TRACKING OF PHYSICAL ACTIVITY AND FITNESS IN PRESCHOOL CHILDREN

TRACKING OF PHYSICAL ACTIVITY AND FITNESS IN PRESCHOOL CHILDREN

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A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements of the Degree Master of Science

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# Descriptive Note

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# ABSTRACT

The early years are characterized by dramatic growth and the development of healthy behaviours, such as physical activity (PA). The objectives of this thesis were to assess one year tracking of fitness and PA in preschoolers and to investigate the relationship between fitness and PA over a one-year period. Four hundred preschoolers (201 boys, 199 girls; 4.5±0.9 years) participated in year 1 and year 2 assessments, 12.1±0.7 months apart. Height and weight were measured to calculate body mass index (BMI) and body fat percentage (%BF) was assessed with bioelectrical impedance analysis (BIA). Two components of fitness were assessed: short-term muscle power (STMP) with a 10-second modified Wingate Anaerobic Test, and aerobic fitness with the Bruce Protocol progressive treadmill (TM) test. Peak Power (PP) and Mean Power (MP) were measures of STMP. TM time and 60-sec heart rate recovery (HRR) were indicators of aerobic fitness. PA data were collected for 7 days with ActiGraph accelerometers, and PA was quantified as the % of wear time (%WT) spent in moderate-to-vigorous PA (MVPA) and vigorous PA (VPA). At year 2, participants were significantly heavier (year 1: 17.9±3.2; year 2: 20.3±3.8kg; *p=*0.000) and taller (year 1: 106.6±7.8; year 2: 113.5±7.8 cm; *p*=0.000). From year 1 to year 2, BMI decreased from 15.7±1.3 to 15.6±1.4 m/kg2 (*p=*0.008) and %BF decreased from 23.2±4.6 to 21.1±4.7% (*p=*0.000). Both PP and MP improved approximately 30 Watts (*p*=0.000) from year 1 (PP: 94.1±37.3; MP: 84.1±30.9) to year 2 (PP: 125.6±36.2; MP: 112.3±32.2). TM time increased 2.4±1.4 minutes (*p*=0.000) from 9.4±2.3 to 11.8±2.3 minutes and HRR was unchanged at 65±14 beats per minute (bpm). MVPA increased from 13.3±2.9 to 13.9±3.0 %WT *(p*=0.003) and VPA increased from 5.8±1.7 to 6.3±1.8 %WT (*p*=0.000). PP and MP tracked moderately to substantially (PP: r=0.89, κ=0.61; MP: r=0.86, κ=0.56). TM time and HRR tracked fairly to strongly (TM time: r=0.82, κ=0.56; HRR: r=0.52, κ=0.23). MVPA and VPA tracked fairly to moderately (MVPA: r=0.59, κ=0.28; VPA: r=0.37, κ=0.38). At year 1 and year 2, PP, MP and HRR were weakly correlated to PA variables (r=0.13-0.23, *p*=0.000-0.02). TM time was correlated to VPA at year 1 (r=0.131, *p*=0.016) and to MVPA and VPA at year 2 (r=0.12-0.15, *p*=0.006-0.023). Boys engaged in more MVPA at year 1 and year 2 (*p*=0.000). Boys and girls were separately divided into groups that decreased, maintained or increased MVPA or VPA from year 1 to year 2. Girls who maintained MVPA had higher weight %iles and %BF than girls who increased MVPA, at both year 1 and year 2. Boys who increased VPA saw a greater increase in HRR than those who maintained VPA (*p*=0.000). Our findings indicate that fitness tracks better than PA over a 12-month period during the early years, and that a weak, positive relationship between these variables exists. Other factors, including measures of body composition, are likely influencing these relationships.

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# LIST OF ABBREVIATIONS AND SYMBOLS

PA Physical activity

BMI Body mass index

%BF Percent body fat

BIA Bioelectrical impedance analysis

STMP Short-term muscle power

TM Treadmill

TPA Total physical activity

MVPA Moderate-to-vigorous physical activity

MP Mean Power

PP Peak Power

HRR Heart rate recovery

%WT Percent wear time

VPA Vigorous physical activity

BPM Beats per minute

TPA Total physical activity

MPA Moderate physical activity

DLW Doubly labelled water

HR Heart rate

LPA Light physical activity

WT Wear time

VO2 Oxygen uptake

NASPE National Association for Sport and Physical Education

CDC Centre for Disease Control

DEXA Dual-energy x-ray absorptiometry

VO2PEAK Peak oxygen uptake

HR Heart rate

WAnT Wingate anaerobic test

HOPP Health Outcome and Physical activity in Preschoolers

ANOVA Analysis of Variance

# Declaration of Academic Achievement

The following is a declaration that the content of the research in this document has been completed by Hilary Caldwell and recognizes the contributions of Dr. Brian Timmons, Nicole Proudfoot, Sara King-Dowling, Natascja D’Alimonte, Leigh Gabel, Dr. John Cairney and Dr. Audrey Hicks in both the research process and the completion of the thesis.

# CHAPTER 1: LITERATURE REVIEW

# Introduction

The early years of life are characterized by rapid growth and development, in both biological and behavioural domains. In these years, young children are quickly growing as they concurrently develop healthy behaviours, such as regular PA. The benefit of encouraging PA in young children is to promote positive health attitudes, knowledge and behaviours that can be carried into adolescence and adulthood (Simons-Morton, Parcel, O'Hara, Blair, & Pate, 1988).This is a period for which we know the least about PA, perhaps based on an assumption that young children are habitually “active enough” and, as such, are reaping the health benefits associated with engaging in PA (Timmons et al., 2012).Unfortunately, this is not the case, as indicators of cardiovascular and cardio-metabolic diseases, such as obesity, are beginning to manifest in young children. The Canadian Health Measures Survey reported that 16.4% of 3-to-5 year olds were overweight or obese (R. C. Colley et al., 2013)*,* and these rates were even higher in older children:20.5% of 5-to-11 years olds and 26.9% of 12-to-17 years olds (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012). Overweight children are at increased risks of: remaining overweight into adulthood (A. S. Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008), developing behavioural problems and developing cardio-metabolic diseases (J. J. Reilly et al., 2003). In addition to the development of a healthy weight, young children are also developing PA behaviours.

PA in the early years is highly transitory and is characterized by sporadic, intermittent activity (Bailey et al., 1995; Obeid, Nguyen, Gabel, & Timmons, 2011)that increases in frequency from age 3 to 5 years (Cardon & De Bourdeaudhuij, 2008; Grontved et al., 2009).Tracking of PA, which refers to the stability of PA participation over time (Malina, 1996), is fair in the early years (Gabel, Obeid, Nguyen, Proudfoot, & Timmons, 2011; Jackson et al., 2003; Kelly, Fairweather, Grant, Barrie, & Reilly, 2004), suggesting that preschoolers have variable habitual PA levels. As such, further investigation into PA is warranted to determine why PA participation is so dynamic in young children. In addition, thresholds of PA participation associated with health benefits are needed.

There is a paucity of literature discussing the volume of PA associated with better health in young children (Tremblay et al., 2012), and more research is needed to understand this topic. The Canadian PA Guidelines for the Early Years were devised in 2012 based on the best available evidence that examined the relationship between PA and health indicators (Timmons et al., 2012)**.** The Guidelines recommend that 3-to-4 year olds should accumulate at least 180 minutes of total PA (TPA), at any intensity, spread throughout the day. By the age of 5 years, preschoolers should progress towards at least 60 minutes of daily energetic play (Tremblay et al., 2012), often characterized as MVPA when assessed with accelerometers. Results from Canadian studies suggest 73-84% of preschoolers met the 180 minutes of TPA guidelines while 14-57% of preschoolers met the 60 minutes of MVPA guideline (R. C. Colley et al., 2013; Gabel et al., 2013). The preschool PA research field is growing, but much less is know about fitness in the early years.

Health-related fitness refers to those characteristics that are most related to health, chronic disease prevention and health promotion (Caspersen, Powell, & Christenson, 1985)*.*Cardiorespiratory fitness may be the most important factor in predicting cardiovascular disease risk (Hurtig-Wennlof, Ruiz, Harro, & Sjostrom, 2007). Indeed, the relationship between increased fitness and improved health is well established in adults (Warburton, Nicol, & Bredin, 2006)and school-aged children (Janssen & LeBlanc, 2010); however, much less is known about this relationship in the early years. Performance on health-related fitness tests, including aerobic fitness tests on a TM and STMP tests on a cycle ergometer, tends to increase from 3 to 6 years of age (Gabel et al., 2011; Gumming, Everatt, & Hastman, 1978; Parizkova, 1996)***.*** Fitness assessments, especially assessments of STMP, have scarcely been conducted with preschoolers in laboratory settings. Tracking of performance on fitness tests exhibits stronger tracking than PA, with moderate one-year tracking observed for performance on aerobic fitness and STMP tests (Gabel et al., 2011; Nemet et al., 2013). The association between PA and fitness in the early years is not well established; however, merits further investigation.

The study of the relationship between PA and fitness has been identified as a major knowledge gap in the preschool PA research field (Pate et al., 2013). Swiss researchers observed positive relationships between TPA, moderate PA (MPA) and VPA and performance on an obstacle course (Bürgi et al., 2011). After participating in a 10-month PA intervention, preschoolers saw greater improvements in aerobic fitness and performance on the obstacle course, compared to those not enrolled in the intervention (Puder et al., 2011).Evidence suggests that fitness in preschoolers can be improved as a result of increased PA (Bürgi et al., 2011; Nemet, Geva, & Eliakim, 2011). Based on the rapid growth and development of preschoolers, studying this relationship over time will be more meaningful than a one-time assessment.

Further investigation of PA and fitness tracking in preschoolers is warranted to determine if health behaviours and characteristics are established in the early years or if they are still susceptible to change later in life. The primary objective of this study is to establish the one-year tracking of PA volume and fitness measures in 3-to-5 year olds. The secondary objective is to determine the relationship between PA volume and fitness over a one-year period in the early years. This will be established by investigating the relationship separately for year 1 and year 2 and then by examining the characteristics of participants who decrease, maintain or increase their PA participation from year 1 to year 2 of the study.

# Physical Activity

## Definition

PA is any bodily movement, produced by skeletal muscles, that increases energy expenditure (Caspersen et al., 1985). Our analyses were focused on the evaluation of habitual PA, measured objectively with accelerometers.

## Assessment and Measurement Considerations

#### 1.2.2.1 Objective versus Subjective Assessment

Methods to assess PA participation in preschoolers can be grouped into subjective and objective assessments. Doubly labelled water (DLW) and indirect calorimetry are considered the gold standard, criterion objective PA measures. The DLW technique provides an indication of total energy expenditure, not only PA. This method uses isotopes that are expensive and requires an invasive process that is not suitable for large studies or young children (Schoeller & Webb, 1984). Indirect calorimetry also assesses energy expenditure, but only during the time a participant is connected to the equipment, making this an inappropriate tool to assess habitual PA participation (Emons, Groenenboom, Westerterp, & Saris, 1992). Subjective PA assessments are able to assess the context of PA participation in addition to habitual PA levels.

Subjective PA assessments in preschoolers use direct observation or proxy reports. Direct observation can include assessments of PA intensity, type, environment, social context and location (Pate, O'Neill, & Mitchell, 2010). Direct observation has been calibrated against indirect calorimetry and is feasible in both home (Bailey et al., 1995) and preschool settings (Brown et al., 2006). The strength of this method lies in its ability to assess all environmental factors that influence PA, but it is not without limitations. It is very burdensome to researchers, participants may react to the observer presence and regular inter-observer reliability tests are necessary (Pate et al., 2010). Direct observation methods often only provide a “snapshot” of a child’s activity, rather than all movement accumulated over a longer period of time. When resources for direct observation or objectively measured PA are not available, some studies rely on the use of proxy reports completed by parents and teachers because preschool-aged participants cannot recall and report their own habitual PA. These types of reports must be interpreted with caution because they have not been validated with objective PA measures (Pate et al., 2010). Several devices can be used to objectively assess regular, habitual PA participation.

Pedometers, heart rate (HR) monitors and accelerometers are devices that can be worn for all waking hours to objectively assess habitual PA. Pedometers measure the frequency, not the intensity, of movement, in the vertical plane only and the output is step counts. They are a cost-effective way to assess PA in a large population (Pate et al., 2010) and, step count targets that correspond to Canada’s Physical Activity Guidelines for the Early Years have been developed (Gabel et al., 2013). HR monitors can be used in preschoolers; however, they assume a linear relationship between PA and HR. This relationship becomes nonlinear at higher PA intensities and HR can also be affected by age and emotional stimuli (Pate et al., 2010). Pedometers and HR monitors are not the most appropriate devices for the purposes of our study. Therefore, accelerometers were chosen to assess PA in this study.

An accelerometer is a small, unobtrusive device that measures the magnitude and volume of movement, when applied to the measurement of PA. In the device, accelerations create forces, which generate an electrical charge relative to the magnitude of the acceleration. The forces are measured at a predefined interval every second (ranging from 10-100) and averaged over a measurement period, known as an epoch (Cliff, Reilly, & Okely, 2009). Accelerometers are attached to a belt, and the device is worn over the right hip (Kelly et al., 2004) because the trunk generates the most PA related energy expenditure (Cliff et al., 2009). These devices allow researchers to measure PA intensities and patterns during all waking hours, for several days, in large samples (Pate et al., 2010). Accelerometers minimize the recording bias associated with direct observation or proxy reports. It must be noted, however, that these devices can only measure movement of the body part to which the device is attached (Cliff et al., 2009). Therefore, an accelerometer attached to the hip cannot assess movement of the arms, or the added stress of carrying something heavy while walking. In addition, accelerometers cannot provide information on the activity type or context of PA (Pate et al., 2010).

Accelerometers can measure movement in either the vertical plane (uniaxial) or three planes (triaxial). Uniaxial and triaxial accelerometers give similar classifications for different PA intensities in both preschoolers (Adolph et al., 2012) and adolescents (Vanhelst et al., 2012). Uniaxial accelerometers have been calibrated and validated thoroughly in preschool populations. For this reason, this thesis will use uniaxial accelerometer data collected in the vertical plane. The measurement of PA with accelerometers is a valid, reliable method (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006; Penpraze et al., 2006) in preschoolers, however it requires several considerations.

#### 1.2.2.2. Epoch Length

PA researchers have not reached a consensus regarding the most appropriate epoch length for assessing PA in preschoolers. A variety of epoch lengths, such as 3 sec (Gabel et al., 2011; Obeid et al., 2011), 5 sec (Vale, Susana Maria Coelho Guimarães et al., 2010), 15 sec (Cardon & De Bourdeaudhuij, 2008; Grontved et al., 2009; Pfeiffer, Dowda, McIver, & Pate, 2009) and 60 sec (R. C. Colley et al., 2013; Jackson et al., 2003) have been used to assess PA in preschoolers. The debate over epoch selection arises from the fact that all activity recorded in an epoch is averaged over its time period, such as 1-minute. Therefore, if a child participates in bouts of both high- and low-intensity activity within that minute, the PA may be misclassified (Cliff et al., 2009). As such, the irregular and sporadic nature of young children’s PA (Bailey et al., 1995) may be best quantified with a shorter epoch, such as 3 or 5 seconds (Obeid et al., 2011; J. J. Reilly et al., 2008).

Various researchers have carried out comparisons of PA outputs from data collected in different epoch lengths. In recent work, Colley et al.had preschoolers wear two Actical accelerometers for 5 days-- one accelerometer recorded activity in 15-sec epochs and the other in 60-sec epochs. The data collected with the 15-sec epoch setting captured more MVPA and sedentary time, but less light PA (LPA) and TPA, compared to the data collected with the 60-sec epoch (Colley, Rachel , Harvey, Alysha, Grattan, Kimberley P, Adamo, Kristi B, 2014).Similar results have been found with accelerometer data that was collected in shorter epochs, and reintegrated into longer epochs by summing the counts of the shorter epochs together. Reilly et al. (2008) initially collected PA data in 15-sec epochs and re-integrated it into 30-, 45- and 60-sec epochs to analyse the differences in MVPA and sedentary behaviour of 5-to-6 year olds. There was no difference across epochs in minutes per day of sedentary behaviour; however, MVPA was underestimated with the 60-sec epoch, indicating that the 15-sec epoch captured more MVPA (J. J. Reilly et al., 2008). In 2010, Obeid et al. observed similar results. Data collected in 3-sec epochs were re-integrated into 15-sec, 30-sec and 1-minute epochs. The results showed that daily minutes of MVPA and VPA decreased steadily as the epoch length increased, with VPA decreasing substantially more than MVPA. The longer epoch lengths overestimated TPA, compared to the 3-sec epoch (Obeid et al., 2011). The dynamic nature of play in young children, coupled with the underestimation of MVPA associated with longer epochs, suggests that a shorter epoch is most appropriate when assessing habitual PA in preschoolers.

