs through specific opportunities to practice and receive feedback (Okely *et al.*, 2008). Parizkova (1996) emphasizes the necessity of providing opportunities to develop movement skills; just as children are not assumed to develop in other areas without assistance (e.g., language, attitude), they should not be assumed to naturally improve upon motor development. Motor skills have been observed to track during childhood at low to moderate levels (Malina, 1996). Motor skill development is a reflection of the integration of many body systems, including sensory, musculoskeletal, cardiorespiratory, and neurological systems (Dwyer *et al.*, 2009) and is observable in a child's ability to interact with his/her environment. Children with poor motor skills may choose to refrain from activities that they find challenging, thus, engage in less PA (Wrotniak *et al.*, 2006). It is possible that this negative influence on PA may result in an increased risk of overweight/obesity and poorer health-related fitness. The relationships between motor skill proficiency and other health measures remain to be investigated during the preschool years.

1.6.1 Assessment of Motor Proficiency

Motor skills can be assessed in terms of the process: the technique of performing a movement broken down into its components (e.g., runs with arms moving in opposition to legs with elbows bent), or the product: the result of the performance (e.g., completes run in less than 5 sec). The process and product are typically positively related, with the performance of the product improving as processes are enhanced (Malina *et al.*, 2004).

There are several tests of motor skill proficiency, with a concise description of each going beyond the scope of this thesis. Some of the more common measures among preschoolers include the Peabody Developmental Motor Scales (PDMS), which combine both process- and product-oriented tasks. This evaluation was developed for children up to 6 years of age to assess the relative developmental abilities of a child, along with identifying skills not completely developed (Wiart & Darrah, 2001). Other assessments frequently used include the Movement Assessment Battery for Children, Bruininks-Oseretsky Test of Motor Proficiency, and the Test of Gross Motor Development.

1.6.2 Relationships between Motor Skill Proficiency and Physical Activity

PA is quite visibly linked with the development of motor skills. As a child's mastery of skillful movement and interaction with his environment improves, so does his ability to be active (Dwyer *et al.*, 2009). A child with better motor skills may find it easier to engage in PA compared to his less competent peers (i.e., more efficient movement may result in lower energy expenditure); thus, the skilled child may choose to engage in more PA, while the less skilled child may choose more sedentary pursuits (Wrotniak *et al.*, 2006). It is quite possible that there is a threshold of motor skill proficiency, below which difficulties in interacting with one's environment lead to significantly lower PA. This was observed in a longitudinal study in 9-to 12-year olds with probable developmental coordination disorder (defined as below the 6th percentile of motor proficiency based on normative data), who persistently engaged in less PA compared to their coordinated peers (Cairney *et al.*, 2010).

In prepubertal children, motor skill proficiency demonstrates a positive relationship with PA and a negative relationship with adiposity (Wrotniak *et al.*, 2006). In a longitudinal analysis, motor proficiency at age 6 was predictive of PA three years later, with significantly higher PA in the group with highest motor skills (Lopes *et al.*, 2010). Significant yet weak relationships between MVPA and movement skills have been observed in preschoolers (r = 0.16 to 0.33) (Fisher *et al.*, 2005; Williams *et al.*, 2008). Williams et al. (2008) reported that even in the absence of obvious motor skill delays, preschool children with poorer fundamental movement skills were less active than children who were more proficient. Between boys and girls, no differences were observed in the overall composite scores of motor proficiency (Fisher *et al.*, 2005; Hardy *et al.*, 2010), while girls demonstrated better locomotor but poorer object control skills compared to boys (Hardy *et al.*, 2010). Because of the cross-sectional nature of investigations in preschoolers to date, it is not known whether limited motor development hinders a child's engagement in PA, or if limited engagement in PA impedes motor development (Fisher *et al.*, 2005). Recently, Burgi et al. (2011) followed a group of preschoolers over 9 months and found that higher baseline PA was predictive of improved motor skills at follow-up but not vice versa, suggesting that PA enhances motor skill development and not the other way around. As these observations are contrary to the longitudinal study in older children cited above, more studies are necessary to confirm this relationship. Regardless, evidence indicates that motor proficiency has an influential role on PA participation. Therefore, this thesis will improve our understanding in the area by taking motor skill proficiency into account when assessing relationships between PA and health measures.

1.6 RELATIONSHIPS BETWEEN HEALTH MEASURES

In the preceding paragraphs, specific relationships between PA and body composition, health-related fitness, BP, and motor proficiency have been discussed, providing a theoretical framework for this thesis (Figure 2). There are important relationships between these health measures in preschoolers that have yet to be discussed and have not been included in Figure 2. Less favorable body composition, for example, is associated with elevated SBP and DBP in preschoolers (Simonetti *et al.*, 2011; Gopinath *et al.*, 2011*a*). Likewise, DBP is negatively correlated with fitness (Gutin *et al.*, 1990), and preschoolers in the highest quintile of a submaximal fitness assessment experienced smaller increases in BP over a 20-month follow-up (Shea *et al.*, 1994). Fitness is also negatively associated with BF% and positively related to motor skill proficiency in preschoolers (Reeves *et al.*, 1999). As none of the above studies investigated the role of PA on these associations, this thesis will provide insight into how PA may mediate relationships between body composition, health-related fitness, blood pressure, and motor proficiency.

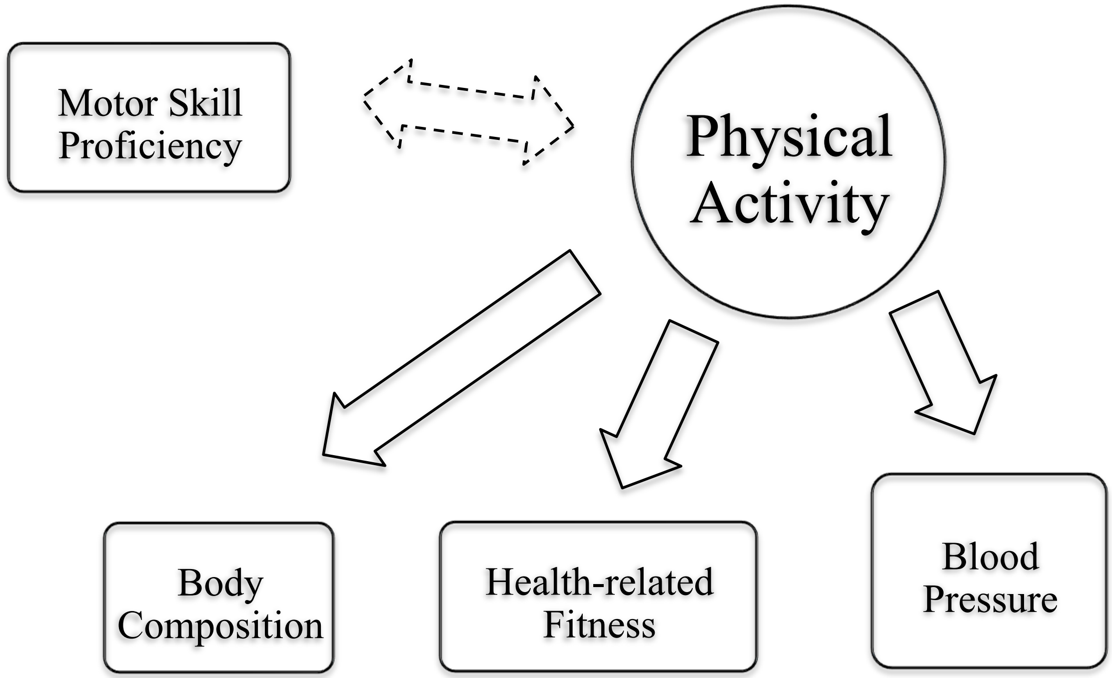

Figure 2. Theoretical model of relationships between physical activity (PA) and health measures. Solid arrows represent characteristics that are likely influenced by PA in preschoolers. Dashed arrows refer to characteristics that might be bidirectional.

1.7 RATIONALE FOR THESIS

PA prevalence and patterns have not been well characterized in Canadian preschool children. Furthermore, there is a paucity of research examining the relationships between PA and health during the early years. Therefore, the objectives of this thesis are to:

1. Assess and describe the prevalence and patterns of PA in 3- to 5-year–old preschoolers using high-frequency accelerometry.
    a. Prevalence: quantify PA (in min/day and as a % of wear)
    b. Patterns: duration and frequency of bouts of PA accumulated and breaks between PA bouts

   c. Relationships between PA and age and sex
   d. Compare PA to existing guidelines

2. Investigate the relationship between PA and health measures in preschoolers.
   a. PA and fitness
   b. PA and body composition
   c. PA and blood pressure
   d. PA and motor skill proficiency

1.8 HYPOTHESES

PA, fitness, body composition, BP, and motor proficiency assessments were performed in healthy preschoolers to test the following hypotheses:

1. Prevalence and patterns: Older children will engage in more PA (min/day and as a % of wear) and more frequent and longer bouts of MVPA with shorter breaks between bouts of PA. Boys will engage in more PA than girls. The majority of children will achieve recommendations for PA.
2. Relationships: Children who accumulate more PA and engage in more frequent and longer bouts of PA will have more favorable body composition, health-related fitness, and blood pressure.

Chapter 2: Methods

2.1 PARTICIPANTS

Ninety-six preschoolers (46 boys, 50 girls; 4.4 ± 0.9 years) participated in the study. Participants were recruited through local partnerships with the Ontario Early Years Centres, preschools, daycares, recreation facilities, and by convenience. All participants were free from health or physical limitations that might prevent them from engaging in PA or exercise. The Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board approved this study. Parents or guardians provided written informed consent prior to their child's participation in the study. For the purpose of this thesis, age reported is chronological age: (date of testing – date of birth).

2.2 STUDY DESIGN

To meet the objectives of the proposed study, a cross-sectional observational design was implemented. Testing was conducted from August 2010 to July 2011. Each child participated in the following study protocol (Figure 3):

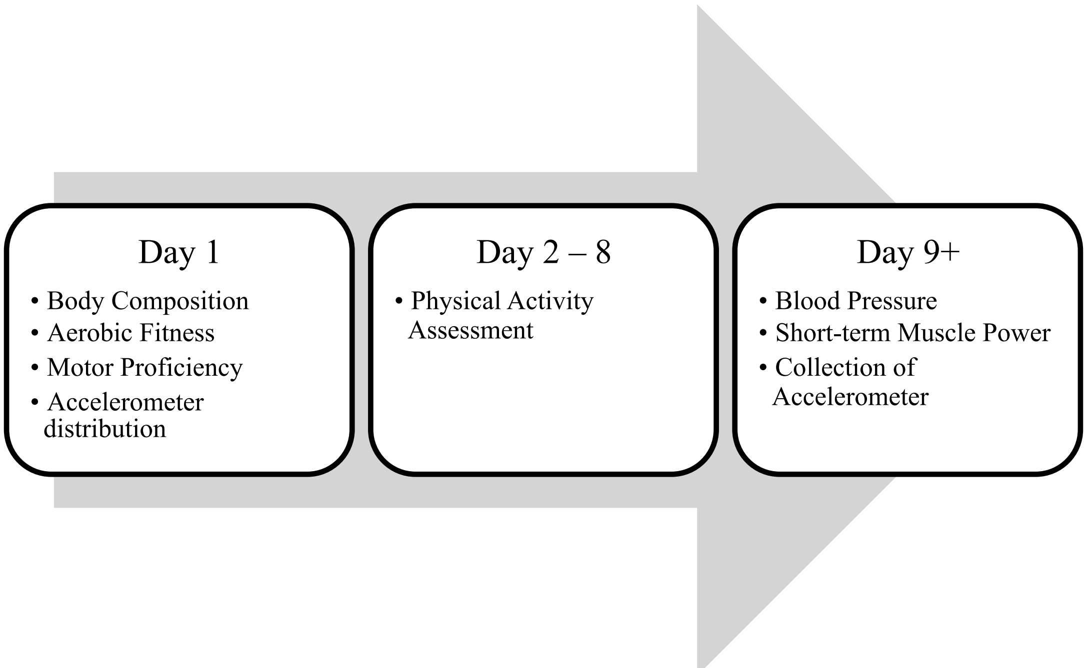

Figure 3. Study Protocol. Participation required approximately 3 hours of commitment.

On day 1, participants arrived at our laboratory at Chedoke Hospital for assessments of body composition, aerobic fitness, and motor skill proficiency, in that order. An accelerometer was fitted to the participant before they left and was worn for the following 7 days. At least 8 days after the initial visit (12.9 ± 7.9 days), the participants visited the Vascular Dynamics Laboratory at McMaster University for cardiovascular health measurements, including assessment of BP (Note: N.A. Proudfoot conducted these measurements). Following the cardiovascular health assessment, participants performed a test of short-term muscle power at McMaster Children's Hospital (Note: due to equipment limitations, short-term muscle power assessments were conducted at visit 1 at Chedoke Hospital prior to the aerobic fitness test for the first 38 participants). Accelerometers were collected at this visit. Each visit lasted approximately 1.5 hours.

2.3 PROTOCOL

2.3.1 Physical Activity

PA was measured using the Actigraph GT3XE accelerometer (Fort Walton Beach, FL, USA). Activity counts were recorded in 3 sec epochs. Accelerometers were fastened to an elastic belt and participants were instructed to wear the accelerometer over their right hip during all waking hours for seven consecutive days, except when engaging in water activities. Parents were given a logbook to record times that the accelerometer was put on and removed during the week of monitoring.

Accelerometer data were visually inspected to ensure that the time recorded in the activity logbook matched the accelerometer output. Any activity counts during reported times of non-wear, as indicated in the logbook, were deleted. All remaining zero counts were treated as inactive time. The data were uploaded to a Microsoft Excel-based Visual Basic for Applications data reduction program to determine PA. PA was defined using cut-points from a previous validation study in a healthy sample of 3- to 5-year olds (Pate *et al.*, 2006). Because Pate et al. (2006) used 15 sec epochs, we divided their cut-points by five to use with our 3 sec epochs. This is a common way to accommodate different epochs (Nilsson *et al.*, 2001; Baquet *et al.*, 2007; Bornstein *et al.*, 2011). Total PA (TPA) was indicated as ≥8 counts/3 sec and MVPA as ≥84 counts/3 sec. To account for different accelerometer wear times between children (min/day), PA data (TPA and MVPA) were reported in relative terms, as a % of wear time (PA min/wear min), and in absolute terms (min/day). Actual monitoring time varied from 1 to 7 days (6.6 ± 1.3 days). Monitoring time for each day varied from 1.7 to 16.6 h (11.1 ± 1.3 h). Participants who wore the accelerometer for ≥ 5h per day on ≥3 days were included in

PA analyses as a % of wear time. Four participants were excluded for not meeting the above criteria; 1 participant refused to wear the accelerometer; 1 participant did not return the accelerometer; therefore, 90 participants and 605 days of PA were included in the PA analyses as a % of wear. For PA comparisons in min/day, participants who wore the accelerometer for ≥10h per day on ≥3 days were included. For this reason, another 6 participants were excluded, resulting in 84 participants and 474 days of PA in the PA analyses in min/day.

PA prevalence was examined using TPA and MVPA in min/day and as % of wear. PA patterns were examined by calculating the frequency and duration of continuous bouts of MVPA and continuous breaks between bouts of MVPA. Continuous bouts refer to consecutive 3 sec epochs of counts ≥84 (MVPA). Continuous breaks refer to consecutive 3 sec epochs of counts <84 (non-MVPA or light PA + sedentary activity). Continuous bouts or breaks frequency was calculated as the number of continuous bouts or breaks per hour of wear, to facilitate comparisons between preschoolers with different accelerometer wear times. Every bout of MVPA is followed by a break of non-MVPA; thus, frequency describes both the number of bouts of MVPA and the number of breaks between bouts of MVPA. Duration of continuous bouts of MVPA and duration of breaks between bouts of MVPA was calculated as the mean duration of continuous bouts and breaks. The examination of PA patterns based on MVPA was chosen because existing literature in preschoolers suggests that more intense activity is associated with improved health outcomes (Moore *et al.*, 1995; Saakslahti *et al.*, 2004; Janz *et al.*, 2005; Williams *et al.*, 2008). Moreover, calculating the PA patterns of other domains of PA (e.g., TPA, light PA) would have produced a volume of data beyond the scope of this thesis.

2.3.2 Body Composition

Standard measurements of height were performed using a calibrated stadiometer to the nearest 0.1cm. Weight was measured to the nearest 0.1kg in light clothing without shoes using a digital scale (BWB-800, Tanita Corporation, Japan). The average of two measurements was used for both height and weight. BMI percentiles based on age and sex were calculated using the CDC data (Kuczmarski *et al.*, 2002). Participants were classified as overweight or obese based on the IOTF BMI cut-offs (Cole *et al.*, 2000*b*) as well as greater than the 85 %ile (overweight) and 95 %ile (obese) using the CDC data. WC was measured to the nearest 0.1cm at the end of a normal expiration at the midpoint between the last floating rib and the iliac crest. The average of two measurements was used.

BF% was assessed by BIA (RJL systems 101A, Miami, FL, USA) according to the manufacturer's instructions (RJL Systems, 1993). Although assessment is influenced by hydration status, due to the age of the participants and the time of testing, it was not possible to make fasting measurements, and voiding of the bladder was not always feasible. Participants were supine with legs extended and abducted approximately 30 degrees. Arms were abducted so that the hands were away from the torso and palms flat on the table. Electrodes were attached to the right side of the body, on the wrist bisecting the ulna head, the hand proximal to the 3rd metacarpal, the ankle bisecting the medial malleolus, and the foot proximal to the middle metatarsals. Values for resistance were taken following 1 – 3 min of resting in the supine position. Lean body mass (LBM) was calculated using an equation validated in young children (Kriemler *et al.*, 2009). BF%

was calculated as [(body weight-LBM)/body weight] × 100. One participant was afraid of the electrodes, thus, BIA data were available for 95 participants.