#### 1.2.2.3 Wear-Time

Wear-time (WT) refers to the minimum number of days and hours per day that an accelerometer needs to be worn to represent habitual PA (Cliff et al., 2009), and this is the minimum amount of PA data needed for a participant to be included in analyses. WT criteria vary from study to study, and daily WT is calculated by subtracting non-wear time from 24 hours (R. C. Colley et al., 2013). In preschoolers, minimum daily WT has varied between studies, ranging from ≥5 hours (Cardon & De Bourdeaudhuij, 2008; R. C. Colley et al., 2013; Gabel et al., 2011; Obeid et al., 2011; Pfeiffer et al., 2009) to ≥6 hours (Jackson et al., 2003) and up to ≥10 hours per day (Vale, Susana Maria Coelho Guimarães et al., 2010). There has also been variation in the minimum number of days to include in analyses; however, most studies use 3-to-5 days (R. C. Colley et al., 2013; Gabel et al., 2011; Kelly et al., 2007; Obeid et al., 2011). It has been suggested that the first day of PA monitoring be excluded to minimize the influence of any behaviour change (Cardon & De Bourdeaudhuij, 2008). In 2006, Penpraze et al. researched the number of days and hours of PA required to obtain representative assessments of PA in young children. While the most reliable measure of PA was 7 days of wear time with 10 hours per day, the authors acknowledged the challenge of collecting so many days of wear, and 3-to-4 days could produce reasonable reliability (80-85%) (Penpraze et al., 2006)*.* Some studies have also chosen to include a combination of weekday and weekend days (Cardon & De Bourdeaudhuij, 2008; Gabel et al., 2011; Jackson et al., 2003; Pfeiffer et al., 2009; Vale, Susana Maria Coelho Guimarães et al., 2010) in WT criteria.

The differences between weekday and weekend PA have been variable in the literature. For example, studies have reported significantly more time in MVPA (Vale, Susana Maria Coelho Guimarães et al., 2010), and others have reported more time in sedentary activities (Cardon & De Bourdeaudhuij, 2008), on weekdays versus weekend days, while other research has not observed differences between weekdays and weekend days (Jackson et al., 2003; Obeid et al., 2011). The discrepancies between PA on weekdays and weekend days could easily have been influenced by the age of the children, and their preschool and/or school schedules. The epoch lengths of the mentioned studies were also variable, so comparing these studies to each other and to our own results would be challenging.

The last component of WT criteria includes the analysis of non-WT. Periods of non-WT, referred to as continuous ‘0’ counts, are removed from data because the accelerometer is sensitive enough to detect small movements and continuous ‘0’ counts are rare (Cliff et al., 2009). Parents and caregivers are often asked to complete a logbook to report all times the accelerometer is put on and taken off (Cardon & De Bourdeaudhuij, 2008). An accurate logbook reduces the burden of analyzing data for non-WT. Non-WT definitions have varied in preschool PA studies. Some studies simply interpret wear and non-WT based on parents’ logbooks (Obeid et al., 2011), while most others have used accelerometer counts. For example, Grontved et al. (2009) reported ≥10 minutes of zero activity as non-wear time (Grontved et al., 2009), Pfeiffer et al. used a straight 60 minutes or more of continuous zeros (Pfeiffer et al., 2009), whereas Colley et al. defined non-wear time as 60 minutes or more of consecutive zeros, with allowance for 1-2 minutes of counts between 0 and 100 (R. C. Colley et al., 2013). In 8-to-13 year olds, the average time for the longest bout of motionless data was 17 minutes. Therefore, it is unlikely a child would appear motionless for a longer time period if wearing the accelerometer. As a result, it is suggested that a 20-minute bout of continuous zeros be classified as non-WT (Esliger, Copeland, Barnes, & Tremblay, 2005).

#### 1.2.2.4 Cut-points

Cut-points allow PA to be biologically meaningful because accelerometers measure activity in raw accelerations, which are then converted by means of a proprietary equation into activity counts. Accelerations ranging in magnitude from 0.05 to 2 G’s are measured, digitized and passed through a digital filter that band-limits the accelerometer to detect regular human motion and reject motion from other sources. The movement is measured multiple times every second and averaged over the epoch length (Timmons, Proudfoot, MacDonald, Bray, & Cairney, 2012). Activity intensity cut-points have been derived from studies that calibrated accelerometers against direct observation (CAUWENBERGHE, Labarque, Trost, BOURDEAUDHUIJ, & Cardon, 2011) or energy expenditure (Pate et al., 2006). In 4-to-6 year olds, accelerometer cut-points for sedentary, LPA, MPA and VPA have been established with direct observation (CAUWENBERGHE et al., 2011). In this study, preschoolers completed a variety of structured activities and a free play session while wearing an accelerometer that recorded activity in 15-sec epochs. The criterion measure was second-by-second direct observation, with the modified Children’s Activity Rating Scale. After analyses, ≤372 counts/15 sec were classified as sedentary activity, 373-584 counts/15 sec as LPA, 585-880 counts/15 sec as MPA and ≥881 counts/15 sec as VPA (CAUWENBERGHE et al., 2011). These intensity counts are much higher than those observed when comparisons with more objective measures were conducted.

Accelerometer cut-points for 3-to-5 year olds were developed using a portable metabolic system as the criterion measure. Calibration data were collected at rest and during paced walking and jogging in a lab setting. Participants wore an accelerometer and a portable metabolic system that collected expired gases and measured breath-by-breath oxygen uptake (VO2). The correlation between VO2 and counts/ 15 sec was high (r=0.82). MPA was defined as a VO2 of 20ml/kg/min and 420 counts/ 15 sec epoch and VPA was defined as a VO2 of 30 ml/kg/min and 842 counts/ 15 sec (Pate et al., 2006). These thresholds allow accelerometer counts to be translated into minutes of engagement in different intensities of PA, which facilitates the analysis of whether participants meet daily PA targets or guidelines.

### **Physical Activity Guidelines for the Early Years**

The development and release of PA Guidelines has been common practice in several developed countries, and there has been a surge in the release of PA Guidelines for young children in the last few years. The first Canadian Guidelines for PA in the Early Years were released in 2012 and they recommend that 3-to-4 year olds accumulate at least 180 minutes of PA, at any intensity, throughout the day, every day. A progression towards at least 60 minutes of energetic play by 5 years of age is recommended (Tremblay et al., 2012), in line with the guideline for 5-to-17 year olds that recommends at least 60 minutes of MVPA daily (Tremblay et al., 2011). A step-count target of 6000 steps per day for 3-to-5 year olds has been published to provide a simpler, alternative method to monitor PA (Gabel et al., 2013).

The Canadian Guidelines for the Early Years were developed in response to a call from health care, childcare, and fitness practitioners who sought healthy living guidance in the early years (Tremblay et al., 2012). A systematic review of the best available evidence regarding PA and its relationship with adiposity, bone health, motor skill development, psychosocial health, cognitive development and cardio-metabolic risk factors in the early years guided the development of these Guidelines (Timmons et al., 2012). Due to a paucity of available research, the most appropriate amount, intensity, frequency, and type of PA needed for optimal growth and development could not be determined. The review concluded that more high-quality research is needed to better establish the relationship between habitual PA participation and health outcomes (Timmons et al., 2012). Other countries have designed and promoted their own sets of PA guidelines.

Australian PA recommendations, similar to Canada’s, suggest that toddlers and preschoolers should be active for at least 180 minutes per day, spread throughout the day (Okely, Salmon, Trost, & Hinkley, 2008). These are in agreement with the United Kingdom’s guidelines for the early years (Active, 2011). In the United States, the National Association for Sport and Physical Education (NASPE) suggests that preschoolers accumulate at least 60 minutes of unstructured daily PA (Clark et al., 2002) plus 60 minutes of structured PA (Strong et al., 2005). These recommendations often influence how PA research interprets the PA levels of children; for example, whether children meet Guidelines, a threshold theoretically associated with health benefits.

### **1.2.4 Physical Activity Levels in the Early Years**

Engagement in PA is dynamic in the early years. Several observational PA studies have found that participation in MVPA increases through the early years, from age 3 to 5 years (Cardon & De Bourdeaudhuij, 2008; Grontved et al., 2009; Pfeiffer et al., 2009). A recent 4 year longitudinal study of PA participation in 3-to-7 year olds observed a decrease in TPA with an increase in sedentary behaviour over the 4 years. Reductions in MVPA were present, however, the increase in sedentary behaviour was mostly attributed to decreases in LPA (Taylor, Williams, Farmer, & Taylor, 2013)**.** PA data, stratified by sex, suggest that young boys engage in more TPA (CAUWENBERGHE et al., 2011; Jackson et al., 2003; Pfeiffer et al., 2009; S. Vale, Santos, Silva, Miranda, & Mota, 2009) and MVPA (Cardon & De Bourdeaudhuij, 2008; Grontved et al., 2009; Pfeiffer et al., 2009) than young girls; however, other studies observed no sex differences (Obeid et al., 2011). The variability of PA engagement in young children is not well understood and investigation of the factors that influence PA participation is necessary. Studies from several developed countries have reported PA levels of preschoolers, and results of engagement in MVPA are quite diverse.

The most recent Canadian research about PA behaviour in the early years found that 3-to-4 year olds accumulated 352 minutes of daily TPA and 66 minutes of daily MVPA. Five-year olds in the same study accumulated 343 minutes of daily TPA and 68 minutes of daily MVPA (R. C. Colley et al., 2013). This study assessed PA with accelerometers set to collect data in 1-minute epochs, an epoch length known to underestimate MVPA (Colley, Rachel , Harvey, Alysha, Grattan, Kimberley P, Adamo, Kristi B, 2014). A study conducted with a small sample of 3-to-5 year olds from our laboratory found that preschoolers accumulated an average 220 minutes of daily TPA and 75 minutes of daily MVPA (Gabel et al., 2013), well exceeding the Canadian Guidelines for the Early Years. International research has also investigated PA participation and, in some cases, interpreted results based on PA Guidelines for that region.

In a sample of over 200 3-to-6 year preschoolers in Portugal, the average MVPA was higher than the Canadian samples at 96 minutes per day. As a result, 93.5% of the preschoolers met a 60 minutes of MVPA guideline, based on 5-sec accelerometer epochs with a WT criteria of ≥10 hours per day (Vale, Susana Maria Coelho Guimarães et al., 2010). A sample of over 700 preschoolers from Australia only engaged in MVPA for 4.8% of their WT (Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012), while Canadian preschoolers engaged in MVPA for approximately 9% of their WT (R. C. Colley et al., 2013).In a sample of 397 3-to-5 year old American preschoolers, average daily MVPA was about 102 minutes, based on Pate’s PA cut-points (Pate et al., 2006), as measured with 15-sec epochs (Beets, Bornstein, Dowda, & Pate, 2011). Most evidence, with the exception of the Australian data, suggest that preschoolers are accumulating 60-100 minutes of daily MVPA, exceeding the Canadian PA Guideline for 5-year olds. It should, however, be noted that not all studies were a representative sample and measurement tools and methods varied across studies. For example, longer epochs may have misclassified higher PA intensities. More research is still needed to determine the most appropriate volume of PA necessary to achieve health benefits, followed by research assessing the prevalence of preschoolers meeting these guidelines and the healthy benefits associated with meeting such guidelines.

### **1.2.5 Physical Activity in the Early Years and Chronic Disease**

The health benefits of PA participation in adulthood (Warburton et al., 2006) and the school-aged years (Janssen & LeBlanc, 2010; Strong et al., 2005) are well documented; however, less is known about the early years. The reasoning for this research gap may relate to an assumption that young children are habitually “active enough”, and consequently, reaping the health benefits of this hypothesized high PA participation (Timmons et al., 2012). In preschoolers, there is low-to-high quality evidence to support the relationship between increased PA participation and improved measures of adiposity, bone and skeletal health, motor skill development, psychosocial development and cardio-metabolic risk factors (Timmons et al., 2012). Lifestyle interventions that implemented physical education programs to young children saw favourable outcomes with respect to adiposity (Kriemler et al., 2010; Nemet et al., 2011; Niederer et al., 2012; Puder et al., 2011) and physical fitness (Kriemler et al., 2010; Nemet et al., 2011; Puder et al., 2011). The links between PA participation and disease risk are not well documented in young children because most clinical symptoms of chronic disease will not appear until much later in life; however, the origins of these diseases, such as childhood inactivity (Telama, 2009) lie in early childhood (J. Twisk, Kemper, & Van Mechelen, 2002a). While there is limited research on the relationship between PA participation and disease risk in children, lessons can still be learned from the current available literature.

In general, PA participation and disease risk demonstrate a dose-response relationship, whereby, the most physically active people are at the lowest risk of developing non-communicable chronic diseases (Warburton et al., 2006). The Amsterdam Growth and Health Longitudinal Study examined the relationship between PA and physical fitness in adolescence and cardiovascular disease risk factors in adulthood (J. Twisk, Kemper, & Van Mechelen, 2002b). A decrease in PA participation from adolescence to adulthood was related to unhealthy cholesterol levels (J. Twisk et al., 2002b) and adolescent PA levels were inversely related to adult sum of skinfolds, an indicator of adiposity (Twisk, J W [xdot] R, Kemper, & van MECHELEN, 2000). The relationship between participation in PA and chronic disease risk is also evident in school-aged children. Strong et al. suggest that there is strong evidence for the beneficial effects of PA on musculoskeletal health, cardiovascular health components, adiposity in overweight youth, and blood pressure in mildly hypertensive youth (Strong et al., 2005). Evidence in school-age children proposes that increased PA participation has favourable effects on blood pressure, BMI, %BF and bone mineral density. A key finding was the dose-response relationship between participation in PA and health benefits, with differences in health risk observed between the least and most active groups. However, moderate amounts of PA can still have positive effects in high-risk children (i.e. obese) (Janssen & LeBlanc, 2010). Similar associations have been observed in younger children.

In 2-to-6 year olds from a large European health study, VPA was inversely correlated with a cardiovascular disease risk score. The risk score was based on systolic blood pressure, total triglycerides, total cholesterol/ HDL cholesterol ratio, insulin resistance and sum of skinfolds. In 6-to-9 year olds in the same study, their cardiovascular disease risk score (which included aerobic fitness) was inversely correlated with MVPA, VPA and TPA. The results found the associations between PA and cardiovascular disease risk were stronger in the children 6-to-9 years old, perhaps suggesting that the risk factors had not yet manifested in younger children (Jiménez-Pavón et al., 2013).This was one of the first investigations of PA and cardiovascular disease risk in children between the ages of 2 and 9 years old and further research is necessary.

The gap in studies investigating the health outcomes of PA in preschoolers requires attention. It is important to determine how PA participation in the early years has an impact on health, from the preschool years to adulthood. Tracking and longitudinal studies are necessary to know if PA behaviours established in the preschool years are predictive of behaviours and health later in life. This research has potential to influence how health policies, PA guidelines and health promotion initiatives target the promotion of PA in the early years.

### **1.2.6 Tracking Physical Activity**

Tracking of a characteristic refers to the stability, or maintenance of relative rank in a group, over time (Malina, 1996)**.** If a trait exhibits strong tracking, it may be predictive of that trait later in life. If a trait displays poor tracking, it is not indicative of future results. For example, if this study determines that PA does not track well in the early years, it may indicate that PA behaviours are not established in the early years and still susceptible to future change. Spearman rank order correlations assess individual tracking and correlation coefficients (r) of <0.3 are considered low, 0.30-0.60 are considered moderate and >0.6 are considered strong (Malina, 1996). Tertile stability is assessed with Kappa statistics and Kappa scores (κ) 0-0.2 are poor, 0.2-0.4 are fair, 0.4-0.6 are moderate, 0.6-0.8 are substantial and 0.8-<1.0 are almost perfect (Munoz & Bangdiwala, 1997). Several studies have investigated how objectively-measured PA tracks through the early years.