2.3.3 Health-Related Fitness

2.3.3.1 Aerobic Fitness

Aerobic fitness was assessed on a treadmill (GE Marquette Series 2000, USA) using the Bruce protocol, a progressive treadmill test (Table 1). Prior to the anthropometric assessment, participants were given several minutes of familiarization on the treadmill at a comfortable walking pace. During the test, participants were instructed to hold onto the handrails to assist with coordination, and a researcher was positioned directly behind the child to ensure safety. A HR monitor was attached to each participant using an adjustable band (Polar Electro, Kempele, Finland). Participants were distracted during the test by pictures on the wall, a movie, and conversation; and motivated by constant verbal encouragement. The test was terminated when the child could no longer keep up with the increasing grade or slope of the treadmill, or by refusal to continue exercising despite verbal encouragement. This was at times manifested by visible emotional distress, using the handrails to lift legs off the treadmill, or falling limp into the researcher's arms. Fourteen tests were terminated prior to a HR of 180 bpm due to emotional distress or refusal to continue. Following test termination, children were immediately seated and asked to remain as still as possible.

Table 1. Bruce Treadmill Protocol

Bruce Treadmill Protocol			
Stage[a]	Speed (km/h)	Grade (%)	Duration (min)
I	2.7	10	3
II	4	12	3
III	5.4	14	3
IV	6.7	16	3
V	8	18	3

[a] There are 7 stages in the full Bruce Protocol. Only 5 are outlined here as none of our participants lasted beyond stage V.

HR measurements were recorded at the following time points: after 1 min of sitting prior to the exercise protocol, every min during the test, the termination of the test, and every 30 sec for 2 min following the test while sitting. HRR (bpm) was used as an index of aerobic fitness and calculated as: (HR_{peak} – $HR_{1minpost}$), where HR_{peak} was the highest HR recorded during the exercise test and $HR_{1minpost}$ as the HR following 1 min of seated recovery. One participant refused to participate in the treadmill assessment and 1 participant had to go to the washroom immediately following test termination, thus, recovery data were not collected. HRR data were available for 94 participants. Participants who did not reach near maximal effort, as determined by a HR ≥180 bpm were not included the aerobic fitness assessments; thus treadmill time and HRR data were available for 80 participants.

2.3.3.2 Short-term Muscle Power

Anaerobic fitness was assessed using a 10 sec modified WAnT (Mini-Wingate) (Nguyen *et al.*, 2011). The test was performed on a mechanically braked cycle ergometer (Fleisch-Metabo, Geneva, Switzerland) according to a protocol similar to the traditional 30 sec Wingate test, which has been previously described (Bar-Or & Inbar, 1996). Briefly, following approximately 2 min of light pedaling, maximal pedaling speed was determined for each child during 20 sec of unloaded, all-out cycling. The 10 sec WAnT was then performed using a braking force equal to 4.5% body mass (standard braking force based on school-aged children), applied when the child reached 80% of their predetermined maximal pedaling speed. PP, the highest power output, and MP, the average power output over the 10 sec test, were calculated and expressed relative to body mass (Watts/kg). Three participants were unable to pedal the ergometer properly on their own, 2 refused to cycle, and 1 did not attend the second visit; therefore, 90 participants were included in the analyses.

2.3.4 Blood Pressure

Seated BP was assessed in the right brachial artery using an automated oscillometric BP monitor (Dinamap Pro 100, Critikon Inc, Tampa, FL, USA). The Dinamap device has been validated against direct radial artery BP readings in infants and children (Park & Menard, 1987). Participants were seated for several min prior to assessment. The participants' arm was supported and feet were on the floor during the measurements. Three measurements were taken using appropriately sized cuffs with 1 min of rest between each measure. An average of the last two readings was used to define SBP and DBP; if SBP readings differed by >5 mmHg, additional readings were taken (Pickering *et al.*, 2005). Some children were very uncomfortable with the BP device; thus, only two measures were taken and averaged. Participants with fewer than two reading were not included in the analyses. Ten participants refused to have their BP taken, 3 only had 1 reading, and 1 participant did not attend the second visit; thus, 82 participants were included in BP analyses.

SBP and DBP were converted into percentiles by age, height, and sex using the fourth report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (Anon, 2004).

2.3.5 Motor Skill Proficiency

Gross motor skills were assessed using the gross motor scale of the Peabody Developmental Motor Scales Second Edition (PDMS-2). Reliability and concurrent validity of the PDMS for preschoolers has been confirmed (Folio & Fewell, 2000). The gross motor scale consists of 170 items, divided into 17 age categories between 0 and 6 years old. Items for 3- to 5-year olds are divided into 3 categories: balance, locomotion, and object manipulation. Items corresponding to the participant's age were performed. A 3-point scoring system was employed whereby participants receive a 0 on tasks they could not complete; 1 on tasks that resembled the item but did not fully meet the criteria; and 2, on tasks performed according to the criteria. Scores were compared to normative data to calculate age-based percentiles and participants were categorized as: poor, below average, average, above average, or superior motor skill proficiency (Folio & Fewell, 2000). For the purpose of this thesis, motor proficiency category is expressed as a dichotomous variable: ≤below average or ≥average motor proficiency. Six participants did not complete the motor skill assessment; thus, 90 participates were included in motor proficiency analyses.

2.4 Statistical Analyses

Prior to analysis, all data were checked for normality using a Kolmogrov-Smirnov test and were visually inspected using histogram plots. All data are presented as mean ± standard deviation (SD), unless otherwise noted. Age-adjusted means are presented where appropriate. Statistical significance was set at $p \leq 0.05$.

To assess the differences in PA prevalence and patterns between boys and girls, independent sample t-tests were performed. Due to unequal sample sizes between boys and girls in age categories (3, 4, or 5 years), we were unable to test independent sex and age effects using ANOVA. Therefore, multiple regression analyses were used to compare PA prevalence and patterns by age (continuous variable) and sex (dichotomous variable). Descriptive statistics were used to examine how many preschoolers met recommendations for PA.

To assess the relationships between PA and health measures, Pearson's correlation coefficients were performed. Partial correlations were used controlling for age and sex where appropriate. Independent sample t-tests were used to compare PA and health measures between participants meeting and not meeting PA recommendations.

Additional analyses were performed. Independent sample t-tests were performed to evaluate differences in health measures between boys and girls. Multiple regression analyses were used to compare health measures by age (continuous variable) and sex (dichotomous variable). Independent sample t-tests were used to compare PA and health measures between: overweight and normal weight participants and ≥average and <average motor-skilled participants. ANCOVAs were performed controlling for age where appropriate. ANCOVAs were performed in STATISTICA (StatSoft, Tulsa, OK, USA) and all other statistics were performed in SPSS for Windows 18.0 (SSPS Inc, Chicago, IL, USA).

Chapter 3: Results

3.1 Participant Characteristics

Participant characteristics are presented in Table 2. Slightly more girls than boys participated in the study. The girls were shorter, weighed less, and tended to be younger than the boys.

Table 2. Participant characteristics

Variable	Total	Girls	Boys	*t*-test *p*-value
n	96	50	46	-
Age (years)	4.43 ± 0.86	4.28 ± 0.85	4.59 ± 0.84	0.079
Height (cm)	106.2 ± 7.7	104.1 ± 6.9	108.3 ± 7.9	0.007
	-	*105.2 ± 4.6*	*107.2 ± 4.6*	-
Weight (kg)	18.0 ± 3.0	17.2 ± 2.3	18.8 ± 3.5	0.005
	-	*17.5 ± 2.3*	*18.5 ± 2.3*	-
BMI (kg/m^2)	15.9 ± 1.1	15.8 ± 1.1	15.9 ± 1.1	0.488
Age breakdown				
n 3 years old	30	19	11	-
n 4 years old	38	20	18	-
n 5 years old	28	11	17	-

Age-adjusted means are presented in italics.

3.2 Physical Activity

Table 3. Physical activity prevalence according to sex.

Variable	Girls (n=47)	Boys (n=43)	t-test *p*-value
MVPA (min/day)[a]	85 ± 20	102 ± 18	<0.001
	87 ± 17	*100 ± 17*	-
TPA (min/day)[a]	242 ± 36	276 ± 31	<0.001
	245 ± 32	*274 ± 32*	-
MVPA (% of wear)	12.2 ± 2.7	14.3 ± 2.8	0.001
	12.4 ± 2.7	*14.1 ± 2.7*	-
TPA (% of wear)	34.5 ± 4.6	38.5 ± 4.5	<0.001
	34.7 ± 4.6	*38.3 ± 4.6*	-

Age-adjusted mean are presented in italics.
[a]For PA analyses in min/day, 84 participants were included (44 girls, 40 boys). MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

In terms of PA prevalence, preschoolers engaged in over 4 h of TPA per day (258 ± 38 min), 1.5 h of which was MVPA (93 ± 21 min). Girls engaged in significantly less TPA and MVPA compared to boys, expressed in min/day and as a % of wear ($p \leq 0.001$ for all; Table 3, Figure 4A). Multiple regression analyses revealed that MVPA and TPA in min/day increased with age ($r^2 = 0.259$ and 0.158, respectively; $p < 0.001$ for both; Figure 4A). As a % of wear, MVPA increased with age ($r^2 = 0.131$, $p \leq 0.001$).

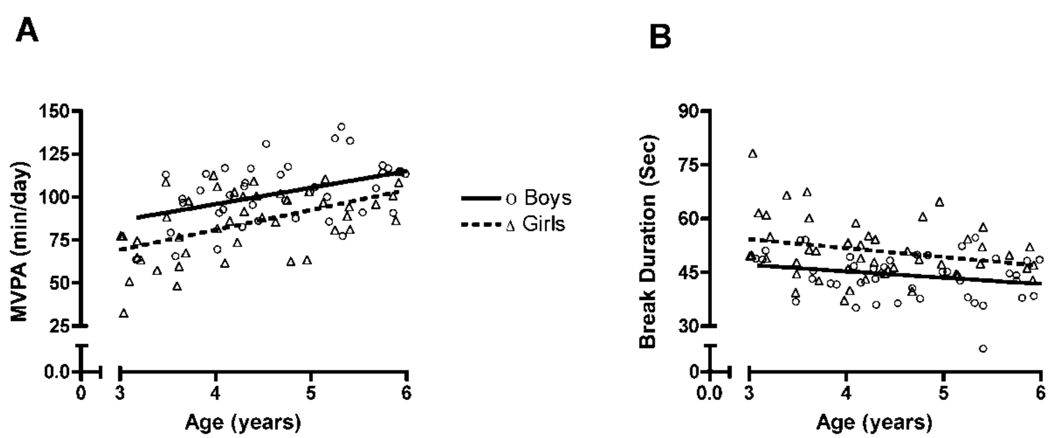

Figure 4. Relationships between physical activity (PA) and age according to sex. A) PA prevalence as described by MVPA (min/day). $r^2 = 0.372$, $p < 0.001$. **B) PA patterns as described by duration of breaks between bouts of MVPA.** $r^2 = 0.231$, $p < 0.001$. Regression models include both age and sex. MVPA, moderate-to-vigorous physical activity.

With respect to PA patterns, 94% of MVPA was accumulated in bouts of 15 sec or less. The average bout of MVPA lasted 7 ± 1 sec with a break of 48 ± 8 sec before the next bout of MVPA. Girls engaged in less frequent bouts of MVPA compared to boys ($p = 0.001$, Figure 5) and their breaks between bouts of MVPA lasted longer compared to the boys ($p < 0.001$; Figure 4B and 5). Multiple regression analyses revealed that frequency and duration of continuous bouts of MVPA increased with age ($r^2 = 0.121$ and 0.120, respectively; $p = 0.001$ for both), while duration of breaks between bouts of

MVPA decreased with age (r^2 = 0.090, p = 0.024, Figure 4B). See Appendix B for complete results.

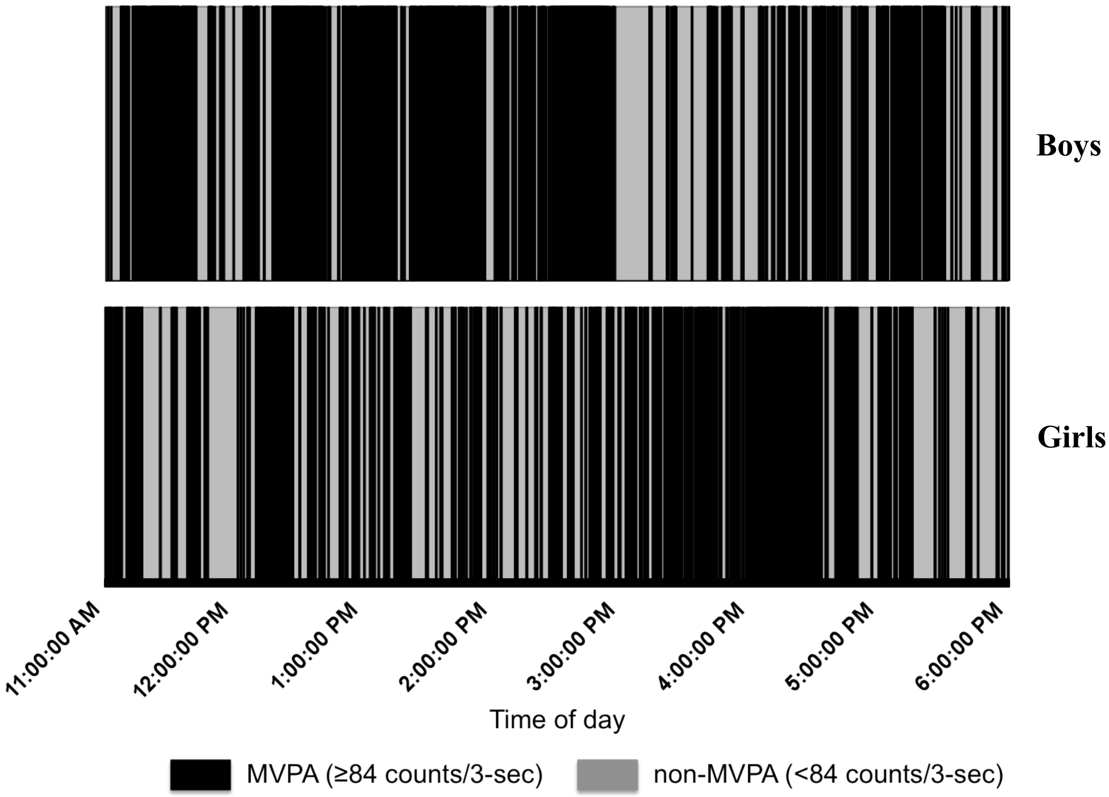

Figure 5. Typical physical activity (PA) patterns in boys and girls. Black lines represent times of MVPA (≥84 counts/3 sec) while grey lines represent breaks between bouts of MVPA (<84 counts/3 sec). It is evident that the male participant (top graph) engaged in more PA and shorter breaks from MVPA compared to the female participant (bottom graph). Participants chosen exhibited typical patterns for boys and girls and were matched for age and total wear time. MVPA, moderate-to-vigorous physical activity.

3.2.1 Physical Activity Guidelines

Ninety-six percent (81 of 84) of participants met the NASPE recommendations for 120 min of PA daily, thus analyses were not run examining differences between the groups meeting and not meeting this recommendation. Seventy-four percent (62 of 84) met the AUS/UK recommendation of 180 min of TPA daily. Preschoolers meeting the

180 min/day recommendations were older ($p = 0.003$), taller ($p = 0.006$), weighed more ($p = 0.050$), had lower BF% ($p = 0.001$), and tended to be boys ($p = 0.083$). Those meeting the AUS/UK recommendation also lasted for longer on the treadmill test ($p = 0.006$) and had greater short-term muscle power based on all measures ($p = 0.029$ to 0.048). Using ANCOVA to control for the effects of age, only BF% remained lower ($p = 0.047$) in the group meeting the AUS/UK recommendations, while there was a trend for longer time to exhaustion on the treadmill test ($p = 0.098$). With respect to compliance with 60 min of MVPA daily (Canadian guidelines for school-aged children), 61% (51 of 84) met this recommendation. Preschoolers meeting the 60 min MVPA recommendation were mostly boys ($p = 0.034$), older ($p = 0.016$), taller ($p = 0.003$), heavier ($p = 0.008$), and had lower BF% ($p = 0.037$). These children exercised for longer until exhaustion on the treadmill test ($p = 0.001$). Using ANCOVA to control for the effects of age, only treadmill test duration remained higher in the group meeting the Canadian school-aged recommendation ($p = 0.039$), while there was still a trend for boys to be more likely to meet this recommendation ($p = 0.085$).

3.3 Body Composition

Six children were classified as overweight using the IOTF cutoffs (none were classified as obese) and 18 as overweight/obese (13/5) using the CDC system. Because of the low prevalence of overweight/obesity using the IOTF cutoffs, relationships presented in this thesis only pertain to the CDC system. There were no differences in BMI %ile or classification of overweight/obesity status between girls and boys. Girls had significantly higher BF% than boys ($p < 0.001$), while boys tended to have larger WC ($p = 0.053$). Multiple regression analyses revealed that BF% was negatively related to age

($r^2 = 0.294$, $p < 0.001$) and WC was positively related to age ($r^2 = 0.170$, $p < 0.001$). See Appendix C for complete results.