Two separate review papers summarized the evidence of PA tracking through various life stages and transitions. They both concluded that tracking is low to moderate in early childhood (Malina, 1996; Telama, 2009). In 3-to-5 year olds, TPA, LPA and MPA exhibited fair one-year tracking, while MVPA and VPA exhibited poor 15-month tracking, based on %WT (Gabel et al., 2011). Another study observed LPA and MVPA tracking and results indicated poor tracking in both intensities over a 2-year period in young children (Kelly et al., 2007). Both of these studies used kappa statistics to determine tracking based on tertile agreement. Spearman correlations coefficients of 0.35 (Kelly et al., 2007), 0.40 (Jackson et al., 2003), and 0.51 (Gabel et al., 2011) have been reported for TPA, suggesting moderate one-to-two year tracking. When 3-year PA tracking was measured in the after school period with a HR monitor, Spearman correlations ranged from 0.57-0.66 and tertile analyses exhibited an almost perfect coefficient of 0.81 (Pate, Baranowski, Dowda, & Trost, 1996). The stronger tracking in this study may be attributable to the strict after-school activity window, while the other studies observed habitual PA. PA tracking studies have observed mixed results in the early years, and these studies have varied in observation lengths, time between PA assessments and the accelerometer methods that were used. More concrete evidence is necessary to further understand tracking in the early years.

# 1.3 Health- Related Fitness

## 1.3.1 Definition

Health-related fitness refers to physiological attributes that are modifiable through PA and exercise and support our bodies to perform movement (L. Armstrong, 2006). The levels of these attributes can range from low to high and are more important to public health than skill-related fitness attributes, such as agility (Caspersen et al., 1985). In young people, higher cardiorespiratory and muscular fitness have shown favourable effects on adiposity, cardiovascular risk factors and skeletal health (Ortega, Ruiz, Castillo, & Sjöström, 2007)*.* For the purpose of this thesis, health-related fitness will be assessed with body composition, aerobic fitness and STMP.

## 1.3.2 Body Composition

### 1.3.2.1 Obesity in the Early Years

Obesity in the early years is often defined by BMI, a measure derived using an individual’s weight (kg) divided by height (m2). BMI cut-offs of ≥25 and ≥30 kg/m2 are used to classify adults as overweight and obese, respectively, based on the health risks associated with these cut-points (T. J. Cole, Bellizzi, Flegal, & Dietz, 2000). The BMI values associated with overweight and obesity are not as straightforward in children and they incrementally rise with increasing age (Shields, 2006). Age and sex-specific cut-points are used to classify BMI in children to account for the rapid growth and development of children (T. J. Cole et al., 2000).

The Centre for Disease Control (CDC) has established growth curves with data from nationally representative American surveys (Kuczmarski et al., 2002). Children who have a BMI that falls <5th percentile are classified as underweight, ≥5th and <85th percentiles are classified as normal weight, ≥85th and <95th percentiles are classified as overweight and those ≥95th percentile are classified as obese (Kuczmarski et al., 2002). About 16-30% of Canadian preschoolers have been classified as overweight or obese (R. C. Colley et al., 2013; Shields, 2006). Children and youth who are overweight are at an increased risk to remain overweight and obese into adulthood (A. S. Singh et al., 2008) and are at a heightened risk for low self-esteem, behavioural problems, and cardiovascular risk factors, such as high blood pressure, insulin resistance and elevated cholesterol (J. J. Reilly et al., 2003). BMI is commonly used to describe weight statuses at both the individual and population levels, but it is only a ratio of body weight and height, and does not take into account body composition, a characteristic that can be effectively assessed with other methods.

### 1.3.2.2 Additional Body Composition Assessments

Additional methods have been commonly used in young children to assess body composition and have shown results related to BMI. In children as young as 3 years of age, %BF, as measured by dual-energy x-ray absorptiometry (DEXA) scan, showed some variability across BMI groups (normal-weight, overweight and obese). However, most participants in this study with low BMI values also had low %BF values and those subjects with high BMI values also showed high %BF values (Taylor, Jones, Williams, & Goulding, 2002). DEXA scans are not always feasible with large studies and alternate methods have been used with success.

BIA is also an accurate tool to predict fat free mass and %BF in young children (Goran et al., 1993). In children, body weight increases much quicker than height, as much as 32-37% greater in 3-to-6 year olds (Parizkova, 1996). In children, the adiposity rebound describes the natural changes of BMI: an increase in BMI from age 0-1 year, a decline until about the age of six, followed by a period of increase into adolescence. An earlier age of adiposity rebound is associated with an increased risk of becoming overweight or obese in adolescence (Rolland-Cachera et al., 1984). While BMI is useful to estimate body composition in preschool-aged children (Eisenmann, Heelan, & Welk, 2004), it does not take fat mass and fat free mass into account. If a growth curve is examined based on %BF alone, the adiposity rebound is less apparent (Malina, Bouchard, & Bar-Or, 2004). Therefore, BMI and %BF are complementary and necessary measures when studying body size in the early years, and they can continue being used to assess how body size changes and tracks through life.

### 1.3.2.3 Body Composition Tracking

Children and youth who are overweight and obese are at increased risk, in some cases twice as high, to be overweight or obese in adulthood. The risk is more prominent in participants with higher levels of overweight or obesity (A. S. Singh et al., 2008). Overweight and obese children have heightened risks of premature mortality and later cardio-metabolic morbidity, including diabetes, hypertension and stroke, later in life (J. Reilly & Kelly, 2010). Over 22 years, from childhood to adulthood, BMI showed moderate tracking in both males and females (r=0.29-0.65) (Herman, Craig, Gauvin, & Katzmarzyk, 2009). A longitudinal study in Japan concluded that about 80% of overweight and obese school-aged children would become overweight and obese adolescents (Nakano et al., 2010). Evidence supports the idea that body composition tracks well form childhood to adulthood.

### 1.3.2.4 Relationship between Body Composition and Physical Activity

Participation in PA, as objectively measured by accelerometry, is negatively associated with adiposity in preschoolers. MVPA and VPA are both associated with lower %BF, as measured by DEXA scans (Collings et al., 2013). In a cohort of Portuguese preschoolers, children with low participation in VPA were more likely to be classified as overweight, determined by BMI, compared to peers with higher VPA participation (Vale, Susana Maria Coelho Guimarães et al., 2010). When observed at preschool, overweight boys had fewer MVPA and VPA intervals per hour, while no weight-related differences were observed in girls (Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003). Due to the relationship between body composition and PA in preschoolers, it is important to consider the body composition of preschoolers when analyzing PA data.

### 1.3.2.5 Relationship between Body Composition and Fitness

Over the past few decades, national fitness levels of Canadian children and youth have significantly declined (Tremblay et al., 2010) while rates of overweight and obesity in youth have increased (Shields, 2006). A one-year PA and lifestyle intervention in Swiss preschoolers observed more beneficial effects on body composition in low versus high fit children (Niederer et al., 2012). Additional analyses from the same intervention found that the overweight and obese children had lower aerobic fitness compared to normal weight children (Ebenegger et al., 2012). A health promotion and PA intervention conducted in Israel kindergarten classes saw increases in aerobic fitness and decreases in BMI percentiles in the participants in the intervention versus the control group (Nemet et al., 2013). These results suggest that interventions that increase the volume of PA programming for young children can have positive changes on both aerobic fitness and weight status.

In a study of school-age children in Belgium, performances on fitness tests were compared between obese and non-obese students, based on BMI and body composition, as measured by the sum of skin folds. The obese children displayed poorer performance on the standing long jump, sit-up, bent-arm hang, speed shuttle run and endurance shuttle run tests—all tests requiring propulsion or lifting of body mass. Handgrip performance was higher in obese youth versus non-obese youth (Deforche et al., 2003). While this study investigated fitness test results between normal weight and obese school-aged children and not preschoolers, it supports the idea of including a measure of body size or body composition when analyzing both aerobic and muscular fitness in children.

## 1.3.3 Aerobic Fitness

### 1.3.3.1 Definition

Aerobic fitness is a health-related fitness attribute that refers to one’s ability to perform dynamic, large muscle, moderate-to-vigorous intensity exercise for a prolonged period of time (L. Armstrong, 2006). These movements depend on the respiratory, cardiovascular and skeletal muscle systems. This is a health-related component of physical fitness because high levels of aerobic fitness are associated with a decreased risk of premature death, especially from cardiovascular disease (L. Armstrong, 2006).

### 1.3.3.2 Assessment and Measurement Considerations

The scarcity of preschool fitness research may be based on an assumption that preschool-aged children are naturally active, and therefore, physically fit (Nguyen, Obeid, & Timmons, 2011). As a result, the most appropriate measurement tools for assessing aerobic or anaerobic fitness in preschoolers have not been established. Over the years, both laboratory and field-based assessments have been conducted to evaluate fitness in young children.

### 1.3.3.3 Lab Versus Field Tests

Aerobic fitness, or peak oxygen uptake (VO2PEAK), is considered to be the best marker for cardiorespiratory function, as measured through indirect calorimetry during a maximal bike or TM test (Dencker, Bugge, Hermansen, & Andersen, 2010). This type of test necessitates participants to wear a mouth-piece and nose plug, requirements that would likely frighten preschool-aged participants, unless provided ample time for habituation. While the majority of VO2PEAK testing in adults has been conducted on a cycle ergometer, it is preferable for young children to use a TM for aerobic fitness tests because their knee extensors are underdeveloped and this may limit performance on a cycle ergometer (Oded Bar-Or & Rowland, 2004). Walking and running tests use energy demand that is related to body weight, and children will not be limited by their smaller size (Simons-Morton et al., 1988). Maximal TM walking and running tests have been feasible with participants as young as 4 years of age (Gumming et al., 1978; van der Cammen-van, Monique HM et al., 2010), and submaximal tests with children as young as 3 years of age (Nguyen et al., 2011). Field-based studies have used the 20-m shuttle run, with minor modifications, to assess aerobic fitness in young children (Bürgi et al., 2011; Kriemler et al., 2010; Nemet et al., 2011). The 20-m shuttle run is simple to administer in a field-based setting, a reliable measure of aerobic fitness and a valid predictor of maximal VO2 in adults and children, but only those over 9 years of age (Leger, Mercier, Gadoury, & Lambert, 1988).

### 1.3.3.4 Bruce Protocol

The Bruce Protocol is commonly used to measure, predict and evaluate VO2PEAK in a laboratory setting on a TM (R. Bruce, Kusumi, & Hosmer, 1973). It is an incremental protocol, and the TM increases in speed and grade every three minutes. Subjects continue to walk and run on the TM until a determined endpoint of fatigue (R. Bruce et al., 1973). While the Bruce Protocol does not require gas exchange measurements, it is still considered a maximal test because it does not have a predetermined, arbitrary endpoint, a trait more commonly associated with submaximal aerobic tests (R. A. Bruce, 1974). Cumming et al. developed normative values for children aged 4-to-18 years of age based on times to exhaustion (Gumming et al., 1978). Time to exhaustion was determined as a refusal to continue despite verbal encouragement (Gumming et al., 1978). In van der Cammen-van Zjip et al.’s more recent work, the end point was less subjective. Children performed the test until voluntary exhaustion, with a HR ≥185 beats bpm or a loss of coordination indicating maximal performance. Normative values for age-specific centiles, for 4-to-5 year old Dutch children, are available (van der Cammen-van, Monique HM et al., 2010). Without VO2PEAK values collected with our participants, a second measure of aerobic fitness, HRR was reported.

### 1.3.3.5 Heart Rate Recovery (HRR)

HRR refers to the rate that HR returns to baseline following exercise (Shetler et al., 2001), due to vagal reactivation after exercise (Imai et al., 1994). A faster HRR is considered to be a marker of good physical fitness, and possibly of habitual PA participation (Shetler et al., 2001). HRR is accelerated in endurance athletes, and delayed in patients with chronic heart failure, when compared to sedentary participants (Imai et al., 1994). In addition, a slower HRR after graded exercise was a predictor of mortality in healthy, older adult males (C. R. Cole, Blackstone, Pashkow, Snader, & Lauer, 1999). Children generally have a faster HRR than adults following aerobic exercise (Mimura & Maeda, 1989), and this is likely influenced by cardiac parasympathetic activity at rest (Ohuchi et al., 2000). The determinants of HRR were assessed in a sample of 5-to-18 year olds who completed maximal exercise testing with the Bruce Protocol. One-minute HRR was attenuated with increasing age while children with higher BMIs and lower exercise endurances exhibited slower 1-minute HRR (T. P. Singh, Rhodes, & Gauvreau, 2008). In samples of 4-to-6 year olds who completed the Bruce Protocol, HRR values of 60-81bpm have been reported (Gumming et al., 1978; Mimura & Maeda, 1989; Wessel, Strasburger, & Mitchell, 2001). Both Bruce Protocol TM time and HRR are appropriate measures to assess aerobic fitness in young children. Additional measurement considerations are necessary to carry out the Bruce Protocol with young children.

### 1.3.3.6 Measurement Considerations with the Bruce Protocol

Aerobic fitness tests have been carried out with relative ease in young children; however, certain modifications and considerations are necessary to ensure success in exercise testing with this young population. One of the most important factors to consider when conducting exercise testing in a paediatric population is that children cannot be regarded as miniature adults (Oded Bar-Or & Rowland, 2004). It is not appropriate to simply adapt exercise tests to fit a smaller body and report results in the same way. For example, researchers had young children complete the regular Bruce Protocol and a Half-Bruce, characterized by 1.5 minute stages so that the increased in speed and grade were not as extreme. Theoretically, this method sounds appropriate for administering the test in young children because the changes in speed and grade were not as extreme, but the researchers concluded the regular Bruce was more appropriate (82).As a result, measurement considerations are necessary to ensure exercise testing is feasible, reliable, valid and safe in this population.

During the protocol, it is our goal to keep children on the TM until exhaustion, a result determined by many factors. First of all, endurance time is influenced by the motivation of the child and the ability of the researchers to motivate and encourage the participant (Gumming et al., 1978). At maximal effort, children have higher maximal HR than adults (Simons-Morton et al., 1988), so determining exhaustion based on HR is more challenging. In 1978, Cumming et al. did not permit children to hold the handrails during a maximal test with the Bruce Protocol because holding on reduces the metabolic cost of the work (Gumming et al., 1978). More than 30 years later, researchers set out to determine updated reference values for Bruce Protocol performance in 4-to-5 year olds. In this study, the children were permitted to hold the handrails to maintain body position and assist with balance (van der Cammen-van, Monique HM et al., 2010). These measurement considerations and suggestions guided our aerobic fitness assessments, conducted with the Bruce Protocol.

### 1.3.3.7 Aerobic Fitness in the Early Years

Performance on aerobic fitness tests increases with increasing age in the early and school-aged years. With the Bruce Protocol, TM times are higher in older children, but this is based on cross-sectional, not longitudinal studies. Normative data from 1978 suggests that 4-to-5 year olds and 6-to-7 year olds will have mean endurance times of 9.97 and 11.47 minutes, respectively (Gumming et al., 1978). These values are similar to a study from Turkey that reported 4-to-6 year olds had an average TM time of 10.01 minutes (Lenk, Alehan, Celiker, Alpay, & Sarici, 1998; van der Cammen-van, Monique HM et al., 2010). Older children also perform better on field-based assessments of aerobic fitness. In a 500-metre run-and-walk test, performance was evaluated in 5-to-6 year old children, with older children performing better than younger children and boys performing significantly better than girls (Parizkova, 1996). Further longitudinal analysis of aerobic fitness is necessary to determine how individual fitness changes through the early years.