3.3.1 Relationships between Body Composition and Physical Activity

Because BF% and PA variables were significantly related to age and sex, correlations were performed controlling for age and sex, while WC correlations were performed controlling for age. No significant relationships were observed between PA and body composition variables (BF%, BMI, and WC). Correlational analyses revealed that WC tended to be larger in preschoolers with higher MVPA as a % of wear ($r = 0.207$, $p = 0.051$) and more frequent MVPA bouts ($r = 0.207$, $p = 0.052$). No differences in PA were observed between children classified as overweight compared to their normal weight peers.

3.4 Health-Related Fitness

HR_{peak} during the treadmill test averaged 195 ± 7 bpm and did not differ between boys and girls. The average treadmill test lasted 9.6 ± 2.4 min, with an average HRR at 1 min of 63 ± 14 bpm. There was a trend for faster HRR in the boys compared to the girls ($p = 0.052$). Multiple regression analyses revealed that time to exhaustion on the treadmill test was positively related to age ($r^2 = 0.560$, $p < 0.001$).

Expressed relative to body mass, PP and MP averaged 4.6 ± 1.5 and 3.9 ± 1.4 W/kg, respectively. Multiple regression analyses revealed that all measures of short-term muscle power increased with age ($r^2 = 0.417 – 0.477$, $p < 0.001$), while boys had significantly higher PP compared to girls ($\Delta r^2 = 0.025$, $p = 0.038$). See Appendix D for complete results.

3.4.1 Relationships between Health-Related Fitness and Physical Activity

In terms of PA prevalence, correlational analyses revealed that HRR was positively related to TPA in min/day and as a % of wear (r = 0.292 and 0.240, p = 0.014 and 0.037, respectively). With respect to PA patterns, HRR was positively related to the frequency of MVPA (r = 0.287, p = 0.012; Figure 6A) and negatively related to duration of breaks between bouts of MVPA (r = -0.259, p = 0.024). Time to exhaustion on the treadmill test, short-term muscle power, and PA variables were significantly related to age, therefore, correlations were performed controlling for age. Time to exhaustion on the treadmill test was positively related to duration of bouts of MVPA (r = 0.326, p = 0.004) with a trend for longer treadmill time with higher MVPA and TPA as a % of wear (r = 0.201 and 0.196, p = 0.084 and 0.092, respectively). Short-term muscle power variables were positively related to MVPA bout duration (r = 0.207 to 0.237, p = 0.029 to 0.058; Figure 6B).

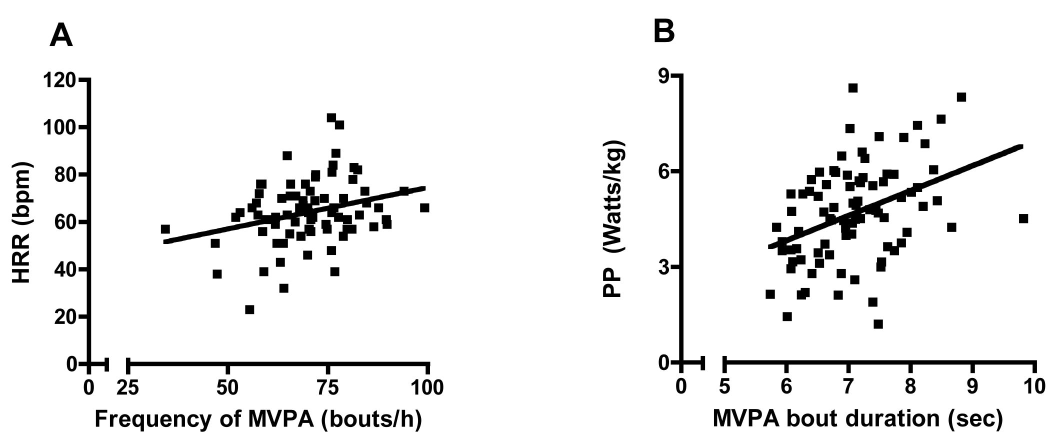

Figure 6 . Relationships between measures of health-related fitness and physical activity. A) HRR and frequency of MVPA . r = 0.287, p = 0.012. **B) Relative PP and MVPA bout duration.** r = 0.234, p = 0.032. MVPA, moderate-to-vigorous physical activity; HRR, heart rate recovery; PP, peak power.

3.5 Blood Pressure

Average SBP and DBP were 97 ± 7 and 61 ± 5 mmHg, respectively. Four participants were classified as pre-hypertensive and 4 as hypertensive. There were no sex differences with respect to absolute BP measures. After using normative data to account for sex, age, and height, girls tended to have a higher SBP %ile compared to the boys ($p = 0.055$). See Appendix E for complete results.

3.5.1 Relationships between Blood Pressure and Physical Activity

DBP %ile was significantly related to age; thus, correlations were performed controlling for age. SBP %ile was positively related to duration of breaks between bouts of MVPA ($r = 0.237$, $p = 0.035$).

3.6 Motor Skill Proficiency

Seventy-one participants (79%) were classified as “average”, “above average”, or “superior” motor proficiency, with the remaining 19 participants (21%) as “below average” or “poor” motor proficiency. There were no sex differences in motor skill proficiency. See Appendix F for complete results.

3.6.1 Relationships between Motor Skill Proficiency and Physical Activity

Motor skill proficiency %ile was positively related to MVPA bout duration ($r = 0.355$, $p = 0.001$). There was a trend for a higher motor proficiency %ile with higher MVPA as a % of wear ($r = 0.207$, $p = 0.058$) and shorter duration of breaks between bouts of MVPA ($r = -0.200$, $p = 0.067$). Preschoolers identified as having below average motor proficiency engaged in less MVPA as % of wear ($p = 0.035$, Figure 7A), shorter bouts of MVPA ($p = 0.006$, Figure 7B), and longer breaks between bouts of MVPA ($p =$

0.024). There was a trend for these children to also engage in less TPA as a % of wear (p = 0.083).

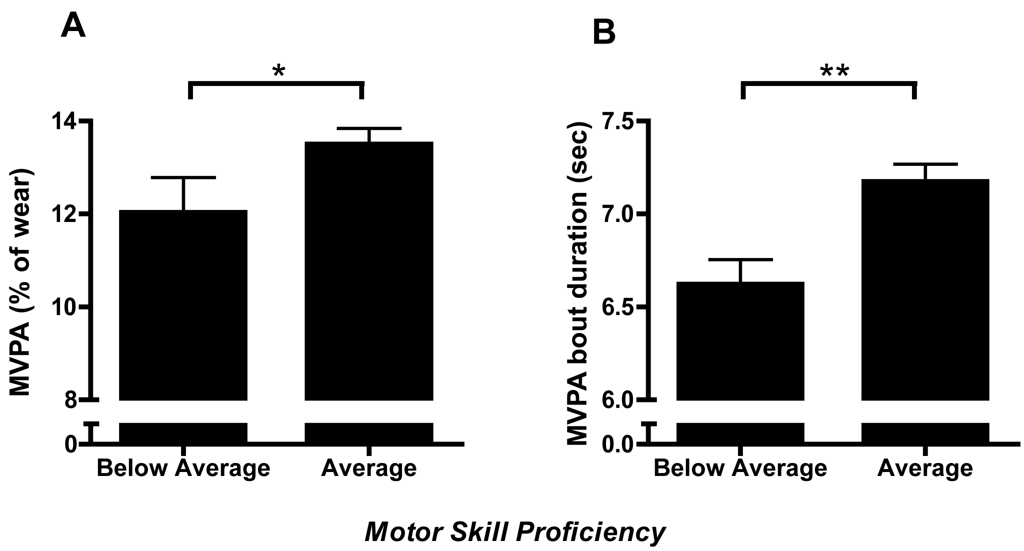

Figure 7. Physical activity according to motor skill proficiency classification. A) MVPA (% of wear). B) MVPA bout duration. Values are means ± SEM. Below average refers to preschoolers with below average or poor motor proficiency. Average refers to preschoolers with average, above average, or superior motor proficiency. *, $p < 0.05$; **, $p < 0.01$. MVPA, moderate-to-vigorous physical activity.

3.7 Relationships between Health Measures

Preschoolers with larger WC had higher absolute SBP (r = 0.262, p = 0.018). Those identified as overweight/obese based on the CDC system had higher SBP, absolute and as a %ile (p = 0.032 and 0.033, respectively) compared to their normal weight peers.

Preschoolers with slower HRR had a higher SBP and DBP %iles (r = -0.285 and -0.315, p = 0.017 and 0.008, respectively) and absolute DBP (r = -0.337, p = 0.004). Preschoolers with poorer motor proficiency had lower short-term power output based on all measures (r = 0.221 to 0.310, p = 0.004 to 0.041). See Appendix H for complete results.

Chapter 4: Discussion

This thesis provides data on important relationships between PA and health measures, for the first time, in preschoolers. PA patterns are comprehensively described as never before in this age group. Health-related fitness variables are characterized for the first time in preschoolers. The relationships between aerobic fitness, short-term muscle power, BP, and PA prevalence and patterns are novel. Finally, relationships between health measures are presented. This thesis begins to fill important gaps in our knowledge regarding the link between PA and preschooler health and provides justification for the promotion of PA throughout the preschool years.

4.1 Physical Activity

4.1.1 Physical Activity Prevalence and Patterns

The rationale to characterize both PA prevalence and patterns in preschool children in this thesis stems from the notion children engaging in similar amounts of PA (prevalence) may accumulate that PA in different manners (patterns). For example, a child may accumulate MVPA frequently for short bouts, while another child may engage in MVPA less frequently, but for longer bouts. As observed in older children (Stone *et al.*, 2009), it is possible that certain PA patterns are more advantageous to health than others.

Previous literature regarding PA prevalence varies considerably as a function of different accelerometer cut-points used. For this reason, estimations of preschooler MVPA have ranged from 25 to 110 min/day and 3 to 13% of wear time (Reilly *et al.*, 2004, 2006; Pate *et al.*, 2004; Fisher *et al.*, 2005; Kelly *et al.*, 2007; Pfeiffer *et al.*, 2009;

Vale *et al.*, 2010). Nevertheless, examining only studies that have used the Pate et al., (2006) cut-points indicate that our results are consistent with the literature. Our finding of 93 min/day of MVPA is similar to studies in preschoolers from the United States (2 studies), Portugal, and Belgium, observing 102 (Beets *et al.*, 2011), 90 (Williams *et al.*, 2008), 102 (Vale *et al.*, 2010), and 91 (van Cauwenberghe *et al.*, 2010) min/day of MVPA, respectively, and slightly higher than values of 75 min/day previously reported from our laboratory (Obeid *et al.*, 2011). The preschoolers in the current study engaged in MVPA for 13% of accelerometer wear time, which is in accord with reports varying from 12-13% (Williams *et al.*, 2008; Vale *et al.*, 2010; Obeid *et al.*, 2011). Fewer studies report preschooler TPA; nonetheless, results of 258 min/day and 36% of wear time are comparable to 220 min/day and 35% of wear (Obeid *et al.*, 2011), 371 min/day (Beets *et al.*, 2011) and 44% of wear (Williams *et al.*, 2008). Consistent with a large body of evidence in preschoolers (Janz *et al.*, 2001; Finn *et al.*, 2002; Pate *et al.*, 2004; Fisher *et al.*, 2005; Hinkley *et al.*, 2008; Vale *et al.*, 2010), we have confirmed that boys are more active than girls, by all measures of PA prevalence. This trend remains consistent throughout the preschool years, as seen in Figure 4A and noted previously by Pfeiffer et al. (2009). Similarly, we found that all measures of PA prevalence increase with age (Jackson *et al.*, 2003; Kelly *et al.*, 2007).

Obeid et al. (2011) observed that preschoolers accumulated 95% of their bouts of MVPA in 15 sec or less, which we confirmed (94%) in our sample. A study in older children using direct observation of PA revealed that 75% of breaks between high intensity activities lasted 54 sec or less (Bailey *et al.*, 1995), which is in accord with our findings of an average of 48 sec between bouts of MVPA. We have expanded on previous findings by characterizing the frequency of continuous MVPA bouts and breaks, along with reporting the average duration of continuous MVPA bouts and breaks.

In concert with higher PA prevalence, we observed a change in PA patterns with age: more frequent and longer duration of continuous bouts of MVPA and shorter duration of continuous breaks between bouts of MVPA from 3 to 5 years of age. With this PA pattern data, we can explain that younger preschoolers are less active than their older peers because they engage in less frequent and shorter bouts of MVPA. Like PA prevalence, boys have more favorable PA patterns than girls (favorable indicating that boys engage in more PA). Although the duration of bouts of MVPA is the same for boys and girls, we can ascertain that girls engage in less MVPA (min/day) because they engage less frequently in MVPA and take longer breaks between bouts of MVPA. It is worthwhile considering the relevance of 66 vs. 74 bouts/h of MVPA in girls and boys, respectively. Over a typical 11 h day, these small differences amount to an average of an additional 88 bouts of MVPA in boys or approximately 10 min of MVPA. Indeed, this amount could make the difference between meeting and not meeting daily PA recommendations for many children.

4.1.2 Physical Activity Guidelines

Evidence-based PA guidelines are established and promoted on the basis of improved health with their compliance. Until quite recently, recommendations with required duration or intensity of PA for children under the age of 6 did not exist, or were lacking scientific evidence. Within the last year, AUS and the UK have released guidelines recommending 180 min of TPA daily, created on the basis of existing preschooler literature (Australian Government Department of Health and Ageing, 2011;

Department of Health, 2011). As these guidelines are quite recent, no study to date has investigated measures of health in children complying with these PA recommendations. The majority of our sample of preschoolers (74%) met the recommended 180 min TPA daily, with older children more likely to comply. After controlling for the effects of age, BF% was lower in those children meeting the guidelines. There was also a trend for longer time to exhaustion on the treadmill test in preschoolers meeting the recommendations. With the knowledge that body fatness is associated with cardiovascular disease risk factors (Twisk *et al.*, 2002), achieving a healthy body composition is one of the primary goals of PA recommendations (Department of Health, 2011). As the only study to our knowledge to assess compliance with these new guidelines, our data suggests that achieving 180 min of TPA daily is beneficial for BF% and perhaps health-related fitness of preschoolers.

Canadian guidelines of 60 min MVPA daily were recently published for children 5 years and older (Canadian Society for Exercise Physiology, 2011). As these guidelines are directed at older children, it is not known if they are appropriate for preschoolers. The majority (61%) of our preschoolers met these recommendations. As with PA prevalence, compliance is confounded by the choice of accelerometer cut-points, thus, only data from studies using the Pate et al. (2006) cut-points are presented below. A small study (30 participants) from our laboratory observed that all preschoolers met 60 min MVPA daily (Obeid *et al.*, 2011); however, the ability to use this data to make valid comparisons is likely reduced because of the small sample. Compliance with 60 min of MVPA daily was 66% in boys and 53% in girls from the United States (Beets *et al.*, 2011), which compared quite closely with our findings of 73 and 50% compliance in boys and girls, respectively. As with compliance to the AUS/UK recommendations, preschoolers achieving recommendations were older. After controlling for the effects of age, time to exhaustion on the treadmill test was longer in those meeting recommendations, indicating better health-related fitness in those complying with recommendations.

While more and larger investigations are warranted examining PA guideline compliance and health in preschoolers, our data suggest that children achieving 180 min of TPA and 60 min of MVPA daily have more favorable body composition and health-related fitness, supporting the use of the above guidelines. As our data have shown age to be a very strong determinant of guideline compliance, it brings to mind the notion that perhaps one recommendation for the entire 3- to 5-year old age range is not appropriate. Out of the 22 children not meeting 180 min TPA, 16 (73%) were under 4.5 years, along with 21 (64%) of the 33 children not meeting 60 min MVPA daily. On the other hand, we have shown that preschoolers not complying with recommendations are less fit and of less favorable body composition, regardless of age. Therefore, efforts to increase PA should be directed at the younger preschool age range (3 to 4.5 years old). Finally, even after controlling for the effects of age, girls tended to be less likely to meet the 60 min of MVPA recommendations along with displaying lower PA prevalence and less favorable PA patterns compared to boys. Disparities in health between sexes as a result of PA prevalence and patterns will be discussed in sections to come. It is possible that sex differences in PA may be a result of societal norms, that by virtue of their sex, girls are expected to be less active than boys; thus, PA is not encouraged to the same extent.

While the cause of lower PA in girls goes beyond the scope of this thesis, these data highlight the need to promote PA equally between boys and girls.

4.2 Body Composition

The prevalence of overweight/obesity in our sample was very low compared to national observations (6 vs. 21% and 19 vs. 30% based on the IOTF and CDC system, respectively) (Shields & Tremblay, 2010), indicating that our sample was not necessarily representative of average overweight/obesity status of Canadian preschoolers, or that today's preschoolers are not as overweight/obese as they once were. Nevertheless, in concert with other studies (Taylor *et al.*, 2008), we noted higher BF% in girls compared to boys, in children as young as 3 years of age, that persisted throughout the preschool years. Previous literature suggests that PA is a determinant of body composition (Davies *et al.*, 1995; Takahashi *et al.*, 1999; Janz, 2002; Trost *et al.*, 2003; Janz *et al.*, 2005; Jago *et al.*, 2005; Metallinos-Katsaras *et al.*, 2007). Apart from observing lower BF% in preschoolers complying with the AUS/UK guidelines and contrary to other studies in preschoolers, we did not observe any relationships between body composition and PA variables. This likely reflects the healthy weight status of most of our sample. Even the 21% classified as overweight/obese based on CDC guidelines were very close to the threshold between normal weight and overweight status (88%ile compared to the 85%ile criteria). While also true for previous studies, it is likely that some of our sample classified as overweight/obese based on BMI were done so due to high lean mass as opposed to high body fat. This was evident in several children who had lower than average BF% (based on their age and sex), yet were classified as overweight/obese based on BMI. The important contribution of diet to energy balance and body composition should also be acknowledged, as PA is only part of the equation. A 3-day food record was completed for each participant involved in this thesis, and while including those data would have added much to describing body composition, its inclusion went beyond the scope of the thesis. Future investigations should aim to collect data from a sample more representative of the population, while also considering the independent and combined effects of diet and PA on body composition variables.

4.3 Health-related Fitness

4.3.1 Aerobic Fitness

For the first time, we have characterized aerobic fitness using time to exhaustion on a maximal treadmill test and HRR in children as young as 3 years of age and demonstrated that these methods are feasible. The average time until exhaustion on the treadmill test of 9.6 min was slightly lower than the 10.2 min observed in a recent study permitting holding of the handrails (van der Cammen-van Zijp *et al.*, 2010). However, when only 4- to 5-year olds (59 children) were examined in our dataset, as in the study above, the average time increased to 10.5 ± 1.9 min, which is consistent with the previous study. Given that energy expenditure should be lower when holding on to the handrails, it makes sense that we observed times to exhaustion that were longer than other studies not permitting holding of handrails (9.0 – 10.0 min) (Cumming *et al.*, 1978; Wessel *et al.*, 2001).

No other studies involving preschoolers have examined HRR at 1 min following maximal exercise. Our observations of a HRR of 60 and 65 bpm in girls and boys, respectively, are substantially faster than the 32 and 39 bpm observed in older children

(5- to 18-year olds) using the same maximal protocol. Other studies have documented HRR following 2 min of recovery in 4- to 5-year olds. While we collected recovery data at 2 min post exercise, it was often difficult to get the children to remain still for that long; thus, we have less confidence in the accuracy of the 2 min HRR data. Nevertheless, HRR at 2 min in our 4- to 5-year olds was 73 bpm (71 bpm in girls and 74 bpm in boys) and quite comparable to the 71, 60 and 79, 81 bpm in girls and boys, respectively, noted in previous studies (Cumming *et al.*, 1978; Wessel *et al.*, 2001). Like Wessel et al. (2001) and Cumming et al., (1978), we observed that boys tended to have faster HRR than girls. It is quite possible that our sample of girls had slower HRR in part as a result of their lower PA engagement.

We found that preschoolers who engaged in more TPA, more frequent MVPA, and shorter breaks between bouts of MVPA, had faster HRR, suggesting that PA has a positive influence on aerobic fitness. Preschoolers who engaged in longer bouts of MVPA also exercised for longer on the treadmill test (controlling for age effects), indicating higher aerobic fitness in these children. While evaluating the mechanisms that link higher PA engagement to higher aerobic fitness was not an objective of this study, it is possible that the two are related by lactate threshold. The cut-point we used for MVPA corresponds to >20 ml/kg/min (Pate *et al.*, 2006), which is quite close to the suggested lactate threshold in children of around 25 ml/kg/min (Bailey *et al.*, 1995). On the basis of physiological principles (Pfitzinger & Freedson, 1997), it is reasonable to assume that preschoolers spending more time at or above their lactate threshold would induce a training effect and, consequently, have higher aerobic fitness compared to children spending less time at this intensity. The speed at which a child recovers from intense activity likely also dictates PA patterns. Thus, it is reasonable to assume that a child who is less fit (takes longer to recover) would also take longer breaks between bouts of activity.

Higher fitness in preschoolers who engaged in more TPA has also been observed in a recent study from Switzerland (Bürgi *et al.*, 2011). We have improved upon their measurements by using higher-resolution accelerometry (3 vs. 15 sec epoch) that captures a more accurate representation of PA (Obeid *et al.*, 2011) along with a laboratory assessment of aerobic fitness (Bruce protocol vs. shuttle run). Consistent with the literature in older children (Dencker *et al.*, 2006; Butte *et al.*, 2007), our correlations between aerobic fitness and PA were of weak to moderate strength (r=0.240 to 0.311), suggesting that similar relationships between aerobic fitness and PA exist throughout childhood.

For the first time, we have demonstrated that PA patterns are related to aerobic fitness in preschoolers. More specifically, the pattern of a higher frequency and longer duration of MVPA and shorter duration of breaks between bouts of MVPA are associated with higher fitness. While unable to infer causality given the cross-sectional nature of the study, knowing that aerobic fitness tracks from childhood into adulthood (Twisk *et al.*, 2002), and the protective effect of aerobic fitness on cardiovascular and metabolic health (Twisk *et al.*, 2002; Steele *et al.*, 2008), our data suggest that PA should be promoted in preschoolers for improved health.

4.3.2 Short-term Muscle Power

Only one previous study to date has assessed short-term muscle power in preschool children (Nguyen *et al.*, 2011). While using the same equipment and 10 sec Wingate protocol, our values for all measures of short-term muscle power were lower than those obtained in previous research (PP: 5.4 vs. 4.6 W/kg; MP: 4.2 vs. 3.9 W/kg). It is likely that their convenience sample of 28 participants was relatively 'fit' and 'coordinated' compared to our cohort of 96 preschoolers. Despite the fact that the braking force applied during the WAnT is relative to body mass, both the current study and Nguyen and colleagues (2011) observed an increase in short-term muscle power (absolute and relative) throughout the preschool years. This is consistent with studies in older children, noting increases in PP and MP with age (Inbar & Bar-Or, 1986; Falk & Bar-Or, 1993). This increase with age is likely attributable to an increase in cross-sectional area of the thigh and calf muscles with growth along with improved motor coordination to generate a faster pedaling speed.

Relationships between short-term muscle power and PA have never before been examined in preschoolers. The rationale for including a measure of short-term muscle power in this thesis was that preschoolers naturally engage in short bouts of PA (~ 7 sec per bout of MVPA as described above). A 10 sec Wingate assessment mimics their natural pattern of accumulating PA, therefore, perhaps making it a more appropriate fitness measure. Indeed, after controlling for the effects of age, we observed higher short-term muscle power (PP, PP/kg, and MP) in preschoolers who engaged in longer bouts of MVPA, while MP/kg also tended to be higher. It is reasonable to assume that MVPA bout duration would be related to MP, as MP is a reflection of the local muscle endurance of the legs, and engaging in longer bouts of MVPA should improve muscular endurance. PP, in this case, the highest instantaneous power output, reflects how much power the musculature of the leg can produce in a very short time. This measure is based on the highest pedaling speed (revolutions) that the participant was able to generate against the braking force, and was highly correlated with MP ($r = 0.959$, $p < 0.001$). We do not know how short-term muscle power relates to health in preschoolers; nevertheless, our data suggest that preschoolers who engage in longer bouts of MVPA have higher short-term muscle power.

4.4 Blood Pressure

The most recent wave of the Canadian Health Measures Survey (CHMS) released normative BP data for Canadian children 6-17 years old, noting that few Canadian children between 6 and 11 years old are prehypertensive or hypertensive (3.7%) (Paradis *et al.*, 2010). The majority of the preschoolers in the current study were of healthy BP based on the same normative data controlling for sex, age, and height; although we observed slightly more (10%) children classified as prehypertensive or hypertensive. While older than our sample, DBP was the same between the 6- to 7-year olds and our preschoolers (61mmHg), whereas our preschoolers had higher SBP (97 vs. 92 mmHg). With knowledge of the positive relationship between BP and age, we expect our sample to have lower SBP than the 6- to 7-year olds. This discrepancy might be explained by differences in our methods. A different automated BP device was used in the studies and the CHMS BP data were an average of the last 5 of 6 BP readings, while ours were typically the average of the last 2 of 3 measures. Although beneficial, it was not feasible to take additional BP measures, as some children were in visible discomfort after only 2 readings. Nevertheless, our prevalence of prehypertension/hypertension was lower than the 14% observed in a large Australian cohort (~2000 preschoolers) (Gopinath *et al.*, 2011*a*). In agreement with recent literature in preschoolers, we observed a trend for higher SBP %ile in girls compared to boys (Simonetti *et al.*, 2011).

For the first time, we report the relationships between BP and PA in preschool children, finding that preschoolers with higher SBP %ile took longer breaks between bouts of MVPA. Observations of higher SBP %ile in girls may be explained by their less favorable PA patterns. In older children and adolescents, general consensus is that PA does little to reduce BP in normotensive individuals, while being beneficial to hypertensive youth (Strong *et al.*, 2005). While intervention or longitudinal analyses are necessary to confirm whether PA is only beneficial to hypertensive preschoolers, our results suggest that PA is related to BP in preschoolers, and that decreasing the duration of breaks between bouts of MVPA may reduce SBP. As research suggests that BP during childhood is predictive of cardiovascular health in adulthood (Raitakari *et al.*, 2003), managing elevated BP during the preschool years by increasing PA prevalence and patterns may benefit future health.

4.5 Motor Skill Proficiency

Previous studies involving preschoolers have demonstrated weak to moderate associations between MVPA and motor skill proficiency ($r = 0.16 - 0.33$) (Fisher *et al.*, 2005; Williams *et al.*, 2008). A study in older children found that motor proficiency was predictive of PA 3 years later (Lopes *et al.*, 2010), while a recent longitudinal study suggests that higher PA is the cause of improved motor proficiency in preschoolers (Bürgi *et al.*, 2011). Although cross-sectional, our study adds to these observations by demonstrating that children who engage in longer bouts of MVPA have better motor proficiency, with a similar strength of relationship (r = 0.36). Children identified as having below average motor skills engaged in less MVPA (% of wear), shorter bouts of MVPA, and longer breaks between bouts of MVPA. If the observations of Burgi et al. (2011) hold true, and it is PA that influences motor proficiency in preschoolers, those with poor motor proficiency should be able to improve their movement skills by increasing their PA, specifically by engaging in longer bouts of, and shorter breaks between bouts of, MVPA.

4.6 Relationships between Health Measures

As discussed above, unlike other studies in preschoolers we did not observe a relationship between BMI, WC, and PA; however, we did observe relationships between body composition and BP. In accord with previous literature (Simonetti *et al.*, 2011; Gopinath *et al.*, 2011*a*), SBP was higher in preschoolers with larger WC, and among children identified as overweight/obese. WC has been identified as a more relevant measure of cardiovascular risk in children and adults than BMI (Han *et al.*, 1998; Maffeis *et al.*, 2001; Watts *et al.*, 2008), as it provides insight into the pattern of fat distribution, which is positively correlated with health risk when around the abdominal region. It is possible that this finding extends to the preschool population as well, as BMI was only predictive of higher BP when stratified by overweight status, while WC was sensitive to BP as a continuous variable. This finding may be relevant to individuals identifying children at increased risk of cardiometabolic conditions (i.e., health practitioners).

Gutin et al. (1990) and Shea et al. (1994) observed reductions (cross-sectional and longitudinal, respectively) in BP in preschoolers with higher aerobic fitness, as assessed by a submaximal fitness protocol. We have improved upon their study design by performing a maximal fitness assessment using HRR as a measure of health-related fitness and by correlating fitness with PA and BP. Preschoolers with better fitness had reduced BP (SBP %ile and DBP %ile) compared to their less fit peers. In addition to the potential direct effects of PA on BP, health-related fitness might mediate the relationships between PA and BP in preschoolers, as HRR was positively correlated with TPA (min/day) and negatively correlated with duration of breaks between bouts of MVPA (while DBP %ile was negatively associated with TPA and SBP %ile was positively associated with duration of breaks between bouts of MVPA). While beyond the scope of this thesis, it is also possible that PA directly influences both BP and HRR through similar mechanisms; thus, the correlations are similar. Regardless of the nature of these relations, both theories imply that PA prevalence and patterns can improve aerobic fitness and cardiovascular health.

Finally, consistent with observations in older children using various methods of assessing short-term muscle power (Rivilis *et al.*, 2011), we observed that preschoolers with poor motor proficiency had lower short-term muscle power. This relationship is quite intuitive, as power output is determined by pedaling speed. Children who are more coordinated are likely able to generate faster pedaling speed with ease, resulting in higher short-term muscle power. While most preschoolers have experience riding a bicycle (personal observation from testing sessions), not all are familiar with cycling as fast as they can against a constant braking force. Fast cycling, as required for the Wingate test, requires significant intermuscular coordination (Keller *et al.*, 2000), perhaps more so than a familiar walking or running task. Both short-term muscle power and motor proficiency were positively related to PA patterns (MVPA bout duration). In this case, in addition to the potential direct effects of PA on short-term muscle power, it is possible that motor proficiency mediates the relationship between PA and short-term muscle power. Engaging in longer bouts of MVPA may result in improved motor skills and thereby enhance a child's ability to generate a fast pedaling speed.

The theoretical model provided on in Figure 2 on page 36 has been modified to reflect findings from this thesis and indicate potential mediating relationships between PA and health measures, as described above (Figure 8).

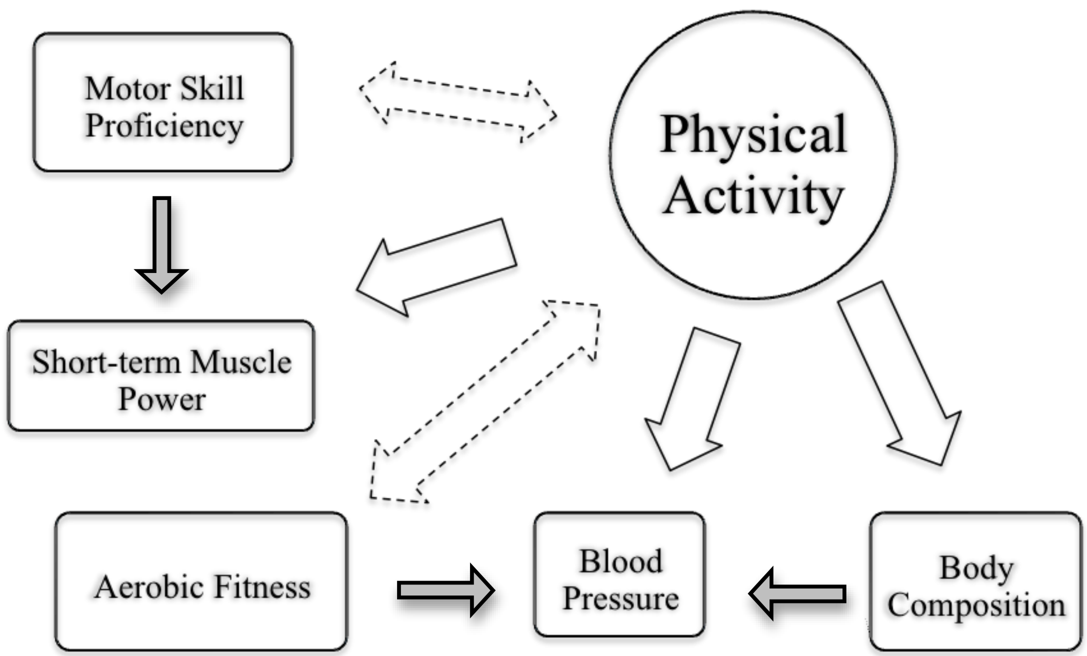

Figure 8. Modified theoretical model based on analyses. Solid arrows represent characteristics that are likely influenced by physical activity (PA). Dashed arrows refer to characteristics that might be bidirectional. Shaded arrows have been added to the diagram to indicate possible mediating relationships between PA and health measures.

4.7 Novelty of the Findings and Relevance to Current Literature

The overall goal of this thesis was to advance our knowledge regarding PA prevalence and patterns in preschool children and to investigate subsequent relationships with health measures. The following points describe how we have met these objectives and their contribution to current literature:

- *For the first time, we have characterized preschoolers' PA patterns (frequency & duration). We have also demonstrated that PA patterns are just as important as PA prevalence in describing relationships with health measures in preschool children.* This study provides the rationale for future investigations to assess PA patterns along with PA prevalence when evaluating relationships with health.
- *For the first time, we have investigated and found support for the promotion of and compliance with new PA guidelines.* Children who met the new AUS/UK recommendations of 180 min TPA had better body composition. Those meeting Canadian guidelines of 60 min MVPA (for school-aged children) had better health-related fitness. These data will facilitate the evaluation of current guidelines and the formation of new guidelines specific to preschoolers in Canada.
- *For the first time, we have demonstrated a relationship between PA and cardiovascular health in preschoolers.* Relationships between health-related fitness, BP, and PA in preschoolers indicate that even at a young age, PA may influence cardiovascular health. These data provides support for the promotion of PA in preschoolers.
- *For the first time, we have demonstrated how PA patterns relate to motor skill proficiency.* Participating in longer bouts of MVPA may be more important to motor

skill development than total PA time (min/day). This has relevance for improving skills in preschoolers who have poor motor proficiency.

- *There are significant sex differences in PA and health measures that warrant attention.* As early as 3 years of age, girls participate in less PA and have less favorable health-related fitness and BP measures. PA promotion should be directed at girls to address this sex disparity.