### 1.3.3.8 Tracking Aerobic Fitness

Tracking of aerobic fitness in young children has not been reported in the literature, and this is based on the lack of longitudinal fitness studies. The literature suggests that performance is improved with increasing age in the early years, and that supplemental physical education can have long-term fitness benefits (Nemet et al., 2013).This is a significant research gap that needs to be addressed to understand how aerobic fitness in the early years may predict aerobic fitness later in life, when its relationship to chronic disease prevention is better understood.

## 1.3.4 Short-Term Muscle Power

### 1.3.4.1 Definition and STMP in the Early Years

Performance on aerobic fitness tests has been continuously studied in the early years, while research regarding performance STMP tests is more limited (N. Armstrong & Welsman, 1997; van Brussel et al., 2007). STMP is characterized by the highest mechanical power that can be performed in an exercise bout that is equal to or shorter than 30 seconds (Van Praagh & Doré, 2002). STMP is not commonly considered a traditional health-related fitness component (Caspersen et al., 1985). However, the rationale for including STMP as a component of health-related fitness in this thesis is its relatedness to the sporadic, intermittent high intensity bouts of activity commonly demonstrated by preschoolers. If most high-intensity PA in preschoolers is accumulated in short bouts, the ability to use STMP would be necessary to facilitate these movements and is, theoretically, a key player in the relationship between fitness and PA. Before the relationship can be established, more information about the STMP of young children is necessary, and this requires the consideration of several physiological traits that are common in young children.

Young children have very different physiology than adults and this needs to be considered when conducting and analyzing STMP tests in this population. First of all, power production is a function of the rate at which energy, adenosine triphosphate, is supplied for muscular work, and muscle power is the neuromuscular system’s ability to produce its highest power output in a given period of time. In high-intensity exercise, children tend to resist fatigue better and recover quicker than adults (Ratel, Duché, & Williams, 2006) because children tend to have a smaller muscle mass and muscle cross-sectional area. In addition, children have a higher content of type I muscle fibres and a higher muscle oxidative capacity, features that attenuate the production of muscle by-products and make young children better at sustaining high intensity exercise (Ratel et al., 2006). These features influence how children perform on both lab and field based assessments of STMP.

#### 1.3.4.1.1 Lab Versus Field Tests

In field-based testing, both jumping and running tests have been used to assess STMP in children for many years. The vertical jump test was developed to measure maximal leg power in adults by having adults jump and the height at the peak of the jump was recorded (Sargent, 1921). The skill does not require high motor ability and can be learned and executed by young children with ease (Van Praagh & Doré, 2002). Sprint running tests are also commonly used to measure running velocity and can be used as an assessment of STMP. These tests are fast and easy to administer in paediatric populations (Van Praagh & Doré, 2002). A 25-metre running dash is reliable in 3-to-5 year olds, with an intraclass correlation coefficient of 0.91 (Nguyen et al., 2011), and time to complete the 25-dash was significantly faster in 4 and 5 year olds versus 3 year olds (Gabel et al., 2011). Performance on the 20-m dash speed improves with age, from 3 to 6 years old, and was faster in boys than girls (Parizkova, 1996). While field tests are appropriate for quick assessments of STMP, laboratory based settings allow for more controlled settings and results.

The most common laboratory test to assess STMP, the Wingate Anaerobic Test (WAnT), is performed on a cycle ergometer. The WAnT was designed to be inexpensive and easy to administer to a variety of populations, including children with disabilities (Bar-Or, 1987; Inbar, Bar-Or, & Skinner, 1996). During the WAnT, a participant performs all-out cycling against a constant braking force (relative to body weight) for a pre-determined amount of time, generally 30 seconds (Inbar et al., 1996). Power is a function of force multiplied by distance over a period of time. For the WAnT, braking force is multiplied by distance pedaled (pedal revolutions x distance per revolution) to produce a power output. STMP can be expressed as mean power (MP), the average power output over the duration of the test and peak power (PP), which is the highest power output achieved during the test and represents the explosive characteristics of someone’s muscle power (van Brussel et al., 2007). These values can be presented as absolute (Watts) or relative to body weight (Watts/kg) values (Inbar et al., 1996). The test is highly reliable and has been validated against many other field and laboratory tests in school-age children (Bar-Or, 1987). A specific protocol was developed and tested for use in younger children.

### 1.3.4.2 Ten-second Modified Wingate Anaerobic Test

In the early years, children mostly accumulate VPA in bouts of less than 15 seconds (Obeid et al., 2011) and they may have a hard time maintaining motivation for the duration of a traditional 30-sec WAnT (Van Praagh & Doré, 2002). In response to these concerns, a 10-second modified WAnT was developed by our lab to assess anaerobic fitness in preschoolers. For the test, maximum pedaling speed was determined. Next, a child began pedaling and when he or she reached 80% of his or her maximum pedaling speed, a braking force of 0.55 Nm per kg of body mass (van Brussel et al., 2007) was applied. Intraclass correlation coefficients were 0.93 for PP and 0.91 for MP, indicating the test was reliable in this population (Nguyen et al., 2011), and appropriately used with several modifications from the original WAnT protocol.

#### 1.3.4.2.1 Measurement Considerations

The 10-second WAnT takes into consideration the smaller size and younger age of the preschoolers with several modifications from the original WAnT protocol. Our laboratory is equipped with an appropriately-sized paediatric cycle ergometer (LODE Corival Pediatric,Groningen, The Netherlands), with adjustable seat height, pedal crank length, and handle-bars. The length of the pedal crank is generally 17.5cm; however, adjustment is necessary when working with different limb lengths (Bar-Or, 1987). Our ergometer is not equipped with toe stirrups, so we tape each participant’s feet to the pedals to allow for a pushing or pulling force to be exerted against the pedals throughout the test (Bar-Or, 1987). Participants who used toe-stirrups during the WAnT have shown better performance (LaVoie, Dallaire, Brayne, & Barrett, 1984). Motivation is also a key component for performance in this ‘all-out’ cycling test and environmental conditions should be standardized for all participants (Bar-Or, 1987). Performance on maximal cycling tests is influenced by intramuscular coordination (Keller, Bar-Or, Kriemler, Ayub, & Saigal, 2000). Nguyen et al. observed that both relative and absolute PP and MP values increased with increasing age in the preschool years (ages 3-to-5 years), which may be attributed, in part, to the development of coordination (Nguyen et al., 2011).

### 1.3.4.3 Tracking Short-Term Muscle Power

A lack of longitudinal fitness studies in young children explains the scarcity of STMP tracking studies. Tracking was assessed in a small sample of 3-to-5 year olds from our laboratory who completed the 10-second WAnT twice, 15 months apart. PP (W/kg) displayed moderate tracking while MP (W/kg) exhibited strong tracking based on Spearman rank order correlations. When analyzed with Kappa statistics, PP (W/kg) demonstrated moderate tracking while MP (W/kg) exhibited strong tracking (Gabel et al., 2011). Tracking was assessed in boys and girls who completed a 15 or 20m sprint in grade 2 and then several years later in grade 6. Spearman tracking coefficients were moderate (r=0.50-0.54) (Falk et al., 2001). STMP tracking literature is minimal; however, its relationship with PA over time is important for the design of health interventions that aim to increase fitness.

### 1.3.4.4 Relationship between PA and Aerobic Fitness and STMP

Pate and colleagues identified multiple research gaps related to the study of PA in preschool children. One broad gap was the need for studies examining the relationship between PA and health, and specifically the relationship with physical fitness (Pate et al., 2013). Over the past three decades, paediatric exercise physiology researchers have debated whether research should focus more on PA or fitness (Lloyd, Colley, & Tremblay, 2010; Rowland, 1995). In 1995, it was suggested that field-based testing of fitness in children was unnecessary given the recent shifts towards lifetime, daily PA, rather than fitness performance (Rowland, 1995). Fifteen years later, the debate continued as researchers suggested it is most appropriate to conduct assessments of physical literacy, rather than fitness or PA in isolation. Physical literacy takes into account physical fitness, motor behaviour, PA behaviour and psycho-social/ cognitive factors, and in combination these factors influence child health (Lloyd et al., 2010).As such, the analyses in this study will investigate both PA and fitness, and how they relate to one another. In adults, a positive relationship between aerobic fitness and daily PA has been established (United States. Public Health Service. Office of the Surgeon General, Centers for Disease Control, Prevention (US), President's Council on Physical Fitness, & Sports (US), 1996), while a meaningful relationship between aerobic fitness and habitual PA in youth remains to be established (N. Armstrong, Tomkinson, & Ekelund, 2011). It is important to understand this relationship to create and implement appropriate health promotion strategies (Dencker et al., 2010). Based on the irregular PA patterns observed in young children (Bailey et al., 1995), it is unclear how well habitual PA is related to aerobic fitness (Dencker et al., 2006).

#### 1.3.4.4.1 Observational Studies

Observational studies that have investigated the relationship between PA and fitness in the early years are scarce; however, the relationship has been observed in school-aged children. In 8-to-11 year olds, a weak positive relationship (*r*=0.23) between TPA, as measured by accelerometry, and VO2PEAK, as measured with a maximal test on a cycle ergometer, was observed. A stronger correlation (*r*=0.31) was observed between daily VPA and VO2PEAK (Dencker et al., 2006). Similar trends were seen in 6-to-7 year olds, wherein boys demonstrated a positive association between TPA, MPA, MVPA and VPA and VO2peak (*r*=0.15-0.28), as measured with a maximal TM test, while only MPA was positively associated with VO2PEAK in girls (*r*=0.14) (Dencker et al., 2010). To our knowledge, the relationship between fitness and PA has not been investigated in observational studies with preschool-aged participants.

Baseline data from a lifestyle intervention conducted in Swiss preschools showed positive associations between aerobic fitness, as measured with the field-based shuttle run test, and TPA (*r*=0.38), MPA (*r*=0.30) and VPA (*r=*0.37), as measured with accelerometers (Bürgi et al., 2011). The literature in preschoolers is extremely scarce and evidence in school-age children is mixed. In these studies, there were a variety of methods used to assess both PA and aerobic fitness. The relationship between PA and STMP remains unstudied, and this warrants further investigation, along with laboratory-based assessments of aerobic fitness.

#### 1.3.4.4.2 Intervention Studies

Several PA interventions have been administered in preschool and kindergarten classes and investigated the changes in fitness following the interventions. In a paediatric population, a dose-response relationship between endurance training and improvements in VO2PEAK exists. If children or youth participate in a 12-week training program, they will experience, on average, an 8-9% increase in VO2PEAK, independent of sex, age and maturation. Greater increases are likely possible with longer training programs (N. Armstrong & Barker, 2010). Training studies are not common practice with young children, but comprehensive, holistic school based PA or physical education interventions have been administered.

The Ballabeina cluster randomized controlled trial was conducted in 40 preschool classes in Switzerland and aimed to assess the effect of a multidisciplinary lifestyle intervention on body composition, aerobic fitness and motor agility. The 10-month intervention included a PA component that consisted of 4 weekly 45-minute PA sessions that aimed to improve motor skills and aerobic fitness (Niederer et al., 2009). Aerobic fitness was assessed with a 20-meter shuttle run test and PA was measured via accelerometry (Bürgi et al., 2011). At follow-up, there was a significantly greater increase in aerobic fitness in those children in the intervention versus control preschool classes (Puder et al., 2011). The Ballabeina study did not assess STMP, but did measure speed to complete an obstacle course as a measure of motor skills and agility. Baseline TPA, MPA and VPA were all associated with a shortened obstacle course time (*r=*0.13-0.17) (Bürgi et al., 2011). Preschoolers showed more pronounced improvements in agility, if they were enrolled in the intervention versus those in the control group (3.2 versus 2.6 seconds faster) (Puder et al., 2011). These results suggest that fitness can be improved after just 10 months of extra PA programming.

A second school-based lifestyle intervention was administered to children attending kindergarten in Israel. The PA component of the intervention involved 45 minutes (3x15 minute sessions) per day of exercise training on 6 days per week for 9 months. Activities were designed as games to be engaging and enjoyable to the students. In addition, students were encouraged to increase habitual PA and decrease sedentary activities. Performance on a modified 10m-shuttle run test, as a measure of aerobic fitness, was significantly improved in the intervention group, versus control group (Nemet et al., 2011).

Evidence from these interventions suggests that PA and fitness are related in the early years because added doses of PA or physical education elicited positive fitness improvements. To our knowledge, the relationship between PA and HRR or STMP in the early years has not yet been investigated. While the relationship between aerobic fitness and PA has been further researched, these studies used field-based methods that have not been deemed reliable or valid for use with preschoolers.

### **1.3.4.5 Tracking the Relationship between Physical Activity and Fitness**

The purpose of studying PA and fitness tracking is to investigate whether events that occur early in the lifespan influence later events (Malina, 1996). Children grow approximately 6cm taller and 2-3kg heavier in each year of early childhood (Santrock, MacKenzie-Rivers, Leung, & Malcomson, 2003), and this may influence performance on fitness tests or engagement in PA. It is not clear how PA or fitness in the early years tracks into older childhood and adulthood. In a 2001 paper, Malina discussed the various pathways between PA, fitness and health during childhood, adolescence and adulthood. He concluded that longitudinal studies that investigated health-related fitness had higher inter-age correlations and tracking than PA tracking data (Malina, 2001).Individual studies have investigated the connections between childhood and adulthood PA and fitness.

Investigations of whether childhood fitness could predict adult PA levels have been carried out. The adult group classified as ‘physically active’ had better performance on a 600-yard run test, sit-up test, and 45-metre dash when they were 12-years old, compared to the adults not classified as ‘physically active’. The children who scored in the lowest 20% of the 600-yard run test were twice as likely to be inactive as adults, compared to their peers who obtained high scores (Dennison, Straus, Mellits, & Charney, 1988). The best evidence for studying this relationship over time in young children involved the long-term results of a PA intervention. One-year following the completion of a school-based, PA intervention in kindergarten classes, aerobic fitness remained significantly elevated in the intervention group participants (Nemet et al., 2013). The long-term results of this study indicate that PA participation in the early years may build a foundation for increased fitness later in life. To our knowledge, there are no studies in preschoolers that simultaneously track the relationship between PA and fitness, but the evidence suggests that higher fitness can have positive long-term benefits.

Current research does not adequately track PA and fitness, individually or concurrently, through the early years. This is a period of considerable growth and development, and understanding how PA and fitness change with growth and development is important for the establishment of healthy living behaviours. If PA or fitness tracks strongly, it may be predictive of behaviours later in life. On the other hand, if PA or fitness track poorly, it may suggest that healthy living behaviours are not established until after the early years. Understanding how the relationship between PA and fitness changes over a one-year period is vital because this knowledge can drive health and PA interventions to be better designed to induce positive changes in PA and fitness. A further investigation of the characteristics of participants who change PA or fitness from baseline to follow-up will also be helpful for understanding factors that influence change.

# Rationale for Thesis and Objectives

Year 1

Physical Activity

Year 2

Physical Activity

Year 1

Physical Fitness

Year 2

Physical Fitness

Tracking

Tracking

**Figure 1.** Theoretical model of the relationships between year 1 and year 2 physical activity and fitness measures.

The changes and tracking of PA and fitness in the early years have not been described previously in the literature. In addition, the relationship between these variables has not been established in the early years, especially how the relationship changes over a 1-year period. Figure 1 outlines the relationships to be investigated in this thesis. The objectives of thesis are to:

1. Determine how PA and fitness change and track over a one-year period from baseline to follow-up.
   1. Changes from year 1 to year 2.
   2. Tracking of each variable from year 1 to year 2.
2. Determine the relationship between PA and fitness over a one-year period.
   1. Describe the relationships between PA and fitness separately for year 1 and year 2 (Arrows 1 and 2 in Figure 1).
   2. Describe the PA changes from year 1 to year 2 and the characteristics of participants who decreased, maintained or increased PA participation.
      * 1. Hypotheses

The following hypotheses were developed based on assessments of body size and composition, PA, aerobic fitness and short-term muscle power that were conducted at year 1 and year 2.

1. Changes and tracking of PA and fitness: Performance on fitness tests will increase from year 1 to year 2 as children grow. Changes in PA will be variable between participants. Tracking will be stronger for fitness variables than PA variables.
2. Relationships: The relationships between PA and fitness will not be different at year 1 and year 2. Changes in PA will be positively associated with changes in fitness.