4.8 Limitations and Future Research Directions

This thesis describes novel relationships between PA and health measures in preschool children. However, as relationships were cross-sectional, we are unable to infer causality. Longitudinal investigations are warranted to accurately characterize the direction of these relationships. Thus, this sample along with additional preschoolers will be followed over the next few years in order to clarify these associations. Specifically, describing dose-response relationships between PA prevalence/patterns and health measures, as informed by future investigations, will aid immensely to the development of future PA guidelines for preschoolers.

The following are specific recommendations and limitations regarding the protocol used in this thesis. Future analyses would benefit from including the information attained from diet records in order to accurately characterize the influences of PA on energy balance and body composition. It was not feasible to characterize body composition using DXA in all participants (e.g., equipment, compliance); however, the use of this assessment would alleviate the need for prediction equations for BIA resistance values and potential discrepancies due to hydration status of participants. While we used a HR monitor to collect HR data during and following the treadmill test, the device is unable to report continuous HR measures; thus, future investigations would gain greater insight into HRR by employing electrocardiography. HRR following exercise is rarely assessed in intervals less than 1 min and, to our knowledge, an interval of less than 1 min has never been reported in children. As HRR at 1 min post-exercise was very fast in our sample (~62 bpm), it is possible that a shorter observation interval (e.g., 15 sec post exercise) might be more strongly related to health in preschoolers. Despite this, significant relationships were observed between HRR at 1 min and PA and health variables. Manual measurements of BP by a sphygmomanometer are recommended to assess BP status (e.g. hypertension) in children and were used for the normative data against which we compared our data (Anon, 2004). However, we chose to use an automated device as it eliminates observer bias, which is especially important given the longitudinal nature of the investigation (i.e., various individuals making assessments). Finally, we acknowledge that the measurements presented in this thesis require the cooperation and attention of the participant, which at times is difficult to achieve given their young age. We made strong efforts to develop rapport with the participants to achieve cooperation and attention during the testing session. Regardless, the first testing session included body composition, fitness, and motor skill proficiency assessments, in that order. The motor skill assessments required the participant's attention for a significant period of time (20 - 40 min); thus, children were often quite tired and distracted during these assessments. By conducting the motor proficiency assessment on a separate visit from the fitness assessments, higher compliance might be achieved, especially in the youngest children.

Accelerometry provides an immense amount of information – in this thesis, one data point for every 3 sec of observation (or approximately 8 million values!). This information is both exciting and overwhelming. The real challenge is how to make sense of it all. This thesis has broken ground with respect to characterizing PA patterns and how they relate to health in preschoolers. While we characterized frequency and duration of bouts of MVPA, we have left light PA; sedentary time; and individually, moderate PA and vigorous PA; to be explored. Similarly, we used average values for frequency and duration of MVPA bouts. These variables could be more extensively explored by examining how the frequency of short bouts of MVPA (e.g., <15 sec) and longer bouts of MVPA (e.g., >1 min) relate to health measures, for example. Finally, PA patterns were examined by intensity as described by the appropriate category (i.e., MVPA as ≥84 counts/3 sec). While software limitations prevented us from analyzing MVPA intensity as a continuous variable (e.g., average MVPA intensity was 148 counts/3 sec for boys and 122 counts/3 sec for girls), future investigations should attempt to characterize the relationships between health and PA intensity as described by a continuous variable.

References

Actigraph (2010). GT3X activity monitor: Actigraph activity monitor devices. Available at: http://www.theactigraph.com/products/gt3x/ [Accessed August 3, 2011].

Adamo KB, Prince SA, Tricco AC, Connor-Gorber S & Tremblay M (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: a systematic review. *Int J Pediatr Obes* **4,** 2–27.

Alpert B, Field TM, Goldstein S & Perry S (1990). Aerobics enhances cardiovascular fitness and agility in preschoolers. *Health Psychol* **9,** 48.

Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S & Andersen LB (2007). Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* **14,** 526–531.

Anon (1996). Bioelectrical impedance analysis in body composition measurement: National Institutes of Health Technology Assessment Conference Statement. *Am J Clin Nutr* **64,** 524S-532S.

Anon (2004). The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* **114,** 555–576.

Arai Y, Saul JP, Albrecht P, Hartley LH, Lilly LS, Cohen RJ & Colucci WS (1989). Modulation of cardiac autonomic activity during and immediately after exercise. *Am J Physiol* **256,** H132–H141.

Armstrong N (2001). Short term power output in relation to growth and maturation. *Br J Sports Med* **35,** 118–124.

Armstrong N & van Mechelen W (2008). *Paediatric Exercise Science and Medicine*, 2nd edn. Oxford University Press.

Australian Government Department of Health and Ageing (2011). Physical activity guidelines. Available at: http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines#rec_0_5 [Accessed July 28, 2011].

Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ & Cooper DM (1995). The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc* **27,** 1033–1041.

Baker JL, Olsen LW & Sørensen TIA (2007). Childhood body-mass index and the risk of coronary heart disease in adulthood. *N Engl J Med* **357,** 2329–2337.

Baquet G, Stratton G, Van Praagh E & Berthoin S (2007). Improving physical activity assessment in prepubertal children with high-frequency accelerometry monitoring: a methodological issue. *Prev Med* **44,** 143–147.

Bar-Or O (1987). The Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Med* **4,** 381–394.

Bar-Or O & Inbar O (1996). *The Wingate Anaerobic Test*. Human Kinetics.

Bar-Or O & Rowland TW (2004). *Pediatric Exercise Medicine: from physiological principles to health care application*. Human Kinetics.

Baraldi E, Cooper DM, Zanconato S & Armon Y (1991). Heart rate recovery from 1 minute of exercise in children and adults. *Pediatr Res* **29,** 575–579.

Baranowski T, Bouchard C, Bar-Or O, Bricker T, Heath G, Kimm SY, Malina R, Obarzanek E, Pate R & Strong WB (1992). Assessment, prevalence, and cardiovascular benefits of physical activity and fitness in youth. *Med Sci Sports Exerc* **24,** S237–S247.

Beets MW, Bornstein D, Dowda M & Pate RR (2011). Compliance with national guidelines for physical activity in u.s. Preschoolers: measurement and interpretation. *Pediatrics* **127,** 658–664.

Bellizzi MC & Dietz WH (1999). Workshop on childhood obesity: summary of the discussion. *Am J Clin Nutr* **70,** 173S-5S.

Benham-Deal T (2005). Preschool children's accumulated and sustained physical activity. *Percept Mot Skills* **100,** 443–450.

Berenson GS, Srinivasan SR, Bao W, Newman WP 3rd, Tracy RE & Wattigney WA (1998). Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* **338,** 1650–1656.

Boreham C & Riddoch C (2001). The physical activity, fitness and health of children. *J Sports Sci* **19,** 915–929.

Bornstein DB, Beets MW, Byun W, Welk G, Bottai M, Dowda M & Pate R (2011). Equating accelerometer estimates of moderate-to-vigorous physical activity: In search of the Rosetta Stone. *J Sci Med Sport* **14,** 404–410.

Burdette HL & Whitaker RC (2005). Resurrecting free play in young children: looking beyond fitness and fatness to attention, affiliation, and affect. *Arch Pediat Adol Med* **159,** 46–50.

Bürgi F, Meyer U, Granacher U, Schindler C, Marques-Vidal P, Kriemler S & Puder JJ (2011). Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: a cross-sectional and longitudinal study (Ballabeina). *Int J Obes (Lond)* **35,** 937–944.

Butani L & Morgenstern BZ (2003). Are pitfalls of oxcillometric blood pressure measurements preventable in children? *Pediatr Nephrol* **18,** 313–318.

Butte NF, Puyau MR, Adolph AL, Vohra FA & Zakeri I (2007). Physical activity in nonoverweight and overweight Hispanic children and adolescents. *Med Sci Sports Exerc* **39,** 1257–1266.

Cairney J, Hay JA, Veldhuizen S, Missiuna C & Faught BE (2010). Developmental coordination disorder, sex, and activity deficit over time: a longitudinal analysis of participation trajectories in children with and without coordination difficulties. *Dev Med Child Neurol* **52,** e67–e72.

van der Cammen-van Zijp, Ijsselstijn H, Takken T, Willemsen SP, Tibboel D, Stam HJ & van den Berg-Emons RJ (2010). Exercise testing of pre-school children using the Bruce treadmill protocol: new reference values. *Eur J Appl Physiol* **108,** 393–399.

Canadian Society for Exercise Physiology (2011). *Physical activity guidelines for children 5-11 years old*. Ottawa, ON, CAN. Available at: http://www.csep.ca/english/view.asp?x=804 [Accessed August 3, 2011].

Canning PM, Courage ML & Frizzell LM (2004). Prevalence of overweight and obesity in a provincial population of Canadian preschool children. *Can Med Assoc J* **171,** 240-242.

Cardon GM & De Bourdeaudhuij IMM (2008). Are preschool children active enough? Objectively measured physical activity levels. *Res Q Exerc Sport* **79,** 326–332.

Caspersen CJ, Powell KE & Christenson GM (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep* **100,** 126–131.

van Cauwenberghe E, Labarque V, Trost SG, de Bourdeaudhuij I & Cardon G (2010). Calibration and comparison of accelerometer cut points in preschool children. *Int J Pediatr Obes* **6,** e582–e589.

Chen KY & Bassett DR (2005). The Technology of Accelerometry-Based Activity Monitors: Current and Future. *Med Sci Sports Exerc* **37,** S490–S500.

Chen X & Wang Y (2008). Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation* **117,** 3171–3180.

Cliff DP, Reilly JJ & Okely AD (2009). Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. *J Sci Med Sport* **12,** 557–567.

Cole CR, Blackstone EH, Pashkow FJ, Snader CE & Lauer MS (1999). Heart-rate recovery immediately after exercise as a predictor of mortality. *N Engl J Med* **341,** 1351–1357.

Cole CR, Foody JM, Blackstone EH & Lauer MS (2000*a*). Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. *Ann Intern Med* **132,** 552–555.

Cole TJ, Bellizzi MC, Flegal KM & Dietz WH (2000*b*). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* **320,** 1240.

Cumming GR, Everatt D & Hastman L (1978). Bruce treadmill test in children: normal values in a clinic population. *Am J Cardiol* **41,** 69–75.

Darr KC, Bassett DR, Morgan BJ & Thomas DP (1988). Effects of age and training status on heart rate recovery after peak exercise. *Am J Physiol* **254,** H340–H343.

Davies PS, Gregory J & White A (1995). Physical activity and body fatness in pre-school children. *Int J Obes Relat Metab Disord* **19,** 6–10.

Dencker M, Bugge A, Hermansen B & Andersen LB (2010). Objectively measured daily physical activity related to aerobic fitness in young children. *J Sports Sci* **28,** 139–145.

Dencker M, Thorsson O, Karlsson MK, Lindén C, Svensson J, Wollmer P & Andersen LB (2006). Daily physical activity and its relation to aerobic fitness in children aged 8-11 years. *Eur J Appl Physiol* **96,** 587–592.

Department of Health (2011). UK physical activity guidelines. Available at: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_127931 [Accessed July 28, 2011].

Dowda M, Pate RR, Trost SG, Almeida MJCA & Sirard JR (2004). Influences of preschool policies and practices on children's physical activity. *J Commun Health* **29,** 183–196.

Dwyer GM, Baur L a & Hardy LL (2009). The challenge of understanding and assessing physical activity in preschool-age children: Thinking beyond the framework of intensity, duration and frequency of activity. *J Sci Med Sport* **12,** 534–536.

Eiberg S, Hasselstrom H, Gronfeldt V, Froberg K, Svensson J & Andersen LB (2005). Maximum oxygen uptake and objectively measured physical activity in Danish children 6-7 years of age: the Copenhagen school child intervention study. *Br J Sports Med* **39,** 725–730.

Ekelund U, Brage S, Besson H, Sharp S & Wareham NJ (2008). Time spent being sedentary and weight gain in healthy adults: reverse or bidirectional causality? *Am J Clin Nutr* **88,** 612–617.

Eliakim A, Nemet D, Balakirski Y & Epstein Y (2007). The effects of nutritional-physical activity school-based intervention on fatness and fitness in preschool children. *J Pediatr Endocrinol Metab* **20,** 711–718.

Esliger DW, Copeland JL, Barnes JD & Tremblay MS (2005). Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. *J Phys Act Health* **2,** 366–384.

Falk B & Bar-Or O (1993). Longitudinal changes in peak aerobic and anaerobic mechanical power of circumpubertal boys. *Pediatr Exerc Sci* **5,** 318–318.

Fernández JR, Redden DT, Pietrobelli A & Allison DB (2004). Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatr* **145,** 439–444.

Finn K, Johannsen N & Specker B (2002). Factors associated with physical activity in preschool children. *J Pediatr* **140,** 81–85.

Fisher A, Reilly JJ, Kelly LA, Montgomery C, Williamson A, Paton JY & Grant S (2005). Fundamental movement skills and habitual physical activity in young children. *Med Sci Sports Exerc* **37,** 684–688.

Folio MR & Fewell RR (2000). *Peabody Developmental Motor Scales: examiner's manual*, 2nd edn. Pro-ED, Texas.

Freedman DS, Khan LK, Serdula MK, Dietz WH, Srinivasan SR & Berenson GS (2005). The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study. *Pediatrics* **115,** 22.

Gopinath B, Baur LA, Garnett S, Pfund N, Burlutsky G & Mitchell P (2011*a*). Body mass index and waist circumference are associated with blood pressure in preschool-aged children. *Ann Epidemiol* **21,** 351–357.

Gopinath B, Hardy LL, Teber E & Mitchell P (2011*b*). Association between physical activity and blood pressure in prepubertal children. *Hypertens Res* **34,** 851-855.

Goran MI, Gower BA, Treuth M & Nagy TR (1998). Prediction of intra-abdominal and subcutaneous abdominal adipose tissue in healthy pre-pubertal children. *Int J Obes Relat Metab Disord* **22,** 549–558.

Gutin B, Basch C, Shea S, Contento I, DeLozier M, Rips J, Irigoyen M & Zybert P (1990). Blood pressure, fitness, and fatness in 5- and 6-year-old children. *JAMA* **264,** 1123–1127.

Han TS, Feskens EJ, Lean ME & Seidell JC (1998). Associations of body composition with type 2 diabetes mellitus. *Diabet Med* **15,** 129–135.

Hardy LL, King L, Farrell L, Macniven R & Howlett S (2010). Fundamental movement skills among Australian preschool children. *J Sci Med Sport* **13,** 503–508.

Hinkley T, Crawford D, Salmon J, Okely AD & Hesketh K (2008). Preschool children and physical activity: a review of correlates. *Am J Prev Med* **34,** 435–441.

Hofman A & Walter HJ (1989). The association between physical fitness and cardiovascular disease risk factors in children in a five-year follow-up study. *Int J Epidemiol* **18,** 830–835.

Holman RL, McGill HC Jr, Strong JP & Geer JC (1958). The natural history of atherosclerosis: the early aortic lesions as seen in New Orleans in the middle of the of the 20th century. *Am J Pathol* **34,** 209–235.

Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, Takeda H, Inoue M & Kamada T (1994). Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. *J Am Coll Cardiol* **24,** 1529–1535.

Inbar O & Bar-Or O (1986). Anaerobic characteristics in male children and adolescents. *Med Sci Sports Exerc* **18,** 264–269.

Jackson DM, Reilly JJ, Kelly LA, Montgomery C, Grant S & Paton JY (2003). Objectively measured physical activity in a representative sample of 3- to 4-year-old children. *Obes Res* **11,** 420–425.

Jago R, Baranowski T, Baranowski JC, Thompson D & Greaves KA (2005). BMI from 3-6 y of age is predicted by TV viewing and physical activity, not diet. *Int J Obes (Lond)* **29,** 557–564.

Janz K (2002). Fatness, physical activity, and television viewing in children during the adiposity rebound period: The Iowa Bone Development Study. *Prev Med* **35,** 563–571.

Janz KF, Burns TL, Torner JC, Levy SM, Paulos R, Willing MC & Warren JJ (2001). Physical activity and bone measures in young children: The Iowa Bone Development Study. *Pediatrics* **107,** 1387–1393.

Janz K, Burns T & Levy S (2005). Tracking of activity and sedentary behaviors in childhood: the Iowa Bone Development Study. *Am J Prev Med* **29,** 171.

Johnson ST, Kuk JL, Mackenzie KA, Huang TT-K, Rosychuk RJ & Ball GDC (2010). Metabolic risk varies according to waist circumference measurement site in overweight boys and girls. *J Pediatr* **156,** 247–252.e1.

Juonala M, Järvisalo MJ, Mäki-Torkko N, Kähönen M, Viikari JSA & Raitakari OT (2005). Risk factors identified in childhood and decreased carotid artery elasticity in adulthood: the Cardiovascular Risk in Young Finns Study. *Circulation* **112,** 1486–1493.

Katzmarzyk PT & Janssen I (2004). The economic costs associated with physical inactivity and obesity in Canada: an update. *Can J Appl Physiol* **29,** 90–115.

Keller H, Bar-Or O, Kriemler S, Ayub BV & Saigal S (2000). Anaerobic performance in 5- to 7-yr-old children of low birthweight. *Med Sci Sports Exerc* **32,** 278–283.

Kelly LA, Reilly JJ, Jackson DM, Montgomery C, Grant S & Paton JY (2007). Tracking physical activity and sedentary behavior in young children. *Pediatr Exerc Sci* **19,** 51–60.