# CHAPTER 2: METHODS

# 2.1 HOPP Study Overview

The Health Outcomes and Physical activity in Preschoolers (HOPP) study is a CIHR-funded, 3-year, observational, longitudinal study. It aims to describe how the prevalence and patterns of PA in preschoolers relate to various health indicators, such as: body composition, aerobic fitness, STMP, motor proficiency, vascular health, health-related quality of life, demographics, children’s behaviour and parents’ beliefs about physical activity for their preschooler. The Hamilton Health Sciences/ Faculty of Health Sciences Research Ethics Board provided ethical approval for the study (Timmons et al., 2012). This thesis will focus on the body composition, aerobic fitness, STMP and PA data that were collected in the first two years of the study (between summer 2010 and summer 2013).

The HOPP study began collecting data in the summer of 2010 and will be complete in the fall of 2014. Before coming to the laboratory for their first visit, parents were sent the consent form to review. At the first visit, written consent was obtained. Parents then completed a medical questionnaire, as well as a series of questionnaires collecting demographic, behavioural, and physical activity information about the child and their family. For the remainder of the first visit, body composition, aerobic fitness, STMP and motor skills were assessed. At the end of the visit, participants were given an accelerometer to wear daily for 7 days to assess each child’s habitual PA levels. The same testing procedure was used in subsequent years.

# 2.2 Participants

Four hundred and nineteen preschoolers were enrolled in the HOPP Study and completed year 1 assessments and 400 preschoolers completed year 2 visits, resulting in a 95% retention rate. Any child with a chronic disease (e.g. asthma, diabetes, etc.) or disability (e.g. cerebral palsy) was not included in the current study. On average, visits were 12.1±0.7 months apart (range: 10.8-17.2 months), and 97% of visits occurred within 12 ±1 months. At year 1, five participants could not complete the assessments due to developmental/health concerns and were therefore excluded for all analyses and not invited to continue their participation in the study. Fourteen participants did not return for year 2 for several reasons, including: family issues, medical issues, time commitments, moved away or unknown reasons (includes scheduling issues).

# 2.3 Body Composition

## 2.3.1 Height and Weight

Height was measured with a calibrated stadiometer to the nearest 0.1cm. Weight was measured to the nearest 0.1kg on a digital scale (BWB-800, Tanita Corporation, Japan), with the participant dressed in light clothing and without shoes. Height and weight were measured twice for each participant and averaged. If the two height or weight measurements were >0.1cm or >0.1kg, respectively, apart, a third measure was taken. The average of the two closest measures was used. BMI was calculated as weight/height2 (kg/m2). BMI percentiles, based on sex and age, were calculated based on CDC growth charts to classify children as underweight (<5th %ile), normal weight (≥5 to <85th %ile), overweight (≥85th to <95th %ile) or obese (≥95th %ile) (Kuczmarski et al., 2002).

## 2.3.2 Percent Body Fat

A BIA (RJL Quantum 2, Tanita Corporation, Japan) was used to assess body composition. The children lay in a supine position with arms and legs extended approximately 30**°**. Arms were pronated so the palms lay flat to the table. Four electrodes were attached to the right side of the body, on the wrist bisecting the ulna head, on the hand proximal to the 3rd metacarpal, on the ankle bisecting the medial malleolus, and on the foot proximal to the middle metatarsals. Values for resistance and reactance were collected after approximately 1 minute of resting in the supine position. For adolescents and adults, the measurement is normally taken for 4-5 minutes (Nichols et al., 2006), but only one minute was used based on our age group. Fat free mass was calculated using an equation that was validated again DEXA in children: (FFM= [(0.77(SexCode)]+[0.46(1-Age)]+[0.32(1-AvgWt)}+[0.41(1-AvgHt2)/(Resistance)-0.77)]. %BF was then calculated as [(body weight- FFM)/ body weight] x 100] (Kriemler et al., 2009).

# 2.4 Health- Related Fitness

## 2.4.1 Short-term Muscle Power

### 2.4.1.1 Modified Wingate Test

STMP was assessed with a modified 10-second WANT that has been shown to be reliable in 3-to-5 year olds (Nguyen et al., 2011). At year 1, 65 children completed the modified Wingate test on a calibrated mechanically braked cycle ergometer (Fleisch-Metabo, Geneva, Switzerland). All subsequent tests were completed on an appropriately sized, electromagnetic braked cycle ergometer (LODE Corival Pediatric, Groningen, The Netherlands). First, participants were asked to pedal as fast as possible for approximately 20 sec or until the pedaling speed plateaued, in order to determine peak pedaling speed. Braking force for the test was calculated as 0.55 Nm per kg of body mass, a force commonly used in children who are less than 14 years old (van Brussel et al., 2007). After a short rest, the participant was instructed to pedal as fast as he or she could. When 80% of the peak pedaling speed was attained, the braking force was applied. At this point, the participant was encouraged to keep pedaling as fast as he or she could for 10-seconds. Both absolute (Watts) and relative (Watts/kg of body mass) PP and MP were used as indicators of STMP. A number of participants could not pedal for the entire 10-second test; for these participants, only PP values were included in analyses.

## 2.4.2 Aerobic Fitness

### 2.4.2.1 Bruce Protocol

Aerobic fitness was assessed with the Bruce Protocol, a progressive TM test that increased in speed and grade every 3 minutes (see Table 1) (R. Bruce et al., 1973). Previous research has shown this protocol to be appropriate in children as young as 4 years old (Gumming et al., 1978; van der Cammen-van, Monique HM et al., 2010). At the beginning of each visit, participants walked on the TM at a comfortable pace to familiarize themselves with the equipment. As a modification from the traditional Bruce Protocol, participants were required to hold the handrails during the practice and the test, and a researcher was positioned behind each participant to ensure safety.

Each participant was fitted with a HR monitor (Polar Electro, Kempele, Finland) before commencing the test and a seated HR was recorded after about 1-minute of rest. During the test, HR was monitored continuously and recorded every minute and at the end of the test.

**Table 1. Bruce Treadmill Protocol**

|  |  |  |  |
| --- | --- | --- | --- |
| Bruce Treadmill Protocol | | | |
| Stage | Speed (km/hr) | Grade (%) | Time (min) |
| I | 2.7 | 10 | 3 |
| II | 4.0 | 12 | 3 |
| III | 5.4 | 14 | 3 |
| IV | 6.7 | 16 | 3 |
| V | 8.0 | 18 | 3 |
| VI | 8.8 | 20 | 3 |
| VII | 9.6 | 22 | 3 |

#### 2.4.2.1.1 Treadmill Time

The test was terminated when the participants were exhausted, could no longer keep up with the speed of the TM, showed signs of emotional distress, or refused to continue despite verbal encouragement. Only participants who achieved a maximal HR >180 bpm were included in the analyses to ensure a maximal, or near maximal, effort was exerted.

#### 2.4.2.1.2 Heart Rate Recovery

Upon termination of the test, the participants were immediately seated and asked to remain as still as possible. The second indicator of aerobic fitness was HRR. During the recovery period, HR was recorded every 30 seconds for 2 minutes. HRR was calculated as the difference between the maximal HR and at each 30-second recovery time point. Higher values indicate faster recovery and greater aerobic fitness. Data for participants who did not remain seated or calm during the recovery period, based on the estimation of the researcher, were excluded.

# 2.5 Physical Activity

PA was assessed with ActiGraph GT3XE and GT3X+ accelerometers (Fort Walton Beach, FL, USA). Strong agreement has been reported between the models and it is acceptable use these two ActiGraph models within the same study (Robusto & Trost, 2012). The accelerometers were set to record activity counts in 3-sec epochs to capture the random, intermittent, high intensity bouts that are characteristic of free-play in children (Bailey et al., 1995; Nilsson, Ekelund, Yngve, & Sjöström, 2002; Obeid et al., 2011). At the end of the first visit, participants were fitted with the accelerometer and instructed to wear it over their right hip during waking hours for seven days, except when they partook in water activities. Parents were instructed to record the times the accelerometer was put on and taken off in the provided logbook (See Appendix C).

The accelerometer data were analyzed with Actilife software. Sixty-minutes of continuous zero counts was used to determine non-wear time, if nothing was noted in the participant’s logbook (see Appendix C). If a parent indicated that the device was taken off, this time was also considered non-WT and excluded. If less than 60 min of zero counts were measured and, there was no indication in the logbook that the device was removed, this time remained in the analyses and was considered sedentary time.

Only participants who wore the accelerometer for at least 3 days with a minimum WT of 10 hours per day were included in the analyses. Daily minutes of PA and the PA %WT were calculated to determine the volume of PA participation for: TPA, MVPA and VPA. The frequency (bouts/day and bouts/hour) and duration of bouts (seconds) of MVPA were calculated to determine the pattern of PA participation. The cut-points for PA intensity were based on cut-points validated in healthy 3-to-5 year old children (Pate et al., 2006).Pate et al., validated accelerometers against expired gas measures from a portable metabolic system. Moderate intensity was defined as 420 counts/ 15 sec epochs and vigorous PA was defined as 842 counts/ 15 sec epoch. To account for the 3-sec epoch used in this study, the Pate cut-points were divided by five. This is common practice in PA research to accommodate different epochs (Nilsson et al., 2002). As such, activity counts were classified as TPA if ≥8 counts/3-sec, MVPA if ≥84 counts/3-sec and VPA if ≥164 counts/3-sec.

# 2.6 Statistical Analyses

Statistical analyses were carried out with SPSS Statistics 20 for Mac (SPSS Inc., Version 20.0, Chicago, IL).All data are presented as means ± standard deviation. Statistical significance was set at *p*<0.05.

## 2.6.1 Participant Characteristics

Participant demographics and characteristics were analyzed separately for year 1 and year 2. Change scores (**Δ=**year 2-year 1) were calculated for all variables. Paired t-tests were conducted to determine if variables were different from year 1 to year 2. 95% confidence intervals of the difference were also computed.

## 2.6.2 Primary Objective Analyses

The primary objective of this thesis was to determine how PA volume and fitness measures track over 12-months in the preschool years. Tracking, the stability of each characteristic, over the one-year period was analyzed two ways. Spearman rank order correlations were used to assess individual rank stability between year 1 and year 2. Correlation coefficients <0.30 were considered low, while coefficients of 0.30-0.60 were considered moderate, and coefficients >0.6 were considered strong (Malina, 1996). For Kappa statistics, participants were categorized into tertiles (N/3: low, middle, high). Kappa statistics were used to assess tertile stability by addressing how participants move between tertiles (either increase, decrease or remain stable). *Same* indicated the same Kappa tertile rank in year 1 and year 2, *higher* indicated a higher rank at year 2 and *lower* indicated a lower rank at year 2. Kappa statistics of 0-0.2 are slight, 0.2-0.4 are fair, 0.4-0.6 are moderate, 0.6-0.8 are substantial, and 0.8-<1.0 are almost perfect strengths of agreement (Munoz & Bangdiwala, 1997). Spearman correlation coefficients were appropriate to assess individual stability over time. The novelty of using Kappa statistics was to assess the odds of remaining within a certain tertile (e.g. low, middle or high fitness) over time (Malina, 1996). Both methods were used because some scores were very similar, and tertile statistics allow multiple participants with similar or the same scores to be classified into the same group.

## 2.6.3 Secondary Objective Analyses

The secondary objective aimed to determine the relationship between PA and physical fitness over a 1-year period. The relationship between year 1 and 2 PA, and between year 1 and year 2 fitness, were examined with tracking, as described above. The next set of relationships to examine was between year 1 PA and fitness, and between year 2 PA and fitness. The literature does not strongly suggest a one-directional relationship between variables. Therefore, bivariate correlations between the variables were carried out.

The relationships between year 1 PA and year 2 fitness, and between year 1 fitness and year 2 PA were examined by studying how these variables changed from year 1 to year 2. Participants were grouped based on whether they increased, decreased or remained stable for each measure of PA and fitness. The groups were determined by previously reported test-retest reliability scores of the measures (Table 2). For example, if a participant’s year 2 PP fell into the range of (year 1 PP +/- error), he or she was categorized as keeping the same PP. Alternately, if his or her PP fell below or above the (year 1 PP +/- error) range, his or her PP was categorized as decreasing or increasing, respectively. Details of the reliability coefficients used are included below in Table 2.

Once it was known whether participants decreased, maintained or improved on a certain measure, the characteristics of those groups were investigated*.* Differences were examined with one-way analysis of variance (ANOVA) with Bonferroni post-hoc analysis.

**Table 2.** **Reliability of Fitness and PA measures**

|  |  |  |
| --- | --- | --- |
| **Measure** | **Reliability** | **Source** |
| PP | 0.93 | Nguyen et al. 2011 |
| MP | 0.91 | Nguyen et al. 2011 |
| Treadmill Time | 0.94 | Cumming et al. 1978 |
| HRR | 0.42 | Nguyen et al. 2011 |
| Physical Activity | 0.80 | Penpraze et al. 2006 |

## 2.6.4 Exploratory Analyses

The exploratory analysis of this thesis aimed to determine how the frequency and duration of bouts of MVPA changed from year 1 to year 2. Bouts of MVPA were consecutive 3-sec epochs of ≥84 counts. Frequency of bouts was characterized as both bouts per day and bouts per hour of accelerometer WT. Duration of bouts refers to the duration of MVPA bouts in seconds. Paired t-tests were conducted to determine differences between year 1 and year 2 data for each participant. Frequency distributions of the changes in bout frequencies and durations were also carried out.

# CHAPTER 3: RESULTS

# 3.1 Participant Characteristics

Participant characteristics are presented below in Table 3***.*** Height, weight and BMI data were available for all participants at year 1 and year 2. BIA data were available for 403 participants in year 1, and 398 participants in year 2 because some participants were not able to remain still or refused to participate in this measure. At year 2, participants were significantly older, taller and heavier. BMI, height percentile, weight percentile and %BF all significantly decreased from year 1 to year 2. The distribution of healthy weight, overweight, obesity and underweight did not significantly change from year 1 to year 2. However, 80% of participants were classified as normal weight compared to 78.3% at year 2, while 15.4% versus 17.5% were overweight or obese at year 1 versus year 2, respectively.

**Table 3. Participant Characteristics at Year 1 and Year 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Year 1** | **Year 2** | **Change**  **(Y2-Y1)** | **95% Confidence Interval of the Difference** | | ***t-*test**  ***p-*value** |
| **Lower** | **Upper** |
| *n* | 400 |  |  |  |  | - |
| **Age (years)** | 4.5±0.9 | 5.5±0.9 | +1.0±0.6 | 1.0 | 1.0 | 0.000\* |
| **Height (cm)** | 106.6±7.8 | 113.5±7.8 | +7.0±1.1 | 6.9 | 7.1 | 0.000\* |
| **Weight (kg)** | 17.9±3.2 | 20.3±3.8 | +2.3±2.2 | 2.3 | 2.4 | 0.000\* |
| **BMI (kg/m2)** | 15.7±1.3 | 15.6±1.4 | -0.8±-0.1 | -0.1 | -0.02 | 0.008\* |
| **Height %ile** | 61.6±27.1 | 60.9±27.3 | -0.6±-0.4 | -1.2 | -0.03 | 0.039\* |
| **Weight %ile** | 57.1±27.5 | 55.9±27.3 | -1.2±-1.2 | -1.9 | -0.5 | 0.002\* |
| **BMI %ile** | 52.3±28.5 | 51.6±28.1 | -0.7±-1.0 | -1.9 | 0.5 | 0.255 |
| **CDC Cutoffs**  Normal weight  Obese  Overweight  Underweight | 80.0%  4.8%  10.6%  4.6% | 78.3%  4.0%  13.5%  4.3% | -1.7%  -0.8%  +2.9%  -0.3% |  |  | 0.810  -  -  -  - |
| **% Body Fat** (*n*=388) | 23.2±4.6 | 21.1±4.7 | -2.1±2.2 | -2.3 | -1.9 | 0.000\* |

Mean ± SD; Age: chronological (date of testing – date of birth); Note: p-values represent the results of paired t-tests conducted for each variable between year 1 and year 2; \* denotes significance at *p*<0.05

# 3.2 Health-Related Fitness

Table 4 displays the health-related fitness results from year 1 and year 2. At year 1, 391 and 355 participants had valid PP and MP scores, respectively while at year 2, 399 and 392 participants had valid PP and MP scores, respectively. At year 1 and 2, PP data was available for 378 participants and MP was available for 343 participants. On average, PP significantly increased (**Δ**PP= Year 2 PP- Year 1 PP) 31.5 Watts (t(377)= -34.893, *p*=0.000) and MP significantly increased (**Δ**MP= Year 2 MP- Year 1 MP) 28.19 Watts (t(342)=31.815, *p*=0.000). TM data were only included for participants who reached a minimum maximal HR of 180 bpm and who were still and calm during HRR. At year 1, the average maximal HR was 196±7 bpm and at year 2, maximal HR was 200±7 bpm. The sample size for valid TM times was 382 in year 1 and 392 in year 2, and 366 participants had valid TM times at year 1 and year 2. TM time significantly increased 2.4 minutes, from 9.4 to 11.8 minutes (t(365)=-33.067, *p*=0.000). HRR data were available at both years for 358 participants and was not significantly changed from year 1 to year 2 (*t*(357)*=*-1.045, *p*=0.297).

**Table 4. Fitness Variables at Year 1 and Year 2**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **N** | **Year 1** | **Year 2** | **Change**  **(Y2-Y1)** | **95% Confidence Interval of the Difference** | | ***t*-test**  ***p*-value** |
| **Lower** | **Upper** |
| **PP (W)** | 378 | 94.1±37.3 | 125.6±36.2 | +31.5±17.6 | 29.7 | 33.3 | 0.000\* |
| **MP (W)** | 343 | 84.1±30.9 | 112.3±32.3 | +28.2±16.4 | 26.5 | 29.9 | 0.000\* |
| **Treadmill Time (min)** | 366 | 9.4±2.3 | 11.8±2.3 | +2.4±1.4 | 2.3 | 2.6 | 0.000\* |
| **60-sec HRR (bpm)** | 358 | 65±14 | 65±14 | -0.8±14.0 | -2.2 | 0.7 | 0.297 |

Note: p-values represent the results of paired t-tests conducted for each variable between year 1 and year 2; \* denotes significance at *p*<0.05

# 3.3 Physical Activity

Valid accelerometer data were available for 365 participants in year 1 and 367 participants in year 2, which corresponded to 335 participants who had valid accelerometer data at both year 1 and year 2. Of the valid data, participants wore the accelerometers for 5.6 ± 1.3 days and 12.1 ± 0.7 hrs/day at year 1, and 5.9 ±1.3 days and 12.0±0.7 hrs/day at year 2. Of these hours, participants engaged in over 4 hours of TPA, which included approximately 1.5 hours of MVPA per day. Engagement in TPA was not changed from year 1 to year 2, however the volume of LPA decreased 3.23 minutes/day. This was compensated by an increase in the volume of VPA by 3.65 minutes/day, or an increase of almost 30 minutes per week. As a result of the increase in VPA, MVPA also increased 4 minutes per day from year 1 to year 2. The patterns for change in PA are the same whether examined as volume in minutes per day or, as %WT. To account for the variation in WT, only PA data as %WT was included in subsequent analyses. In addition, only intensities of MVPA and VPA will be included as the aim of this thesis is to investigate the relationship of PA and fitness, and the literature suggests that higher intensity PA is most related to fitness (Dencker et al., 2006)**.**

Figures 2 and 3 show that both boys and girls increased their engagement in MVPA and VPA from year 1 to year 2 (*p*=0.000). While both groups increase, boys engaged in more MVPA and VPA than girls at both years 1 and 2 (*p*=0.000).

**Table 5.** Physical Activity Variables at Year 1 and Year 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variable**  **(n=336)** | **Year 1** | **Year 2** | **Change**  **(Y2-Y1)** | **95% Confidence Interval of the Difference** | | ***t-test***  ***p*-value** |
| **Lower** | **Upper** |
| **Wear Time (hrs/day)** | 12.1±0.7 | 12.1±0.7 | +0.0±0.8 | -0.1 | 0.1 | 0.921 |
| **TPA (min/d)** | 256.2±37.9 | 257.1±37.1 | +0.9±37.0 | -3.1 | 4.8 | 0.673 |
| **MVPA (min/d)** | 96.3±21.6 | 100.5±21.6 | +4.2±20.8 | 1.9 | 6.4 | 0.000\* |
| **VPA (min/d)** | 41.9±12.6 | 45.5±13.1 | +3.7±12.4 | 2.3 | 5.0 | 0.000\* |
| **LPA (min/d)** | 159.9±22.2 | 156.7±21.3 | -3.2±21.1 | -5.5 | -1.0 | 0.005\* |
| **TPA (%WT)** | 35.5±5.0 | 35.6±5.1 | +0.1±4.5 | -0.4 | 0.6 | 0.586 |
| **MVPA (%WT)** | 13.3±2.9 | 13.9±3.0 | +0.58±2.7 | 0.3 | 0.9 | 0.003\* |
| **VPA (%WT)** | 5.8±1.7 | 6.3±1.8 | +0.51±1.7 | 0.3 | 0.7 | 0.000\* |
| **LPA (%WT)** | 22.1±2.9 | 21.7±2.9 | -0.44±2.6 | -0.7 | 0.2 | 0.003\* |

Note: p-values represent the results of paired t-tests conducted for each variable between year 1 and year 2; \* denotes significance at *p*<0.05

**Figure 2.** Sex differences in MVPA at year 1 and year 2

**Figure 3.** Sex differences in VPA at year 1 and year 2

# 3.4 Primary Objective- Tracking

The primary objective was to assess fitness and PA tracking from year 1 to year 2. The strength of STMP, TM time, and HRR tracking was strong according to the Spearman correlations (*r*= 0.517-0.886). PP was substantial (κ= 0.61), MP (κ= 0.56) and TM time (κ= 0.56) were moderate and HRR was fair (κ= 0.23), based on Kappa statistics. Table 7 indicates whether participants maintained their tertile group (labelled as *‘same’*), increased to a higher tertile (labelled as *‘higher’*) or decreased to a lower tertile (labelled as *‘lower’*). 73.8% of PP values, 70.8% of MP values and 70.8% of TM time values maintained their same tertile group from year 1 to year 2, while only 48.6% of HRR values remained in the same group.

**Table 6. Tracking Fitness from Year 1 to Year 2**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **N** | **Spearman** | **Sig.** | **Strength** |  | **Kappa** | **Sig.** | **Strength** |
| **PP** | 378 | 0.89 | <0.001\* | Strong |  | 0.61 | <0.001\* | Substantial |
| **MP** | 343 | 0.86 | <0.001\* | Strong |  | 0.56 | <0.001\* | Moderate |
| **TM Time** | 366 | 0.82 | <0.001\* | Strong |  | 0.56 | <0.001\* | Moderate |
| **HRR** | 358 | 0.52 | <0.001\* | Moderate |  | 0.23 | <0.001\* | Fair |

Note: \*denotes significance at the *p*<0.05 level

**Table 7. Kappa Statistics Tertile Agreement for Fitness Measures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Same** | **Higher** | **Lower** | **Total** |
| **PP** | 279 | 57 | 42 | 378 |
| **MP** | 243 | 67 | 33 | 343 |
| **TM Time** | 259 | 55 | 52 | 366 |
| **HRR** | 174 | 99 | 85 | 358 |

Note: \*denotes significance at the *p*<0.05 level

Both MVPA and VPA displayed strong tracking based on Spearman correlations (MVPA: r=0.586; VPA: r=0.569) and fair tracking as per Kappa statistics (MVPA: κ =0.281; VPA: κ =0.375). 52.1% and 58.3% of MVPA (%WT) and VPA (%WT) values, respectively, maintained their tertile rankings from year 1 to year 2.

**Table 8. Tracking PA from Year 1 to Year 2**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **N** | **Spearman** | **Sig.** | **Strength** |  | **Kappa** | **Sig.** | **Strength** |
| **MVPA (%WT)** | 336 | 0.59 | <0.001\* | Moderate |  | 0.28 | <0.001\* | Fair |
| **VPA (%WT)** | 336 | 0.57 | <0.001\* | Moderate |  | 0.38 | <0.001\* | Fair |

Note: \*denotes significance at the *p*<0.05 level

**Table 9. Kappa Statistics Tertile Agreement for PA Measures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Same** | **Higher** | **Lower** | **Total** |
| **% MVPA** | 175 | 84 | 77 | 336 |
| **% VPA** | 196 | 73 | 67 | 336 |

Note: \*denotes significance at the *p*<0.05 level

# 3.5 Secondary Objective

The secondary objective was to determine the relationship between fitness and PA over a one year-period. The first part of this analysis was to determine the bivariate correlations between year 1 fitness and PA and, between year 2 fitness and PA. These results are displayed in Tables 10 and 11. At year 1, MVPA was correlated with PP, MP and 60-sec HRR, while VPA was correlated with all fitness measures. At year 2, MVPA and VPA were correlated with all fitness measures. The strongest correlations at year 1 and year 2 were between MVPA and 60-second HRR (Y1: r=0.232, Y2: r=0.188).

**Table 10. Bivariate Correlations Between Year 1 Physical Activity and Fitness**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **PP** | **MP** | **HRR60** | **TM Time** |
| **MVPA (%WT)** | Correlation | .138\* | .126\* | 0.232\* | 0.101 |
| *p*-value | 0.01 | 0.023 | 0.000 | 0.063 |
| **VPA (%WT)** | Correlation | .183\* | .180\* | 0.224\* | .131\* |
| *p*-value | 0.001 | 0.001 | 0.000 | 0.016 |

\* denotes significance at p<0.05.

**Table 11. Bivariate Correlations Between Year 2 Physical Activity and Fitness**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **PP** | **MP** | **HRR60** | **TM Time** |
| **MVPA (%WT)** | Correlation | .120\* | .112\* | 0.188\* | 0.120\* |
| *p*-value | 0.022 | 0.034 | 0.000 | 0.023 |
| **VPA (%WT)** | Correlation | .134\* | .127\* | 0.159\* | 0.145\* |
| *p*-value | 0.01 | 0.016 | 0.003 | 0.006 |

\* denotes significance at p<0.05.

These correlations confirm that there is a relationship between PA and fitness; however, the novelty of this project is to determine these relationships over a one-year period, rather than simply as two separate and unrelated time points. Performance on fitness tests, represented as PP, MP and TM time increased from year 1 to year 2 (Table 4). The PA measures and HRR were more variable (Tables 4 and 5).

**Figure 4.** **Individual ΔMVPA for Female Preschoolers**

**Figure 5. Individual ΔVPA for Female Preschoolers**



**Figure 6. Individual ΔMVPA for Male Preschoolers**



**Figure 7. Individual ΔVPA for Male preschoolers**

Boys were more active than girls at year 1 (*p*=0.000) and year 2 (*p*=0.000) so subsequent results will be displayed separately for girls and boys. The groups for increasing, maintaining or decreasing PA were determined by the test-retest reliability co-efficient of 0.8 for accelerometers in preschool children (Penpraze et al., 2006). For example, if year 2 MVPA was within the range classified as reliable, it was considered maintaining MVPA. If below or above this range, the participant either decreased or increases MVPA, respectively. For ΔMVPA (Δ=Y2 MVPA- Y1 MVPA), 5.0% (*n*=8) of girls decreased, 69.2% (*n*=110) maintained and 25.8% (*n*=41) increased their MVPA. For ΔVPA (Δ=Y2 VPA- Y1 VPA), 10.7% (*n*=17) of girls decreased, 52.2% (*n*=83) maintained and 37.1% (*n*=59) increased their VPA. In boys, 9.0% (*n*=16) decreased, 66.1% (*n*=117) maintained and 24.9% (*n*=44) increased their MVPA. Among the boys, 11.9% (*n*=21) decreased, 52.5% (*n*=93) maintained and 35.6% (*n*=63) increased their VPA.

Once changes in MVPA and VPA were described, the characteristics of the participants who decreased, maintained or increased their PA participation were investigated. No differences in fitness (PP, MP, TM Time, or 60-sec HRR) were observed between those girls who increased, maintained or decreased MVPA or VPA. Girls who maintained their MVPA had higher weight %iles and %BF than girls who increased their MVPA, at both year 1 and year 2. No differences between MVPA or VPA groups in age or participant characteristics were observed in boys. The boys who increased VPA from year 1 to year 2 saw a greater increase in 60-sec HRR than those who maintained VPA (see Appendix F for more detailed results).

For simplicity in displaying results, the participants who decreased PA (either MVPA or VPA as %WT) will be labelled as group 1, those who maintained will be labeled as group 2 and those who increased will be labeled as group 3 in Tables 12 and 13. Boys who decreased or maintained their MVPA had higher year 1 MVPA than those who increased MVPA (Table 12, *p*=0.000=0.004). In girls, year 1 MVPA was higher in those who decreased activity versus those who increased activity (Table 12, *p*=0.002) and higher in those who maintained versus those who increased activity (Table 12, *p*=0.001). At year 2, those participants who engaged in the most MVPA at year 1 now engaged in the least; and this held true for boys and girls (Table 12, p=0.000-0.011).

Year 1 VPA was significantly higher in the girls who maintained their VPA participation versus those who increased VPA participation (Table 12, *p*=0.000). Boys who decreased or maintained their VPA had lower VPA (%WT) at year 1 (Table 13, *p=*0.000) that those who increased VPA. Year 2 VPA was lowest in the boys and girls who decreased VPA, compared to those who maintained or increased VPA (Table 13, *p=*0.000-0.028).

**Table 12. PA Differences between ΔMVPA Groups**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Girls | | Boys | |
| Group Differences | *p*-value | Group Differences | *p*-value |
| **Y1 MVPA (%WT)** |  |  | 1>2 | 0.004\* |
| 1>3 | 0.002\* | 1>3 | 0.000\* |
| 2>3 | 0.001\* | 2>3 | 0.000\* |
| **Y2 MVPA (%WT)** | 1<2 | 0.011\* | 1<2 | 0.001\* |
| 1<3 | 0.000\* | 1<2 | 0.000\* |
| 2<3 | 0.000\* | 2<3 | 0.010\* |
| **Δ MVPA (%WT)** | 1<2 | 0.000\* | 1<2 | 0.000\* |
| 1<3 | 0.000\* | 1<3 | 0.000\* |
| 2<3 | 0.000\* | 2<3 | 0.000\* |

NOTE: 1: decreased, 2: maintained, 3: increased.

**Table 13. PA Differences between ΔVPA Groups**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Girls | | Boys | |
| Group Differences | *p*-value | Group Differences | *p*-value |
| **Y1 VPA (%WT)** | 1>2 | 1.000 | 1>2 | 0.023\* |
| 1>3 | 0.126 | 1>3 | 0.000\* |
| 2>3 | 0.000\* | 2>3 | 0.000\* |
| **Y2 VPA (%WT)** | 1<2 | 0.000\* | 1<2 | 0.001\* |
| 1<3 | 0.000\* | 1<2 | 0.000\* |
| 2<3 | 0.001\* | 2<3 | 0.028\* |
| **Δ VPA (%WT)** | 1<2 | 0.000\* | 1<2 | 0.000\* |
| 1<3 | 0.000\* | 1<3 | 0.000\* |
| 2<3 | 0.000\* | 2<3 | 0.000\* |

NOTE: 1: decreased, 2: maintained, 3: increased.

# 3.6 Exploratory Analysis

The exploratory analysis section examined how frequency and duration of MVPA bouts changed from year 1 to year 2. Paired t-tests revealed that only bout duration *t*(334)=-6.498, *p*=0.001, and not bout frequency, represented as bouts per day, *t*(335)=-0.896, *p*=0.371 and bouts per hour of WT *t(*335)=1.063, *p*=0.289, was significantly changed at year 2. Bout duration increased 0.24 seconds per bout for boys and girls. When analyzed separately, girls increased their bout duration by 0.24±0.66 seconds and the boys increased their bout duration by 0.23 ±0.68 seconds per bout. Sex differences were not evident in Δ bout duration (*p*=0.944).