Kelly LA, Fairweather SC, Grant S, Barrie S & Reilly JJ (2004). Comparison of two accelerometers for assessment of physical activity in preschool children. *Pediatr Exerc Sci* **16,** 324–333.

Klesges RC, Klesges LM, Eck LH & Shelton ML (1995). A longitudinal analysis of accelerated weight gain in preschool children. *Pediatrics* **95,** 126.

Kriemler S, Puder J, Zahner L, Roth R, Braun-Fahrländer C & Bedogni G (2009). Cross-validation of bioelectrical impedance analysis for the assessment of body composition in a representative sample of 6- to 13-year-old children. *Eur J Clin Nutr* **63,** 619–626.

Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF & Johnson CL (2002). 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat 11*1–190.

Kwon S, Janz KF, Burns TL & Levy SM (2011). Effects of adiposity on physical activity in childhood: Iowa Bone Development Study. *Med Sci Sports Exerc* **43,** 443–448.

Labarthe DR (1999). Prevention of cardiovascular risk factors in the first place. *Prev Med* **29,** S72–S78.

Lawes CMM, Vander Hoorn S & Rodgers A (2008). Global burden of blood-pressure-related disease, 2001. *Lancet* **371,** 1513–1518.

Lazarus R, Baur L, Webb K & Blyth F (1996). Body mass index in screening for adiposity in children and adolescents: systematic evaluation using receiver operating characteristic curves. *Am J Clin Nutr* **63,** 500–506.

Lee CD, Blair SN & Jackson AS (1999). Cardiorespiratory fitness, body composition, and all-cause and cardiovascular disease mortality in men. *Am J Clin Nutr* **69,** 373–380.

Lenk MK, Alehan D, Celiker A, Alpay F & Sarici U (1998). Bruce treadmill test in healthy Turkish children: endurance time, heart rate, blood pressure and electrocardiographic changes. *Turk J Pediatr* **40,** 167–175.

Lin L-Y, Kuo H-K, Lai L-P, Lin J-L, Tseng C-D & Hwang J-J (2008). Inverse correlation between heart rate recovery and metabolic risks in healthy children and adolescents: insight from the National Health and Nutrition Examination Survey 1999-2002. *Diabetes Care* **31,** 1015–1020.

Lobstein T, Baur L & Uauy R (2004). Obesity in children and young people: a crisis in public health. *Obes Rev* **5 Suppl 1,** 4–104.

Lopes VP, Rodrigues LP, Maia JAR & Malina RM (2010). Motor coordination as predictor of physical activity in childhood. *Scand J Med Sci Sports* doi:10.1111/j.1600-0838.2009.01027.x.

Maffeis C, Pietrobelli A, Grezzani A, Provera S & Tatò L (2001). Waist circumference and cardiovascular risk factors in prepubertal children. *Obes Res* **9,** 179–187.

Malina RM (1996). Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport* **67,** S48–S57.

Malina RM (2001). Physical activity and fitness: pathways from childhood to adulthood. *Am J Hum Biol* **13,** 162–172.

Malina RM, Bouchard C & Bar-Or O (2004). *Growth, Maturation, and Physical Activity*, 2nd edn. Human Kinetics.

Metallinos-Katsaras ES, Freedson PS, Fulton JE & Sherry B (2007). The association between an objective measure of physical activity and weight status in preschoolers. *Obesity* **15,** 686–694.

Moore LL, Nguyen US, Rothman KJ, Cupples LA & Ellison RC (1995). Preschool physical activity level and change in body fatness in young children. The Framingham Children's Study. *Am J Epidemiol* **142,** 982–988.

Mora S, Cook N, Buring JE, Ridker PM & Lee I-M (2007). Physical activity and reduced risk of cardiovascular events: potential mediating mechanisms. *Circulation* **116,** 2110–2118.

Must A & Strauss RS (1999). Risks and consequences of childhood and adolescent obesity. *Int J Obes Relat Metab Disord* **23 Suppl 2,** S2–S11.

Myers MG & Valdivieso MA (2003). Use of an automated blood pressure recording device, the BpTRU, to reduce the "white coat effect" in routine practice. *Am J Hypertens* **16,** 494–497.

National Association for Sport and Physical Education (2009). *Active start: a statment of physical activity guidelines for children from birth to age 5.*, 2nd edn. Reston, VA, USA.

Nguyen T, Obeid J & Timmons BW (2011). Reliability of fitness measures in 3- to 5-year-old children. *Pediatr Exerc Sci* **23,** 250–260.

Nilsson A, Ekelund U, Yngve A & Sjöström M (2001). Assessing Physical Activity Among Children With Activity Monitors Using Different Time Sampling Intervals and Placements. *Med Sci Sports Exerc* **33,** S252.

Obeid J, Nguyen T, Gabel L & Timmons BW (2011). Physical activity in Ontario preschoolers: prevalence and measurement issues. *Appl Physiol Nutr Metab* **36,** 291–297.

Ohuchi H, Suzuki H, Yasuda K, Arakaki Y, Echigo S & Kamiya T (2000). Heart rate recovery after exercise and cardiac autonomic nervous activity in children. *Pediatr Res* **47,** 329–335.

Okely AD, Salmon J, Trost SG & Hinkley T (2008). Discussion paper for the development of physical activity recommendations for children under 5 years. *Australian Department of Health and Ageing Canberra, Australia*.

Oliver M, Schofield GM & Kolt GS (2007). Physical activity in preschoolers: understanding prevalence and measurement issues. *Sports Med* **37,** 1045–1070.

Olstad DL & McCargar L (2009). Prevention of overweight and obesity in children under the age of 6 years. *Appl Physiol Nutr Metab* **34,** 551–570.

Paradis G, Tremblay MS, Janssen I, Chiolero A & Bushnik T (2010). Blood pressure in Canadian children and adolescents. *Health Rep* **21,** 15–22.

Parizkova J (1996). *Nutrition, Physical Activity, and Health in Early Life*. CRC Press.

Park MK & Menard SM (1987). Accuracy of blood pressure measurement by the Dinamap monitor in infants and children. *Pediatrics* **79,** 907–914.

Pate RR (1991). Health-related measures of children's physical fitness. *J Sch Health* **61,** 231–233.

Pate RR, Dowda M & Ross JG (1990). Associations between physical activity and physical fitness in American children. *Am J Dis Child* **144,** 1123–1129.

Pate RR, Almeida MJ, McIver KL, Pfeiffer KA & Dowda M (2006). Validation and calibration of an accelerometer in preschool children. *Obesity* **14,** 2000–2006.

Pate RR, Pfeiffer KA, Trost SG, Ziegler P & Dowda M (2004). Physical activity among children attending preschools. *Pediatrics* **114,** 1258–1263.

Pels AE 3rd, Gilliam TB, Freedson PS, Geenen DL & MacConnie SE (1981). Heart rate response to bicycle ergometer exercise in children ages 6-7 years. *Med Sci Sports Exerc* **13,** 299–302.

Penpraze V, Reilly J, MacLean CM, Montgomery C, Kelly LA, Paton JY, Altchison T & Grant S (2006). Monitoring of physical activity in young children: *Pediatr Exerc Sci* **18,** 483–492.

Petersen L, Schnohr P & Sørensen TIA (2004). Longitudinal study of the long-term relation between physical activity and obesity in adults. *Int J Obes Relat Metab Disord* **28,** 105–112.

Pfeiffer KA, Dowda M, McIver KL & Pate RR (2009). Factors related to objectively measured physical activity in preschool children. *Pediatr Exerc Sci* **21,** 196–208.

Pfitzinger P & Freedson PS (1997). Blood lactate responses to exercise in children: Part 2. Lactate Threshold. *Pediatr Exerc Sci* **9,** 299–307.

Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG & Roccella EJ (2005). Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation* **111,** 697–716.

Pierpont GL & Voth EJ (2004). Assessing autonomic function by analysis of heart rate recovery from exercise in healthy subjects. *Am J Cardiol* **94,** 64–68.

Pietrobelli A, Wang Z & Heymsfield SB (1998). Techniques used in measuring human body composition. *Curr Opin Clin Nutr Metab Care* **1,** 439–448.

Puyau MR, Adolph AL, Vohra FA & Butte NF (2002). Validation and calibration of physical activity monitors in children. *Obes Res* **10,** 150–157.

Puyau MR, Adolph AL, Vohra FA, Zakeri I & Butte NF (2004). Prediction of activity energy expenditure using accelerometers in children. *Med Sci Sports Exerc* **36,** 1625–1631.

Quattrin T, Liu E, Shaw N, Shine B & Chiang E (2005). Obese children who are referred to the pediatric endocrinologist: characteristics and outcome. *Pediatrics* **115,** 348–351.

Raitakari OT, Juonala M, Kähönen M, Taittonen L, Laitinen T, Mäki-Torkko N, Järvisalo MJ, Uhari M, Jokinen E, Rönnemaa T, Akerblom HK & Viikari JSA (2003). Cardiovascular risk factors in childhood and carotid artery intima-media thickness in adulthood: the Cardiovascular Risk in Young Finns Study. *JAMA* **290,** 2277–2283.

Reeves L, Broeder CE, Kennedy-Honeycutt L, East C & Matney L (1999). Relationship of fitness and gross motor skills for five- to six-yr.-old children. *Percept Mot Skills* **89,** 739–747.

Reilly JJ, Jackson DM, Montgomery C, Kelly LA, Slater C, Grant S & Paton JY (2004). Total energy expenditure and physical activity in young Scottish children: mixed longitudinal study. *The Lancet* **363,** 211–212.

Reilly JJ (2008). Physical activity, sedentary behaviour and energy balance in the preschool child: opportunities for early obesity prevention. *Proc Nutr Soc* **67,** 317–325.

Reilly JJ, Kelly L, Montgomery C, Williamson A, Fisher A, McColl JH, Conte RL, Paton JY & Grant S (2006). Physical activity to prevent obesity in young children: cluster randomised controlled trial. *BMJ* **333,** 1041–1041.

Rivilis I, Hay J, Cairney J, Klentrou P, Liu J & Faught BE (2011). Physical activity and fitness in children with developmental coordination disorder: A systematic review. *Research in Developmental Disabilities* **32,** 894–910.

RJL Systems (1993). *Fluid & Nutrition Status: Operations & Instructions Manual*. Clinton Twp, MI, USA.

Rutenfranz J, Lange Andersen K, Seliger V, Ilmarinen J, Klimmer F, Kylian H, Rutenfranz M & Ruppel M (1982). Maximal aerobic power affected by maturation and body growth during childhood and adolescence. *Eur J Pediatr* **139,** 106–112.

Saakslahti A, Numminen P, Varstala V, Helenius H, Tammi A, Viikari J & Valimaki I (2004). Physical activity as a preventive measure for coronary heart disease risk factors in early childhood. *Scand J Med Sci Sports* **14,** 143–149.

Savin WM, Davidson DM & Haskell WL (1982). Autonomic contribution to heart rate recovery from exercise in humans. *J Appl Physiol* **53,** 1572–1575.

Shea S, Basch CE, Gutin B, Stein AD, Contento IR, Irigoyen M & Zybert P (1994). The rate of increase in blood pressure in children 5 years of age is related to changes in aerobic fitness and body mass index. *Pediatrics* **94,** 465.

Shields M (2006). Overweight and obesity among children and youth. *Health Rep* **17,** 27–42.

Shields M & Tremblay MS (2010). Canadian childhood obesity estimates based on WHO, IOTF and CDC cut-points. *Int J Pediatr Obes* **5,** 265–273.

Sigmund E, De Ste Croix M, Miklánková L & Frömel K (2007). Physical activity patterns of kindergarten children in comparison to teenagers and young adults. *Eur J Public Health* **17,** 646–651.

Simonetti GD, Schwertz R, Klett M, Hoffmann GF, Schaefer F & Wühl E (2011). Determinants of blood pressure in preschool children: the role of parental smoking. *Circulation* **123,** 292–298.

Sinaiko AR, Steinberger J, Moran A, Prineas RJ & Jacobs DR Jr (2002). Relation of insulin resistance to blood pressure in childhood. *J Hypertens* **20,** 509–517.

Singh TP, Rhodes J & Gauvreau K (2008). Determinants of heart rate recovery following exercise in children. *Med Sci Sports Exerc* **40,** 601–605.

Steele RM, Brage S, Corder K, Wareham NJ & Ekelund U (2008). Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. *J Appl Physiol* **105,** 342–351.

Stone MR, Rowlands AV, Middlebrooke AR, Jawis MN & Eston RG (2009). The pattern of physical activity in relation to health outcomes in boys. *Int J Pediatr Obes* **4,** 306–315.

Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pivarnik JM, Rowland T, Trost S & Trudeau F (2005). Evidence based physical activity for school-age youth. *J Pediatr* **146,** 732–737.

Takahashi E, Yoshida K, Sugimori H, Miyakawa M, Izuno T, Yamagami T & Kagamimori S (1999). Influence factors on the development of obesity in 3-year-old children based on the Toyama Study. *Prev Med* **28,** 293–296.

Taylor RW, Jones IE, Williams SM & Goulding A (2000). Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. *Am J Clin Nutr* **72,** 490–495.

Taylor RW, Jones IE, Williams SM & Goulding A (2002). Body fat percentages measured by dual-energy X-ray absorptiometry corresponding to recently recommended body mass index cutoffs for overweight and obesity in children and adolescents aged 3-18 y. *Am J Clin Nutr* **76,** 1416–1421.

Taylor RW, Williams SM, Carter PJ, Goulding A, Gerrard DF & Taylor BJ (2011). Changes in fat mass and fat-free mass during the adiposity rebound: FLAME study. *Int J Pediatr Obes*.

Taylor RW, Williams SM, Grant AM, Ferguson E, Taylor BJ & Goulding A (2008). Waist circumference as a measure of trunk fat mass in children aged 3 to 5 years. *Int J Pediatr Obes* **3,** 226–233.

Telford A, Salmon J, Timperio A & Crawford D (2005). Examining physical activity among 5- to 6- and 10- to 12-year-old children: The children's leisure activities study. *Pediatr Exerc Sci* **17,** 266–280.

Temple VA, Naylor PJ, Rhodes RE & Higgins JW (2009). Physical activity of children in family child care. *Appl Physiol Nutr Metab* **34,** 794–798.

Timmons BW, Naylor PJ, Pfeiffer KA & Sheperd RJ (2007). Physical activity for preschool children-how much and how? *Appl Physiol Nutr Metab* **32,** S122–S134.

Trost SG, Sirard JR, Dowda M, Pfeiffer KA & Pate RR (2003). Physical activity in overweight and nonoverweight preschool children. *Int J Obes Relat Metab Disord* **27,** 834–839.

Trost SG, McIver KL & Pate RR (2005). Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sports Exerc* **37,** S531–S543.

Trost SG, Pate RR, Freedson PS, Sallis JF & Taylor WC (2000). Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* **32,** 426–431.

Tucker P (2008). The physical activity levels of preschool-aged children: A systematic review. *Early Child Res Q* **23,** 547–558.

Twisk JWR, Kemper HCG & van Mechelen W (2002). Prediction of cardiovascular disease risk factors later in life by physical activity and physical fitness in youth: general comments and conclusions. *Int J Sports Med* **23 Suppl 1,** S44–S49.

Vale S, Silva P, Santos R, Soares-Miranda L & Mota J (2010). Compliance with physical activity guidelines in preschool children. *J Sports Sci* **28,** 603–608.

Vivekananthan DP, Blackstone EH, Pothier CE & Lauer MS (2003). Heart rate recovery after exercise is a predictor of mortality, independent of the angiographic severity of coronary disease. *J Am Coll Cardiol* **42,** 831–838.

Wang L, Su SW & Celler BG (2006). Time constant of heart rate recovery after low level exercise as a useful measure of cardiovascular fitness. *Conf Proc IEEE Eng Med Biol Soc* **1,** 1799–1802.

Washington RL, van Gundy JC, Cohen C, Sondheimer HM & Wolfe RR (1988). Normal aerobic and anaerobic exercise data for North American school-age children. *J Pediatr* **112,** 223–233.

Watts K, Bell LM, Byrne SM, Jones TW & Davis EA (2008). Waist circumference predicts cardiovascular risk in young Australian children. *J Paediatr Child Health* **44,** 709–715.

Wessel HU, Strasburger JF & Mitchell BM (2001). New standards for the bruce treadmill protocol in children and adolescents. *Pediatr Exerc Sci* **13,** 392.

Whitaker RC, Wright JA, Pepe MS, Seidel KD & Dietz WH (1997). Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* **337,** 869–873.

Whitworth JA (2003). 2003 World Health Organization (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. *J Hypertens* **21,** 1983–1992.

WHO (2011*a*). WHO | Childhood overweight and obesity. *Childhood overweight and obesity*. Available at: http://www.who.int/dietphysicalactivity/childhood/en/ [Accessed July 9, 2011].

WHO (2011*b*). WHO | The top 10 causes of death. *The top 10 causes of death*. Available at: http://www.who.int/mediacentre/factsheets/fs310/en/index.html [Accessed July 9, 2011].

Wiart L & Darrah J (2001). Review of four tests of gross motor development. *Dev Med Child Neurol* **43,** 279–285.

Williams HG, Pfeiffer KA, O'Neill JR, Dowda M, McIver KL, Brown WH & Pate RR (2008). Motor skill performance and physical activity in preschool children. *Obesity* **16,** 1421–1426.

Wong S-N, Tz Sung RY & Leung LC-K (2006). Validation of three oscillometric blood pressure devices against auscultatory mercury sphygmomanometer in children. *Blood Press Monit* **11,** 281–291.