**TABLE 14. Year 1 and Year 2 Bouts of MVPA**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variable**  **(n=336)** | **Year 1** | **Year 2** | **Change (Y2-Y1)** | **95% Confidence Interval of the Difference** | | ***t*-test**  ***p*-value** |
| **Lower** | **Upper** |
| **Bouts/ Day** | 841.5±147.4 | 848.6±149.5 | 7.1± 145.7 | -8.5 | 22.8 | 0.371 |
| **Bouts/Hour** | 69.9±11.8 | 70.6±12.3 | 0.7±11.1 | -0.5 | 1.8 | 0.289 |
| **Bout Dur. (sec)** | 6.8±0.7 | 7.0±0.7 | 0.2±0.7 | 0.2 | 0.3 | 0.000\* |

Note: *\** denotes significance at the *p*<0.05 level.





**Figure 8. Frequency distribution of ΔMVPA bouts per day**

**Figure 9.** **Frequency distribution of ΔMVPA bouts per hour of WT**



**Figure 10. Frequency distribution of ΔMVPA**

**bout duration per day**

# CHAPTER 4: DISCUSSION

This thesis serves to fill a significant knowledge gap about the relationship between fitness and PA over-time in healthy preschoolers. The positive association between PA and fitness is well documented in older children (Strong et al., 2005) and adults (Warburton et al., 2006), but much less is known about the association in young children. By understanding these relationships and how they change over time, we can establish whether healthy behaviours are well rooted in the early years or if they are still susceptive to change in the years to come. The first step in filling this research gap was to determine how each variable changed and tracked over time- a duration of approximately 12 months in this study. The relationships between fitness and PA at year 1 and year 2 were then analyzed separately for each year. Last, the characteristics of participants who increased, maintained or decreased PA from year 1 to year 2 were examined. In order to investigate these relationships, an investigation of the changes and tracking of the individual variables is necessary.

# 4.1 Characteristics of Preschoolers

The participants in this study were 3-to-5 years olds at year 1, with an average age of 4.5 years. While the preschoolers were significantly taller and heavier at year 2, BMI remained at the 52nd %ile. At year 1, 15.4% of preschoolers were overweight or obese and 17.5% were overweight or obese at year 2. Our sample was comparable to the 3-to-5 year olds in the most recent Canadian Health Measures Survey sample, in which 16.4% of participants were overweight and obese (R. C. Colley et al., 2013), and to a sample of 3-to-6 year olds from New Zealand whose prevalence of overweight and obesity was 16.4% (Taylor et al., 2013). By knowing that the body size of the participants in our study is similar to those in other studies, our results can be transferable and relevant to a wider population of preschoolers.

# 4.2 Physical Activity of Preschoolers

Changes in PA between year 1 and year 2 were variable, depending on the PA intensity variable of interest. On average, TPA (as minutes or as %WT) was not changed at year 2; however, some participants decreased TPA by 100 minutes while other increased by 100 minutes. Engagement in LPA (as minutes or as %WT) decreased from year 1 to year 2, and this was compensated by an increase in VPA, and consequently MVPA. Other PA research conducted in preschoolers observed similar results and trends. In a cross-sectional study, 5 year olds engaged in less TPA and more MVPA than 3-to-4 year olds even though this study reported that children engaged in approximately 350 minutes of TPA (R. C. Colley et al., 2013) versus the 250 minutes reported in our study. A longitudinal study assessed PA in children who were 3 years old at baseline and 5 years old at follow-up. An increase in MVPA was observed, from 2% of monitoring time at baseline to 4% at follow-up (J. J. Reilly et al., 2004). Other researchers reported that 3-to-4 year olds spent 2% of WT in MVPA, and this increased to 4% of WT 24-months later (Kelly et al., 2007). In our study, participants engaged in MVPA for 13% of WT at year 1 and 14% at year 2, suggesting much higher PA participation compared to the other samples. The absolute changes in PA are important to see trends in change, but the changes only provide information about how the group mean changes. Within our sample, there was considerable variability in PA participation at year 1 and year 2. As a result, the changes in PA were also variable and this can be better understood if longitudinal data is analyzed with tracking statistics.

## 4.2.1 Tracking of Physical Activity in Preschoolers

Our sample experienced an overall increase in MVPA as children grew older, but the changes were variable between participants. Tracking of PA variables was carried out and the Spearman tracking coefficients were moderate (Malina, 1996)at 0.59 and 0.57 for MVPA (%WT) and VPA (%WT), respectively. The Kappa statistics were not as strong: 0.28 for MVPA and 0.38 for VPA (Munoz & Bangdiwala, 1997). For MVPA and VPA, 50-60% of children remained in the same tertile, 20-25% moved to a higher tertile and 20-25% moved to a lower tertile. Tracking coefficients reported in the literature have been variable and, as a result our findings are only consistent with some previous work. A Spearman tracking coefficient of 0.40 for TPA was observed in preschoolers whose PA assessments were one-year apart (Jackson et al., 2003), while Kelly at al. reported a 24-month Spearman tracking coefficient of 0.37 and a Kappa statistic of 0.01, suggesting much weaker tracking. Kelly et al.’s sample was only 42 children, which likely contributes to the very low Kappa statistics because the tertile groups were much smaller than our PA sample of over 300 preschoolers. The tracking statistics observed in preschoolers imply that engagement in PA is variable over time, and that year 1 PA was not a strong predictor of year 2 PA, suggesting that PA behaviours may not be well established in the early years and still susceptible to changes later in life.

# 4.3 Fitness of Preschoolers

Performance on fitness tests improves with increasing age in the early years, and this was evident in both our results and in the related literature. It is hypothesized that the differences between STMP in children and adolescents were based on neuromuscular factors, hormonal factors and improved motor coordination (Van Praagh & Doré, 2002). In our sample, both PP and MP increased approximately 30% from year 1 to year 2. To our knowledge, only two studies, both from our lab, have published PP and MP data that were collected from young children (Gabel et al., 2011; Nguyen et al., 2011). In 3-to-5 year olds, Nguyen et al. observed a higher PP (103 W vs. 94 W) and a comparable MP (82 W vs. 84 W) to our sample. Children who were 5-years old produced higher PP and MP than the 3 and 4 year olds (Nguyen et al., 2011). Field-based testing confirms that performance on STMP tests, such as the 20 or 25m dash, improves with increasing age in the early years (Gabel et al., 2011; Parizkova, 1996), and this trend has been seen in performance on aerobic fitness tests as well.

TM time was approximately 25% longer at year 2 than at year 1. HRR was unchanged at year 2; however, HRR is not as strong of a performance measure as the other fitness variables. HRR is an indicator of how quickly someone can recover from exercise, and as such, is a surrogate of aerobic fitness. Theoretically, the preschoolers could be performing better on fitness tests as a result of changes in growth, coordination and motivation but their aerobic fitness, as indicated by HRR, remained stable. In the literature, children have achieved similar VO2 max values as adults on maximal fitness tests, but the children displayed poorer performance than the adults, suggesting factors other than fitness influenced their performance, such as coordination or body size (Simons-Morton et al., 1988). Cumming et al. observed that time to exhaustion on the Bruce Protocol in 4-to-5 year olds was 9.97 minutes and 11.47 minutes in 6-to-7 year olds (Gumming et al., 1978). In a more recent study in the Netherlands, 4-to-6 year olds completed the Bruce Protocol and percentile scores were published. The 4.5 year olds at the 50th percentile, theoretically comparable to our year 1 sample, lasted 9.1-9.9 minutes (separate analyses for boys and girls). This falls in line with our observation of an average time of 9.5 minutes at year 1. HRR in our group was stable from year 1 to year 2 at 65 bpm, comparable to 4-to-6 year olds who achieved values from 59-69 bpm, following the Bruce Protocol (Mimura & Maeda, 1989). At 2 minutes following the Bruce Protocol, HRR in 4-to-6 year olds has been reported as 72-79 bpm (Gumming et al., 1978), and the maximum HR was similar to our study. These HRR values are likely higher because they were reported after 2 minutes of recovery, rather than the 1-minute HRR reported in our results. Aerobic fitness tests have been performed more commonly in preschoolers than STMP assessments, but there is a lack of longitudinal data so changes in aerobic fitness and tracking have scarcely been reported.

## 4.3.1 Tracking of Fitness in Preschoolers

Fitness measures have demonstrated better tracking than PA measures, based on both Spearman and Kappa statistics. In our study, both PP and MP exhibited strong tracking based on Spearman correlation coefficients, while Kappa statistics showed substantial PP and moderate MP tracking. A previous study from our lab observed strong Spearman tracking for both PP/kg and MP/kg and Kappa statistics showed moderate PP/kg and almost perfect MP/kg tracking (Gabel et al., 2011). This particular study only observed tracking in 17 participants, so Kappa statistics should be interpreted with care because each tertile group was very small. Spearman tracking correlations for performance on a 1-mile walk/run test, a measure of aerobic fitness, were investigated in boys and girls who were in kindergarten at baseline and grade 1 at follow-up. Tracking was moderate, r=0.50 and r=0.53 for boys and girls, respectively (McMillan & Erdmann, 2010). In our study, TM time exhibited strong and HRR displayed moderate tracking, based on Spearman. For Kappa statistics, 71% of preschoolers remained the same tertile for TM time, 15% moved higher and 14% moved to a lower tertile. HRR was not as stable as only 49% remained in the same tertile, 28% moved higher and 24% moved to a lower tertile. TM time likely displayed better tracking than HRR because TM times, for the most part, increased form year 1 to year 2 while changes in HRR were more variable between participants.

# 4.4 Differences in the Tracking of PA and Fitness in Preschoolers

The differences between PA and fitness can be interpreted partly from their definitions. PA is any bodily movement produced by the skeletal muscles that results in a substantial increase in energy expenditure, while fitness refers to the characteristics that influence one’s ability to carry out PA (L. Armstrong, 2006). In other words, PA can be considered the behaviour of participating in movement, while fitness is how well one can perform such movements. Therefore, it is not surprising that PA is more variable than fitness. Performance on fitness tests also has higher reliability (r=0.91-0.94) (Gumming et al., 1978; Nguyen et al., 2011) than PA measures (r=0.80-0.84) (Penpraze et al., 2006), confirming the higher stability of fitness measures.

Fitness is more stable than PA, but both variables have their own unique set of correlates, determinants and predictors. In our sample, performance on fitness tests was better in boys than girls and increased with increasing age. Engagement in PA was also higher in boys than girls. The strongest reported correlates of increased PA in children were decreased perceived barriers, increased intentions and preferences for PA, previous involvement in PA, high parental PA, greater access to facilities and programs and more time spent outdoors (Sallis, Prochaska, & Taylor, 2000). Genetics can explain 40-60% of the variation in aerobic or anaerobic power (Bouchard & Malina, 1983). In addition, muscle fibres for anaerobic exercise are determined in early development and remain relatively fixed for a lifetime so some children may be genetically predisposed to success on the STMP test. The same is true for aerobic performance (Powers & Howley, 2007). Parental PA has also been reported as a predictor of child’s aerobic fitness (Voss & Sandercock, 2012). While these factors help to explain the tracking differences in PA and fitness, the two variables are both still involved in movement and associated with one another.

# 4.5 Relationship between Fitness and PA in Preschoolers

Both PA and fitness are related to engaging in movement, but it is not clear if PA predicts fitness or vice versa. The correlations between fitness measures and PA variables were first examined separately for year 1 and year 2. The correlation coefficients between STMP (PP and MP) and PA (MVPA and VPA, as %WT) ranged from 0.13 to 0.18 at year 1 and were slightly lower at year 2, ranging from 0.11 to 0.13. The correlation coefficients between HRR and PA also decreased from 0.22-0.24 at year 1 to 0.16-0.19 at year 2. The correlation coefficients between TM time and PA improved from 0.10-0.13 at year 1 to 0.12-0.15 at year 2. These correlations were lower than what has been reported in the literature. In 6-to-7 year old girls, the correlation between MPA and VO2PEAK was 0.14. In boys from the same study, correlation coefficients were similar: r=0.18, 0.17 and 0.12 for correlations between and VO2PEAK and MPA, MVPA and VPA, respectively (Dencker et al., 2006). A correlation coefficient of 0.37 was reported in 4-to-6 year olds for the relationship between MVPA, as measured with accelerometers, and aerobic fitness, as assed with the 20-m shuttle run (Bürgi et al., 2011). Research about STMP and PA in preschoolers is extremely rare and studying this topic in an observational study is extremely novel. The relationship between PA and fitness is complex because each variable is influenced by so many other factors and it is not possible to control all of these factors in an observational study. PA interventions that were conducted in preschool and kindergarten classes have seen positive effects on fitness.

Interventions that increased the dose of PA in preschools and kindergarten classes have reported favourable changes in fitness. The interventions did not assess STMP, but a PA program in Switzerland had participants complete an obstacle course. Performance on the obstacle course was considered an assessment of agility and took less than 20 seconds to complete. It involved running, jumping and climbing-- tasks that likely required STMP for success. At baseline, those children who engaged in more MPA or VPA performed better on the obstacle course (Bürgi et al., 2011). After 10 months of additional PA programming, the children in the intervention group improved performance on an obstacle course, compared to the intervention group (Puder et al., 2011). Kindergarten students in a 10-month PA intervention in Israel experienced positive changes in aerobic fitness, as measured by the 10-m shuttle run, opposed to students not enrolled in the intervention (Nemet et al., 2011). The most promising work that has investigated this relationship has been interventions that increased PA volume and observed positive fitness changes.

Studying the relationship between PA and fitness over time is more meaningful than a single “snapshot”, especially in the early years. The correlates of PA, such as environment, are constantly changing and influencing these traits. The two intervention models, one in Switzerland and one in Israel, have shown that comprehensive, holistic health promotion interventions that increased the volume of physical education or PA in preschool and kindergarten classes induced positive fitness benefits in young children. These results prompted us to analyze the relationship between PA and fitness over-time by studying the characteristics of participants based on whether they decreased, maintained or improved PA participation.

## 4.5.1 Sex Differences in the Relationship between Fitness and PA in Preschoolers

The relationships between PA and fitness were analyzed by investigating the characteristics, including fitness measures, of participants who increased, maintained or decreased engagement in PA from year 1 to year 2. Sex differences were observed in PA and some fitness measures, so analyses were conducted separately for boys and girls (see Appendix D). For the most part, the participants who decreased their MVPA or VPA from year 1 to year 2 had the highest MVPA or VPA at year 1 and the lowest at year 2. The opposite was true for the participants who increased their MVPA or VPA; they had the lowest MVPA or VPA at year 1 and the highest at year 2. Because PA participation is variable over time, PA promotion programs or interventions should target all children to help develop healthy PA habits. The only differences observed between groups in girls were higher year 1 and year 2 weight percentiles and %BF in girls who maintained MVPA versus those who increased MVPA. These results are similar to previous literature that found MVPA and VPA were associated with decreased %BF in preschoolers (Collings et al., 2013). The boys who maintained their VPA from year 1 to year 2 displayed smaller changes in HRR than those who increased VPA, corresponding to a +5bpm change in the group who increased VPA. This suggests that boys who increased VPA volume from year 1 to year 2 experienced positive health benefits because a higher HRR is indicative of higher aerobic fitness. In our study, HRR referred to how quickly HR slowed down after exercise. If a child can recover quickly from high intensity exercise, they may be able to engage in high-intensity activity again, with little rest in between bouts. Or, perhaps the child can sustain VPA for longer without fatiguing.

# 4.6 Exploratory Analysis

The exploratory analysis portion of this thesis examined if, and how, the frequency and duration of MVPA bouts changed from year 1 to year 2. The sporadic nature of play in young children (Bailey et al., 1995) prompted this analysis because the investigation of bouts is becoming an additional avenue to study PA, as measured by accelerometry. It has been previously reported that 95% of bouts of MVPA in preschoolers are ≤ 15 seconds in duration (Obeid et al., 2011). To capture bouts of MVPA, accelerometer data is best recorded in short epochs because longer bouts may misclassify PA. For example, if a 1-minute epoch is used and a preschoolers engages in 10 seconds of MVPA followed by 50 seconds of sedentary behaviour, that short MVPA bout will likely be “washed out”, and the PA analysis would not credit the child for his or her participation in that short bout of MVPA. In our sample, the frequency of bouts of PA did not change from year 1 to year 2, but the duration of bouts increased approximately 0.25 seconds, suggesting the children are better at sustaining high-intensity activity as they age, however it is unclear if a 0.25 second change is biologically meaningful. To our knowledge, this is the first longitudinal analysis of MVPA bouts. In the future, this method of assessment will likely become more popular to determine how preschoolers are accumulating PA in the day. Understanding the volume and these patterns of activity are necessary to design the best suited health promotion programs and interventions.