Wrotniak BH, Epstein LH, Dorn JM, Jones KE & Kondilis VA (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics* **118,** e1758–e1765.

Appendices

Appendix A: Parent/Guardian consent form

McMaster University
Health Sciences

Hamilton Health Sciences
EXEMPLARY CARE • ACADEMIC EXCELLENCE

PARENT CONSENT FORM

Title of Study: *Health Outcomes and Physical activity in Preschoolers: The HOPP Study*

Principal Investigator: *Brian W. Timmons (PhD), Children's Exercise & Nutrition Centre*

Co-Investigators: *Steven Bray (PhD), Department of Kinesiology, McMaster University*
Maureen MacDonald (PhD), Department of Kinesiology, McMaster University
John Cairney (PhD), Department of Family Medicine, McMaster University

Study Sponsor: *Canadian Institutes of Health Research*

INTRODUCTION

Your child is being invited to participate in a research study conducted by Dr. Brian Timmons because they are 3 to 5 years of age. In order to decide whether or not you want to be a part of this research study, you should understand what is involved and the potential risks and benefits. This form gives detailed information about the study, which will be discussed with you. Once you understand the study, you will be asked to sign this form if you wish to participate. Feel free to discuss it with your family and take your time to make your decision.

WHY IS THIS RESEARCH BEING DONE?

We believe that exercise and physical activity are good for young children and that play is an important part of child development. But we do not know how much physical activity is required for good health. The need to recommend appropriate levels of physical activity has never been greater because more children are becoming overweight and opportunities for preschoolers to be physically active are being replaced by sedentary activities. The best way to understand the relationships between physical activity and health is to follow the same children over time (called longitudinal research) with regular assessments of physical activity and health.

WHAT IS THE PURPOSE OF THIS STUDY?

The main purpose of this study is to determine how physical activity is related to health in preschoolers. We also hope to learn about nutrition habits in preschoolers and barriers parents face to getting their preschooler active. We will make these assessments once per year for 3 years to understand how the relationships between these important variables change or stay the same during the early years.

April 12, 2010 – Parent Consent Form (HOPP) – Version 2 Page 1 of 1

McMaster University Health Sciences

Hamilton Health Sciences
EXEMPLARY CARE • ACADEMIC EXCELLENCE

WHAT WILL MY CHILD'S RESPONSIBILITIES BE IF THEY TAKE PART IN THE STUDY?

If you and your child volunteer to participate in this study, we will ask you to do the following things:

• Make 2 visits to our laboratories separated by about 8 days. At the first visit, your child will have some testing done at the Children's Exercise and Nutrition Centre (Chedoke Hospital). At the second visit, testing will be done in the Department of Kinesiology, which is at McMaster University. During each visit we will perform different tests on your child.

• At the Children's Exercise & Nutrition Centre, we will record your child's weight and height, determine their percent body fat, and measure their waist circumference. They will pedal our special bicycle for as fast as they can for about 10 sec. They will then walk on a treadmill for as long as they can to determine fitness while we record their heart rate during and shortly after the exercise test. We will have you fill out some questionnaires at this visit to tell us about your child's health and issues about their physical activity. When it is time to leave, we will put a small pager-like device, called an accelerometer, on the waist of your child. This little box (about the size of a matchbox) will record their physical activity over the next 8 days. We will explain how to care for it during this time. This visit will take about 1.5 hours.

• At the Department of Kinesiology, we will measure the health of the main blood vessel in your child's neck. This test requires your child to lie on a bed for about 15 min for the measurements to be taken. We will then assess your child's motor skills by having them do some running, hopping, and ball-throwing tasks, and this takes about 40 min. We will have you fill out some more questionnaires at this visit to tell us about your child's health and issues about their well-being. This visit will take about 1.5 hours.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

There are no unusual risks or discomforts associated with your child's participation in this study. Your child may feel a little tired after the exercise tests, but this feeling won't last long. If your child already rides a tricycle or a bicycle, the bike test is no different than what they might experience while riding their own machine as fast as they can. Your child may not be used to walking on a treadmill so we will ensure they can safely do this task. To measure body composition we will use a special machine that estimates how much water is in your child's body by sending a small electrical current through your child's body. The current is so small that they will not feel it at all and it will not hurt them whatsoever. To measure blood vessels, we will use the same ultrasound machine that doctors use to take a picture of a baby during a pregnancy. We will ask you about your confidence in providing your child opportunities to be physically active. You can answer these questions to the extent you feel comfortable doing so. Any information collected from you and your child will become anonymous to ensure confidentiality.

HOW MANY PEOPLE WILL BE IN THIS STUDY?

We are asking boys and girls aged 3 to 5 years from the Hamilton and surrounding communities to participate. We plan to test 400 children once per year for 3 years in a row. Your participation is voluntary.

WHAT ARE THE POSSIBLE BENEFITS FOR MY CHILD AND/OR FOR SOCIETY?

We cannot promise any personal benefits to you or your child from their participation in this study. You will learn how several health characteristics of your child (body fat, blood vessel health, and physical fitness) compares with other children their age. You will also learn how these things change over time and whether these markers of health are associated with how much physical activity or play they do. By participating in this study, you will be contributing to knowledge that will be used to develop physical activity guidelines for Canadian preschoolers.

WHAT INFORMATION WILL BE KEPT PRIVATE?

All of your information will be stored in filing cabinets under the supervision of Dr. Brian Timmons for 25 years. We will supervise access to your child's information by other people in our group, only if necessary. Your child will be assigned a subject number, and this number will be used to identify them. Records identifying your child will be kept confidential. If the results of the study are published, their identity will remain confidential.

CAN PARTICIPATION IN THE STUDY END EARLY?

If your child volunteers to be in this study, you or your child may withdraw at any time with no prejudice. The investigator may withdraw your child from this research if circumstances arise which warrant doing so.

WILL MY CHILD BE PAID TO PARTICIPATE IN THIS STUDY?

Your child will not be paid to participate in this study, but we will provide them a gift package including various trinkets and a certificate of participation each year of the study. We will also reimburse you for any parking expenses and provide you an annual "*physical activity report card*". You will be able to make regular visits to our website for updates on the HOPP study.

IF I HAVE ANY QUESTIONS OR PROBLEMS, WHOM CAN I CALL?

If you have any questions about the research now or later, please contact Nicole Proudfoot at 905-521-2100, ext 77217 or proudfna@mcmaster.ca.

If you have any questions regarding your rights as a research participant, you may contact the Office of the Chair of the Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board at 905-521-2100, ext. 42013.

McMaster University Health Sciences

Hamilton Health Sciences
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CONSENT STATEMENT

I have read the preceding information thoroughly. I have had the opportunity to ask questions, and all of my questions have been answered to my satisfaction and to the satisfaction of my child. I agree to allow my child to participate in this study entitled: *"Health Outcomes and Physical activity in Preschoolers: The HOPP Study"*. I understand that I will receive a signed copy of this form.

____
Name of Participant (child's name)

____
Printed Name of Legally Authorized Representative

______________________________ ____________
Signature of Legally Authorized Representative Date

Consent form administered and explained in person by:

____
Printed Name of Person Obtaining Consent

______________________________ ____________
Signature of Person Obtaining Consent Date

SIGNATURE OF INVESTIGATOR:

In my judgement, the participant is voluntarily and knowingly giving informed consent and possesses the legal capacity to give informed consent for their child to participate in this research study.

____
Printed Name and title

______________________________ ____________
Signature of Investigator Date

Appendix B: Physical Activity Data and Statistics

B.1 t-test by sex

Variable	Total (n=90)	Girls (n=47)	Boys (n=43)	t-test *p*-value
PA Prevalence				
MVPA (min/day)[a]	93 ± 21	85 ± 20	102 ± 18	<0.001
	-	*87 ± 17*	*100 ± 17*	-
TPA (min/day)[a]	258 ± 38	242 ± 36	276 ± 31	<0.001
	-	*245 ± 32*	*274 ± 32*	-
MVPA (% of wear)	13.2 ± 3.0	12.2 ± 2.7	14.3 ± 2.8	0.001
	-	*12.4 ± 2.7*	*14.1 ± 2.7*	-
TPA (% of wear)	36.4 ± 4.9	34.5 ± 4.6	38.5 ± 4.5	<0.001
	-	*34.7 ± 4.6*	*38.3 ± 4.6*	-
PA Pattern				
Frequency of MVPA continuous bouts (bouts/h)	70 ± 12	66 ± 12	74 ± 11	0.001
	-	*67 ± 11*	74 ± *11*	-
MVPA bout duration (sec)[b]	7.1 ± 0.8	6.9 ± 0.8	7.2 ± 0.7	0.034
	-	*6.9 ± 0.7*	*7.2 ± 0.7*	-
Duration of breaks between bouts of MVPA (sec)[b]	47.8 ± 8	51.0 ± 8.2	44.2 ± 6.2	<0.001
	-	*50.7 ± 7.2*	*44.6 ± 7.2*	-

Age-adjusted means are presented in italics.
[a] For absolute PA analyses (min/day), 84 participants were included (44 girls, 40 boys).
[b] While continuous bouts and breaks were only measured to the nearest sec, the values within this table are presented to the nearest 0.1 sec to facilitate comparisons. MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

B.2 Multiple regression by age and sex

Variable	Model	Variables	b	SE	ß	*p*-value	Δr^2	r^2	Model sig.
MVPA (min/day)	1	Age	12.424	2.318	.509	.000	-	.259	.000
	2	Age	10.920	2.183	.448	.000	.113	.372	.000
		Sex	14.201	3.719	.342	.000			
TPA (min/day)	1	Age	18.766	4.356	.430	.000	-	.185	.000
	2	Age	15.466	4.061	.354	.000	.142	.327	.000
		Sex	28.736	6.943	.385	.000			
MVPA (% of wear)	1	Age	1.250	.343	.362	.000	-	.131	.000
	2	Age	1.068	.334	.309	.002	.082	.214	.000
		Sex	1.716	.586	.292	.003			
TPA (% of wear)	1	Age	1.210	.592	.213	.044	-	.045	.044
	2	Age	.832	.561	.146	.141	.134	.180	.000
		Sex	3.660	.970	.372	.000			
Frequency of MVPA (bouts/h)	1	Age	4.935	1.415	.348	.001	-	.121	.001
	2	Age	4.208	1.381	.297	.003	.078	.200	.000
		Sex	6.862	2.353	.284	.005			
Duration of MVPA bouts	1	Age	.308	.089	.346	.001	-	.120	.001
	2	Age	.282	.090	.317	.002	.027	.147	.001
		Sex	.257	.155	.167	.101			
Duration of breaks between bouts of MVPA	1	Age	-2.782	.943	-.300	.004	-	.090	.004
	2	Age	-2.151	.886	-.232	.017	.141	.231	.000
		Sex	-6.124	1.532	-.382	.000			

b, b coefficients; SE, standard error of b; ß, standardized coefficients; r^2, coefficients of determination.
Model 1 included only age; model 2 included age and sex. MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

B.3 t-test by compliance with physical activity (PA) guidelines

Variable	*180 min of TPA* Not Meeting (n=22)	Meeting (n=62)	t-test p – value[b]	*60 min MVPA* Not Meeting (n=33)	Meeting (n=51)	t-test p – value[c]
Sex (boys/girls)	7/15	33/29	0.083	11/22	29/22	0.034
Age (years)	4.04 ± 0.87	4.66 ± 0.80	0.003	4.22 ± 0.86	4.67 ± 0.82	0.016
Height (cm)	102.6 ± 8.8	107.9 ± 6.9	0.006	103.5 ± 8.8	108.5 ± 6.3	0.003
Weight (kg)	16.9 ± 3.5	18.4 ± 2.8	0.050	16.9 ± 3.2	18.7 ± 2.7	0.008
BMI (%ile)	15.9 ± 1.1	15.8 ± 1.0	0.486	15.7 ± 1.0	15.8 ± 1.1	0.635
WC (cm)	52.2 ± 3.7	53.0 ± 3.3	0.335	52.0 ± 3.1	53.3 ± 3.5	0.066
BF (%)	26.3 ± 4.5	22.7 ± 4.3	0.001	24.9 ± 4.6	22.7 ± 4.5	0.037
HRR (bpm)[a]	61 ± 12	66 ± 14	0.177	62 ± 13	67 ± 13	0.170
Treadmill Time (min)[a]	8.4 ± 2.2	10.2 ± 2.2	0.006	8.7 ± 2.3	10.5 ± 2.1	0.001
PP (Watts)	72.2 ± 36.2	92.0 ± 38.9	0.048	79.9 ± 43.8	91.4 ± 35.6	0.203
PP (Watts/kg)	4.1 ± 1.4	4.9 ± 1.5	0.038	4.4 ± 1.6	4.8 ± 1.5	0.349
MP (Watts)	59.5 ± 29.0	77.5 ± 32.2	0.029	67.0 ± 35.2	76.6 ± 30.2	0.202
MP (Watts/kg)	3.4 ± 1.3	4.1 ± 1.3	0.033	3.8 ± 1.4	4.0 ± 1.3	0.401
SBP (mmHg)	95 ± 9	98 ± 7	0.147	96 ± 7	98 ± 8	0.175
SBP (%ile)	54 ± 25	59 ± 22	0.439	57 ± 22	58 ± 23	0.880
DBP (mmHg)	60 ± 6	61 ± 5	0.421	60 ± 5	61 ± 4	0.419
DBP (%ile)	73 ± 15	73 ± 12	0.941	74 ± 15	73 ± 12	0.854
Motor Proficiency (%ile)	35 ± 23	45 ± 8	0.077	42 ± 25	44 ± 22	0.645

[a] Only participants reaching an HR_{peak} of 180 were included in analyses, thus, 70 participants were included in t-tests (17/53 and 27/42 for not meeting/meeting 180 min TPA and 60 min MVPA, respectively).

[b] ANCOVA controlling for the effects of age was conducted, following which only BF% remained significantly different between groups p = 0.047), with a trend for longer treadmill time (p = 0.098).

[c] ANCOVA controlling for the effects of age was conducted, following which only treadmill time remained significantly different between groups p = 0.039), with a trend for higher compliance in boys (p = 0.085). BMI, body mass index WC, waist circumference; BF, body fat; HRR, heart rate recovery; PP, peak power; MP, mean power; SBP, systolic blood pressure; DBP, diastolic blood pressure; TPA, total physical activity; MVPA, moderate-to-vigorous physical activity.

Appendix C: Body Composition Data and Statistics

C.1 t-test by sex

Variable	Total (n=96)	Girls (n=50)	Boys (n=46)	*t* test *p*-value
BMI (%ile)	57 ± 26	58 ± 25	56 ± 26	0.710
	-	*58 ± 27*	*56 ± 26*	-
n Overweight (IOTF/CDC)	6/18	2/10	4/8	0.348/0.747
WC (cm)	52.9 ± 3.4	52.3 ± 3.2	53.6 ± 3.6	0.053
	-	*52.5 ± 3.1*	*53.4 ± 3.1*	-
BF %	23.6 ± 4.7	26.4 ± 3.5	20.5 ± 3.8	<0.001
	-	*26.1 ± 3.1*	*20.8 ± 3.1*	-

Age-adjusted means are presented in italics. BMI, body-mass index; IOTF, International Obesity Task Force; CDC, Centre for Disease Control; WC, waist circumference; BF, body fat.

C.2 Multiple regression by age and sex

Variable	Model	Variables	b	SE	ß	*p*-value	Δr^2	r^2	Model sig.
BMI (%ile)	1	Age	.083	3.076	.003	.979	-	.000	.979
	2	Age	.399	3.141	.010	.924	.002	.002	.929
		Sex	-2.043	5.352	-.040	.703			
WC (cm)	1	Age	1.650	.376	.412	.000	-	.170	.000
	2	Age	1.558	.380	.389	.000	.016	.186	.000
		Sex	.870	.648	.128	.183			
BF %	1	Age	-2.985	.480	-.542	.000	-	.294	.000
	2	Age	-2.455	.371	-.446	.000	.301	.595	.000
		Sex	-5.230	.632	-.557	.000			

b, b coefficients; SE, standard error of b; ß, standardized coefficients; r^2, coefficients of determination.
Model 1 included only age; model 2 included age and sex. BMI, body-mass index; IOTF, International Obesity Task Force; CDC, Centre for Disease Control; WC, waist circumference; BF, body fat.

C.3 t-test by classification of overweight/obesity

Variable	Normal weight (n=78)	Overweight/Obese (n=18)	t-test *p* – value
Sex (boys/girls)	38/40	8/10	0.747
Age (years)	4.47 ± 0.85	4.26 ± 0.87	0.358
Height (cm)	106.3 ± 7.4	105.4 ± 8.9	0.640
Weight (kg)	17.6 ± 2.7	19.7 ± 3.8	0.007
WC (cm)	52.3 ± 3.0	55.9 ± 3.6	0.000
BF (%)	23.1 ± 4.5	25.3 ± 5.3	0.076
HRR (bpm)	63 ± 15	67 ± 10	0.320
Treadmill Time (min)	9.2 ± 2.2	9.1 ± 2.9	0.397
PP (Watts)	85.8 ± 38.5	88.9 ± 46.2	0.773
PP (Watts/kg)	4.7 ± 1.5	4.3 ± 1.6	0.388
MP (Watts)	72.7 ± 32.5	70.4 ± 35.6	0.799
MP (Watts/kg)	4.0 ± 1.4	3.5 ± 1.3	0.158
SBP (mmHg)	97 ± 8	102 ± 4	0.032
SBP (%ile)	56 ± 23	72 ± 15	0.033
DBP (mmHg)	61 ± 5	61 ± 3	0.965
DBP (%ile)	73 ± 14	75 ± 11	0.707
Motor Proficiency (%ile)	46 ± 23	37 ± 22	0.120
MVPA (min/day)	93.3 ± 19.8	92.2 ± 26.4	0.854
TPA (min/day)	257.8 ± 35.8	261.8 ± 46.6	0.722
MVPA (% of wear)	13.1 ± 2.6	13.7 ± 4.2	0.443
TPA (% of wear)	36.2 ± 4.5	37.6 ± 6.5	0.413
MVPA continuous bout frequency (bouts/h)	69.4 ± 11.0	72.3 ± 16.5	0.512
MVPA continuous bout duration (sec)[a]	7.1 ± 0.8	6.9 ± 0.9	0.308
Break duration between bouts of MVPA (sec)[a]	47.8 ± 7.0	47.8 ± 12.2	1.000

[a] While continuous bouts and breaks were only measured to the nearest sec, the values within this table are presented to the nearest 0.1 sec to facilitate comparisons. BMI, body mass index; WC, waist circumference; BF, body fat; HRR, heart rate recovery; PP, peak power; MP, mean power, SBP, systolic blood pressure, DBP, diastolic blood pressure; MVPA, moderate to vigorous physical activity; TPA, total physical activity.

C.4 Correlations between body composition and physical activity (PA)

			PA variables						
Control Variable	Body Composition Variable		MVPA (min/day)	TPA (min/day)	MVPA (% of wear)	TPA (% of wear)	Frequency of MVPA (bouts/h)	Duration of MVPA (sec)	Duration of breaks from MVPA (sec)
-	BMI (%ile)	r	.068	.135	.069	.079	.114	-.095	-.008
		p-value	.539	.220	.516	.458	.285	.373	.938
		df	84	84	90	90	90	90	90
Age	WC (cm)	r	.191	.181	.207	.162	.207	.087	-.185
		p-value	.083	.120	.051	.130	.052	.417	.082
		df	81	81	87	87	87	87	87
Age & Sex	BF (%)	r	-.006	-.113	-.050	-.163	-.013	-.031	.029
		p-value	.961	.316	.648	.133	.904	.776	.786
		df	79	79	85	85	85	85	85

BMI, body-mass index; WC, waist circumference; BF, body fat; MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

Appendix D: Health-Related Fitness Data and Statistics

D.1 t-test by sex

Variable	Total (n=90)	Girls (n=47)	Boys (n=43)	t-test *p*-value
Treadmill time (min)[a]	9.2 ± 2.5	8.8 ± 2.4	9.6 ± 2.6	0.147
	-	*9.4 ± 1.6*	*9.8 ± 1.6*	-
HRR (bpm)[a]	62 ± 14	60 ± 15	65 ± 13	0.055
	-	*61 ± 14*	*66 ± 14*	-
PP (Watts)	86.4 ± 40.0	75.8 ± 27.2	98.0 ± 47.8	0.007
	-	*80.3 ± 28.6*	*93.1 ± 28.7*	-
PP (Watts/kg)	4.6 ± 1.5	4.3 ± 1.3	5.0 ± 1.7	0.037
	-	*4.5 ± 1.1*	*4.8 ± 1.2*	-
MP (Watts)	72.2 ± 33.0	65.0 ± 24.7	80.2 ± 38.9	0.027
	-	*68.8 ± 23.6*	*76.0 ± 23.7*	-
MP (Watts/kg)	3.9 ± 1.4	3.7 ± 1.2	4.1 ± 1.5	0.175
	-	*3.8 ± 1.1*	*3.9 ± 1.1*	-

Age-adjusted means are presented in italics.
[a] Only participants reaching a HR_{peak} of 180 were included in analyses, thus 80 participants were included in t-test (42 girls, 38 boys). HRR, heart rate recovery; PP, peak power; MP, mean power.

D.2 Multiple regression by age and sex

Variable	Model	Variables	b	SE	ß	*p*-value	Δr^2	r^2	Model sig.
Treadmill Time (min)	1	Age	2.068	.208	.752	.000	-	.560	.000
	2	Age	2.034	.211	.736	.000	.005	.565	.000
		Sex	.349	.357	.074	.331			
HRR (bpm)	1	Age	2.715	1.857	.163	.148	-	.027	.148
	2	Age	2.148	1.857	.131	.243	.038	.064	.077
		Sex	5.555	3.151	.197	.082			
PP (Watts)	1	Age	32.691	3.652	.690	.000	-	.477	.000
	2	Age	31.308	3.642	.661	.000	.025	.502	.000
		Sex	12.846	6.097	.162	.038			
PP (Watts/kg)	1	Age	1.226	.144	.673	.000	-	.453	.000
	2	Age	1.193	.145	.655	.000	.010	.463	.000
		Sex	.312	.244	.102	.204			
MP (Watts)	1	Age	27.501	2.973	.702	.000	-	.493	.000
	2	Age	26.726	3.005	.682	.000	.012	.505	.000
		Sex	7.199	5.031	.110	.156			
MP (Watts/kg)	1	Age	1.049	.132	.646	.000	-	.417	.000
	2	Age	1.041	.135	.646	.000	.001	.418	.000
		Sex	.079	.226	.029	.728			

b, b coefficients; SE, standard error of b; ß, standardized coefficients; r^2, coefficients of determination.
Model 1 included only age; model 2 included age and sex. HRR, heart rate recovery; PP, peak power; MP, mean power.

D.3 Correlations between health-related fitness and physical activity (PA)

			PA variables						
Control Variable	Fitness Variable		MVPA (min/day)	TPA (min/day)	MVPA (% of wear)	TPA (% of wear)	Frequency of MVPA (bouts/h)	Duration of MVPA (sec)	Duration of breaks from MVPA (sec)
-	HRR (bmp)	r	.188	.292	.179	.240	.287	-.027	-.259
		p-value	.120	.014	.122	.037	.012	.820	.024
		df	70	70	76	76	76	76	76
Age	Treadmill Time (min)	r	.154	.166	.201	.196	.051	.326	-.139
		p-value	.205	.172	.084	.092	.662	.004	.235
		df	67	67	73	73	73	73	73
Age	PP (Watts)	r	.075	.019	.162	.041	.069	.237	-.161
		p-value	.507	.869	.140	.712	.532	.029	.142
		df	78	78	83	83	83	83	83
Age	PP (Watts/kg)	r	.016	-.047	.097	-.010	.006	.234	-.104
		p-value	.886	.678	.377	.924	.957	.032	.343
		df	78	78	83	83	83	83	83
Age	MP (Watts)	r	.057	.002	.141	.023	.052	.232	-.134
		p-value	.617	.984	.197	.836	.635	.033	.233
		df	78	78	83	83	83	83	83
Age	MP (Watts/kg)	r	-.008	-.067	.061	-.035	-.017	.207	-.061
		p-value	.944	.553	.579	.754	.875	.058	.577
		df	78	78	83	83	83	83	83

HRR, heart rate recovery; PP, peak power; MP, mean power; MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

Appendix E: Blood Pressure Data and Statistics

E.1 t-test by sex

Variable	Total (n=81)	Girls (n=41)	Boys (n=40)	t-test *p*-value
SBP (mmHg)	97 ± 7	97 ± 8	97 ± 7	0.871
	-	*98 ± 7*	*97 ± 7*	-
SBP (%ile)	58 ± 22	63 ± 23	54 ± 21	0.055
	-	*63 ± 22*	*53 ± 22*	-
DBP (mmHg)	61 ± 5	61 ± 5	61 ± 5	0.731
	-	*61 ± 5*	*60 ± 5*	-
DBP (%ile)	74 ± 13	74 ± 13	73 ± 13	0.725
	-	*73 ± 13*	*74 ± 13*	-

Age-adjusted means are presented in italics. SBP, systolic blood pressure; DBP, diastolic blood pressure.

E.2 Multiple regression by age and sex

Variable	Model	Variables	b	SE	ß	*p*-value	Δr^2	r^2	Model sig.
SBP (mmHg)	1	Age	1.455	.946	.171	.128	-	.029	.128
	2	Age	1.550	.970	.182	.114	.003	.032	.281
		Sex	-.812	1.673	-.055	.629			
SBP (%ile)	1	Age	-.367	2.896	-.014	.900	-	.000	.900
	2	Age	.782	2.906	.030	.789	.047	.047	.154
		Sex	-9.788	5.012	-220	.054			
DBP (mmHg)	1	Age	.680	.608	.125	.267	-	.016	.267
	2	Age	.754	.624	.138	.230	.004	.020	.457
		Sex	-.628	1.075	-.067	.561			
DBP (%ile)	1	Age	-4.288	1.656	-.280	.011	-	.078	.011
	2	Age	-4.343	1.702	-.283	.013	.000	.079	.041
		Sex	.467	2.935	.018	.874			

b, b coefficients; SE, standard error of b; ß, standardized coefficients; r^2, coefficients of determination.
Model 1 included only age; model 2 included age and sex. SBP, systolic blood pressure; DBP, diastolic blood pressure.

E.3 Correlations between blood pressure and physical activity (PA)

			PA variables						
Control Variable	Blood Pressure Variable		MVPA (min/day)	TPA (min/day)	MVPA (% of wear)	TPA (% of wear)	Frequency of MVPA (bouts/h)	Duration of MVPA (sec)	Duration of breaks from MVPA (sec)
-	SBP (mmHg)	r	.064	.001	.053	.002	.006	.033	.059
		p-value	.592	.994	.641	.987	.958	.773	.608
		df	73	73	79	79	79	79	79
-	SBP (%ile)	r	.064	.001	-.124	-.109	-.143	-.153	.237
		p-value	.592	.994	.277	.339	.209	.177	.035
		df	73	73	79	79	79	79	79
-	DBP (mmHg)	r	-.067	-.146	.006	-.038	-.068	.092	.064
		p-value	.571	.219	.956	.737	.549	.421	.577
		df	73	73	79	79	79	79	79
Age	DBP (%ile)	r	.169	-.122	-.036	-.032	-.098	.018	.105
		p-value	.155	.306	.753	.778	.393	.878	.361
		df	70	70	76	76	76	76	76

SBP, systolic blood pressure; DBP, diastolic blood pressure; MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

Appendix F: Motor Skill Proficiency Data and Statistics

Variable	Total (n=90)	Girls (n=47)	Boys (n=43)	t-test
Motor proficiency (%ile)	45 ± 23	48 ± 24	41 ± 22	0.181
	-	*48 ± 23*	*41 ± 23*	-
n Below Average[a]	19	9	10	0.638

Age-adjusted means are presented in italics.
[a] Below average motor proficiency includes those classified as "below average" or "poor".

F.2 Multiple regression by age and sex

Variable	Model	Variables	b	SE	ß	*p*-value	Δr^2	r^2	Model sig.
Motor proficiency	1	Age	-1.207	2.879	-.045	.676	-	.002	.676
(%ile)	2	Age	-.510	2.920	-.019	.862	.019	.021	.404
		Sex	-6.322	4.918	-.139	.202			

b, b coefficients; SE, standard error of b; ß, standardized coefficients; r^2, coefficients of determination.
Model 1 included only age; model 2 included age and sex.

F.3 Correlations between motor proficiency and physical activity (PA)

			PA variables						
Control Variable	Motor Proficiency		MVPA (min/day)	TPA (min/day)	MVPA (% of wear)	TPA (% of wear)	Frequency of MVPA (bouts/h)	Duration of MVPA (sec)	Duration of breaks from MVPA (sec)
-	Motor	r	.088	.032	.207	.135	.073	.355	-.200
	Proficiency	*p*-value	.438	.779	.058	.220	.506	.001	.067
	(%ile)	df	80	80	85	85	85	85	85

MVPA, moderate-to-vigorous physical activity; TPA, total physical activity.

F.4 t-test by motor proficiency category

Variable	Below Average (n=19)	Average (n=71)	t-test p – value[b]
Sex (boys/girls)	10/9	33/38	0.648
Age (years)	4.37 ± 0.88	4.51 ± 0.84	0.519
Height (cm)	103.7 ± 6.3	107.2 ± 7.9	0.084
Weight (kg)	17.4 ± 2.6	18.3 ± 3.1	0.249
BMI (%ile)	60 ± 27	58 ± 26	0.705
WC (cm)	52.9 ± 3.6	53.2 ± 3.4	0.796
BF (%)	24.1 ± 5.5	23.3 ± 4.5	0.553
HRR (bpm)	65 ± 13	64 ± 14	0.664
Treadmill Time (min)	8.9 ± 1.9	9.9 ± 2.3	0.119
PP (Watts)	70.4 ± 27.5	91.6 ± 41.7	0.056
PP (Watts/kg)	3.9 ± 1.2	4.8 ± 1.6	0.025
MP (Watts)	57.6 ± 23.8	77.1 ± 33.9	0.032
MP (Watts/kg)	3.2 ± 1.1	4.1 ± 1.4	0.016
SBP (mmHg)	97 ± 6	98 ± 8	0.773
SBP (%ile)	62 ± 19	59 ± 23	0.628
DBP (mmHg)	59 ± 6	61 ± 4	0.119
DBP (%ile)	72 ± 17	74 ± 13	0.723
MVPA (min/day)	87.0 ± 26.4	96.2 ± 18.7	0.180
TPA (min/day)	251.6 ± 51.8	262.8 ± 31.9	0.392
MVPA (% of wear)	12.0 ± 3.2	13.7 ± 2.8	0.035
TPA (% of wear)	34.8 ± 5.7	37.1 ± 4.6	0.083
MVPA continuous bout frequency (bouts/h)	66.3 ± 14.9	71.6 ± 11.1	0.099
MVPA continuous bout duration (sec)[a]	6.6 ± 0.6	7.2 ± 0.8	0.006
Break duration between bouts of MVPA (sec)[a]	51.4 ± 10.7	46.5 ± 7.2	0.024

[a] While continuous bouts and breaks were only measured to the nearest sec, the values within this table are presented to the nearest 0.1 sec to facilitate comparisons. BMI, body mass index; WC, waist circumference; BF, body fat; HRR, heart rate recovery; PP, peak power; MP, mean power, SBP, systolic blood pressure, DBP, diastolic blood pressure; MVPA, moderate to vigorous physical activity; TPA, total physical activity.

Appendix G: Relationships between Health Measures – Data and Statistics

G.4 Correlations between body composition, health-related fitness, and blood pressure

			Body Composition			Blood Pressure				
			BMI (kg/m^2)	WC (cm)	BF (%)	SBP (mmHg)	SBP (%ile)	DBP (mmHg)	DBP (%ile)	Motor Proficiency (%ile)
Fitness Variables	HRR (bpm)	r	.036	.023	-.212	-.195	-.285	-.337	-.315	-.187
		p-value	.750	.842	.059	.106	.017	.004	.008	.104
		df	80	80	80	70	70	70	70	77
	Treadmill Time (min)	r	-.022	-.019[a]	-.106[a]	.096	-.110	.096	-.139[a]	.142
		p-value	.847	.865	.354	.427	.367	.431	.255	.219
		df	80	77	77	70	70	70	67	77
	PP (Watts)	r	.214	.481[a]	-.003[a]	.185	-.098	.095	-.178[a]	.221
		p-value	.043	.000	.975	.101	.388	.404	.117	.041
		df	90	87	86	80	80	80	77	86
	PP (Watts/kg)	r	.055	.194[a]	-.120[a]	.195	-.028	.092	-.093[a]	.267
		p-value	.607	.069	.266	.084	.803	.418	.415	.013
		df	90	87	86	80	80	80	77	86
	MP (Watts)	r	.140	.362[a]	-.017[a]	.203	-.063	.104	-.148[a]	.262
		p-value	.187	.000	.872	.072	.579	.357	.192	.015
		df	90	87	86	80	80	80	77	86
	MP (Watts/kg)	r	-.039	.039[a]	-.118[a]	.203	.015	.101	-.047[a]	.310
		p-value	.718	.715	.274	.071	.897	.371	.679	.004
		df	90	87	86	80	80	80	77	86

[a] Indicates variables that were both significantly related to age; thus, correlations were performed controlling for age.
HRR, heart rate recovery; PP, peak power; MP, mean power; BMI, body mass index; WC, waist circumference; BF, body fat; SBP, systolic blood pressure; DBP, diastolic blood pressure.

G.4 Correlations between body composition, health-related fitness, and blood pressure continued.

			Blood Pressure				
			SBP (mmHg)	SBP (%ile)	DBP (mmHg)	DBP (%ile)	Motor Proficiency (%ile)
Body Composition	BMI (kg/m^2)	r	.117	.089	-.023	.026	-.108
		p-value	.299	.432	.841	.815	.309
		df	81	81	81	81	90
	WC (cm)	r	.262	.024	.138	-.053[a]	-.080
		p-value	.018	.830	.218	.639[a]	.451
		df	81	81	81	78	90
	BF (%)	r	-.003	.122	.072	.051	-.024
		p-value	.978	.278	.525	.651	.824
		df	81	81	81	78	89
	Motor Proficiency (%ile)	r	-.073	-.098	-.021	-.085	
		p-value	.531	.398	.856	.464	
		df	76	76	76	76	

[a] Indicates variables that were both significantly related to age; thus, correlations were performed controlling for age.
BMI, body mass index; WC, waist circumference; BF, body fat; SBP, systolic blood pressure; DBP, diastolic blood pressure.