**4.7 Novelty of Findings**

The goal of this thesis was to investigate how the relationship between PA and fitness changed over a one-year period in preschoolers. These analyses involved first understanding how the individual variables tracked from year 1 to year 2 and how they related to each other at year 1 and then at year 2. This thesis established several novel findings:

1. For the first time, one-year tracking of aerobic fitness was investigated in Canadian preschoolers. The Bruce Protocol has been previously used to assess aerobic fitness in young children, but only one time-point was used. We observed that TM times were 20% longer at year 2, versus year 1. We assessed the tracking of TM time and HRR. TM time exhibited strong tracking based on Spearman correlations and moderate tracking based on Kappa statistics. HRR displayed moderate Spearman correlations and fair tracking based on Kappa statistics.
2. One-year tracking of STMP was investigated in a large population. The 15-month tracking of STMP was previously assessed in a sample of 17 preschoolers in our laboratory. This thesis expands the knowledge of this topic. Both PP and MP exhibited strong Spearman tracking, while PP exhibited substantial and MP exhibited moderate tracking, based on Kappa statistics.
3. For the first time, one-year tracking of MVPA and VPA was assessed with both Spearman correlations and Kappa statistics. Tracking of MVPA and VPA in the early years has not previously been assessed over one-year, but only over 15 or 24 months. Children grow so rapidly that frequent assessments of PA are necessary to decipher when changes in PA participation occur.
4. The relationship between objectively measured PA and lab-based fitness tests over a one-year period was studied for the first time in preschoolers. To our knowledge, no observational studies have investigated this relationship over more than one time-period. Girls who maintained MVPA had higher weight percentiles and %BF than those girls who increased MVPA. We observed that changes in MVPA were not associated with changes in fitness, but that changes in VPA were associated with changes in HRR in boys. Fitness differences between groups may not have been seen because changes in MVPA or VPA were so variable and may not have changed enough to elicit changes in performance on fitness tests. Additional traits and variables are also likely influencing the relationship. In addition, the participants who decreased their MVPA or VPA from year 1 to year 2 showed the highest PA at year 1, so perhaps they were still displaying the health benefits of this elevated PA.

# Limitations

This thesis investigated novel relationships between PA and fitness over a one-year period in the early years. With only two time-points, longitudinal analyses were not possible and tracking statistics were used. More time points would also be helpful to infer further causality in the relationships. In addition, success of the testing sessions was often influenced by the cooperation, motivation and attention of the young participants. The downside of children not cooperating was missing or invalid data. The assessors worked hard to develop rapport with participants and were encouraging to all children during the testing sessions.

The Bruce Protocol has been used to assess aerobic fitness in preschooler since the 1970s, but the reliability of TM test has not been determined in preschoolers, only with children as young as 7 years old (Gumming et al., 1978). HRR is a reliable measure of aerobic fitness in preschoolers (Nguyen et al., 2011). The STMP test on the cycle ergometer was, anecdotally, very popular among the young participants; however, some young children did not yet have the coordination to pedal the bicycle for the 10-seconds of the WaNT. Further investigation of how to incorporate an additional measure of STMP, such as running dash or long jump, could be valuable.

Accelerometers are a widely used tool in the assessment of PA in children. PA assessments were only completed once a year so the results may have been related to the season of data collection. Of the year 2 visits, 97% occurred within 12±1 months of the year 1 visits, so it can be assumed that at least 97% of the assessments took place in the same season at year 1 and year 2. The newer accelerometers, the GT3X+ models, are water resistant and can be used when children play in a sprinkler or splash pad (Actigraph, 2013). Unfortunately, these devices cannot be worn while swimming so any activity accumulated in a pool would have been missed. Lastly, we used accelerometer cut-points that were validated, but only in 3-to-5 year olds (Pate et al., 2006). At year 2, a third of the sample were 6 years old. There is no set of PA cut-points that have been validated in children 3-to-6 years old. The Pate cut-points, validated in 3-to-5 year olds classify MPA as 420-1320 counts/15 sec (Pate et al., 2006) while the Evenson cut-points, validated in 6-7 year olds, classify MPA as 574-1002 counts/15 sec (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008). For VPA, the Pate cut-points use a threshold of >1320 counts/15 sec (Pate et al., 2006) and the Evenson cut-points use >1003 counts/15 sec (Evenson et al., 2008). Both sets of cut-points correspond to a certain VO2, but the VO2 thresholds used by Evenson were slightly higher for MPA and lower for VPA than those used by Pate. As such, it would be inappropriate to start using a different set of cut-points once children turn 6 and compare this PA to data collected when they were 3-to-5 years old. This topic will require further investigation more for future analyses of the HOPP study PA data.

# 4.9 Future Directions

This study provided novel PA and fitness data that contributes to understanding these variables and their relationship in the early years. This area of research is still emerging and further contributions are necessary. Young children are growing rapidly and more frequent assessments may be more appropriate to capture the effects of growth and body size on performance of fitness tests. For example, when results of performance on the Bruce Protocol in 4-to-5 year olds were stratified by age where each category was 0.25 years and girls experienced an increase of approximately 6 seconds each quarter year and boys experienced an increase of approximately 25 seconds per quarter year, from age 4.0 to 5.75 (van der Cammen-van, Monique HM et al., 2010). As mentioned, the investigation of PA cut-points will be necessary to further analyze data across accelerometer calibration age groups. The supplemental analyses of this thesis looked at the duration and frequency of bouts of MVPA, but only as averages. Organizing the participants into groups, such as tertiles, and investigating the relationships between bouts of MVPA and fitness may yield some very interesting observations. Based on the relationships observed between VPA and fitness measures, analysis of bouts of VPA would also be a valuable addition to the study of preschool PA.

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**Appendix A: Participant Consent Form**

Macintosh HD:Users:hilarycaldwell:Desktop:Untitled Extract Pages.pdf

Macintosh HD:Users:hilarycaldwell:Desktop:Untitled Extract Pages.pdf

Macintosh HD:Users:hilarycaldwell:Desktop:Untitled Extract Pages.pdf

Macintosh HD:Users:hilarycaldwell:Desktop:Untitled Extract Pages.pdf

**Appendix B: Medical Questionnaire**

Macintosh HD:Users:hilarycaldwell:Desktop:HOPP-MEDICAL QUESTIONNAIRE-3.pdf

**Appendix C: Physical Activity Log**



**Appendix D:**

**Sex Differences in Participant Characteristics, Fitness and Physical Activity**

**Table 15.** **Sex Differences in Year 1 Participant Characteristics**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | ***t*-test**  ***p*-value** |
| **Lower** | **Upper** |
| **Age (yrs)** | 4.5±0.9 | 4.5±0.9 | -0.2 | 0.2 | 0.890 |
| **Height (m)** | 105.8±7.9 | 107.2±7.6 | -2.9 | 0.1 | 0.064 |
| **Weight (kg)** | 17.6±3.1 | 18.2±3.2 | -1.2 | -0.01 | 0.046\* |
| **BMI (m/kg2)** | 15.6±1.3 | 15.8±1.3 | -0.4 | 0.1 | 0.346 |
| **Height %ile** | 60.9±26.6 | 62.6±27.5 | -7.0 | 3.5 | 0.507 |
| **Weight %ile** | 56.4±25.9 | 58.3±29.0 | -7.2 | 3.4 | 0.476 |
| **BMI %ile** | 54.2±28.0 | 62.6±27.5 | -1.7 | 9.3 | 0.170 |
| **%BF** | 26.0±3.7 | 20.4±3.5 | 4.9 | 6.3 | 0.000\* |
| **CDC Cut-Offs**  Normal Weight  Overweight  Obese  Underweight | 80.6%  14.1%  1.9%  3.4% | 79.3%  7.2%  7.7%  5.8% |  |  | 0.122 |

Note: \* denotes significance at *p*<0.05

**Table 16.** **Sex Differences in Year 2 Participant Characteristics**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | | ***t-*test**  ***p*-value** |
| **Lower** | | **Upper** |
| **Age (yrs)** | 5.5±0.9 | 5.5±0.9 | -0.2 | 0.2 | | 0.922 |
| **Height (m)** | 112.8±7.9 | 114.2±7.6 | -2.9 | 0.1 | | 0.072 |
| **Weight (kg)** | 20.1±3.8 | 20.5±3.8 | -1.2 | 0.3 | | 0.235 |
| **BMI (m/kg2)** | 15.6±1.4 | 15.6±1.4 | -0.2 | 0.3 | | 0.718 |
| **Height %ile** | 59.6±26.9 | 62.2±27.8 | -7.7 | 2.8 | | 0.344 |
| **Weight %ile** | 56.0±25.8 | 55.8±28.7 | -5.1 | 5.6 | | 0.921 |
| **BMI %ile** | 54.3±28.1 | 48.9±27.8 | -0.1 | 10.9 | | 0.055 |
| **%BF** | 23.8±3.9 | 18.5±3.8 | 4.6 | 6.1 | | 0.000\* |
| **CDC Cut-Offs**  Normal Weight  Overweight  Obese  Underweight | 75.9%  1.6%  2.0%  3.5% | 80.6%  8.5%  6.0%  5.0% |  |  | | 0.774 |

Note: \* denotes significance at *p*<0.05

**Table 17.** Sex Differences in Y1 Fitness Measures

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | ***t-*test**  ***p*-value** |
| **Lower** | **Upper** |
| **PP (W)** | 89.2±37.0 | 98.7±37.8 | -16.9 | -2.1 | 0.013\* |
| **PP/kg (W/kg)** | 4.9±1.4 | 5.2±1.4 | -0.6 | -0.07 | 0.014\* |
| **PP/kg FFM (W/kg)** | 6.6±1.8 | 6.5±1.7 | -0.3 | 0.4 | 0.224 |
| **MP (W)** | 81.1±30.6 | 86.6±31.6 | -12.0 | 1.00 | 0.097 |
| **MP/kg (W/kg)** | 4.4±1.2 | 4.6±1.3 | -0.4 | 0.1 | 0.183 |
| **MP/kg FFM (W/kg)** | 5.9±1.5 | 5.7±1.5 | -0.1 | 0.5 | 0.827 |
| **TM Time (min)** | 9.0±2.1 | 9.6±2.4 | -1.0 | -0.10 | 0.017\* |
| **Max HR (bpm)** | 197±7 | 196±8 | -0.7 | 2.3 | 0.287 |
| **60-sec HRR (bpm)** | 63±15 | 67±13 | -6.8 | -1.0 | 0.008 |

Note: \* denotes significance at *p*<0.05

**Table 18.** Sex Differences in Year 2 Fitness Measures.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | ***t-*test**  ***p-*value** |
| **Lower** | **Upper** |
| **PP (W)** | 118.6±39.2 | 127.2±37.9 | -15.8 | -1.2 | 0.022\* |
| **PP/kg (W/kg)** | 5.8±1.0 | 6.1±1.0 | -0.5 | -0.1 | 0.002\* |
| **PP/kg FFM (W/kg)** | 7.6±1.3 | 7.5±1.2 | -0.1 | 0.4 | 0.351 |
| **MP (W)** | 103.8±32.0 | 110.3±32.3 | -12.9 | -0.1 | 0047\* |
| **MP/kg (W/kg)** | 5.1±1.0 | 5.3±1.0 | -0.42 | -0.0 | 0.021\* |
| **MP/kg FFM (W/kg)** | 6.7±1.2 | 6.5±1.1 | -0.1 | 0.4 | 0.217\* |
| **TM Time (min)** | 11.4±3.2 | 12.0±2.5 | -0.04 | -0.002 | 0.032\* |
| **Max HR (bpm)** | 200±6 | 199±7.3 | -9.7 | -4.4 | 0.026\* |
| **60-sec HRR (bpm)** | 61±14 | 68±13 | 0.2 | 2.9 | 0.000\* |

Note: \* denotes significance at *p*<0.05

**Table 19.** Sex Differences in Year 1 Physical Activity Measures

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | ***t-*test**  ***p-*value** |
| **Lower** | **Upper** |
| **TPA (min/d)** | 242.3±32.5 | 169.5±37.8 | -34.4 | -19.8 | 0.000\* |
| **MVPA (min/d)** | 88.2±18.2 | 103.97±21.9 | -19.9 | -11.6 | 0.000\* |
| **VPA (min/d)** | 38.2±10.8 | 45.4±13.3 | -9.7 | -4.7 | 0.000\* |
| **LPA (min/d)** | 154.1±20.5 | 165.5±22.3 | -15.8 | -6.7 | 0.000\* |
| **TPA (%WT)** | 33.7±4.5 | 37.2±4.9 | -4.4 | -2.5 | 0.000\* |
| **MVPA (%WT)** | 23.3±2.6 | 14.3±2.9 | -2.6 | -1.5 | 0.000\* |
| **VPA (%WT)** | 5.3±1.5 | 14.3±2.9 | -1.3 | -0.6 | 0.000\* |
| **LPA (%WT)** | 21.4±2.8 | 22.8±2.9 | -2.0 | -0.8 | 0.000\* |
| **Bouts/ Day** | 791.0±130.0 | 889.3±150.0 | -127.3 | -69.4 | 0.000\* |
| **Bouts/ Hour** | 66.0±10.8 | 73.6±11.8 | -9.9 | -5.2 | 0.000\* |
| **Bout Dur. (sec/bout)** | 6.6±0.7 | 7.0±0.7 | -0.5 | -0.2 | 0.000\* |

Note: \* denotes significance at *p*<0.05

**Table 20:** Sex Differences in Year 2 Physical Activity Measures

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Girls** | **Boys** | **95% Confidence Interval of the Difference** | | ***t-*test**  ***p-*value** |
| **Lower** | **Upper** |
| **TPA (min/d)** | 243.6±36.6 | 267.7±34.1 | -31.3 | -16.8 | 0.000\* |
| **MVPA (min/d)** | 91.9±20.7 | 107.0±20.2 | -19.4 | -11.0 | 0.000\* |
| **VPA (min/d)** | 41.6±12.9 | 48.4±12.4 | -9.5 | -4.3 | 0.000\* |
| **LPA (min/d)** | 151.8±21.7 | 160.8±20.5 | -13.3 | -4.7 | 0.000\* |
| **TPA (%WT)** | 34.1±5.1 | 36.9±4.6 | -3.9 | -1.9 | 0.000\* |
| **MVPA (%WT)** | 12.9±2.9 | 14.8±2.7 | -2.5 | -1.3 | 0.000\* |
| **VPA (%WT)** | 5.8±1.8 | 6.7±1.7 | -1.2 | -0.5 | 0.000\* |
| **LPA (%WT)** | 21.2±3.0 | 22.2±2.8 | -1.6 | -0.4 | 0.001\* |
| **Bouts/ Day** | 798.8±144.9 | 891.0±139.1 | -121.4 | -63.1 | 0.000\* |
| **Bouts/ Hour** | 67.1±12.2 | 73.8±11.4 | -9.2 | -4.3 | 0.000\* |
| **Bout Dur. (sec/bout)** | 6.8±0.70 | 7.2±0.70 | -0.01 | 0.001 | 0.000\* |

Note: \* denotes significance at *p*<0.05

**Appendix E: Variable Correlations**

**Table 21.** Year 1 Bivariate Correlations

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Age** | **Avg Ht** | **Avg Wt** | **BMI** | **%BF** | **PP** | **PP/kg** | **MP** | **MP/ kg** | **TM time** | **HRR 60** | **Avg MVPA** | **Avg VPA** | **Per MVPA** | **Per VPA** |
| **Age** | 1 | .820\* | .611\*\* | -.139\* | -.433\* | .715\* | .702\* | .685\* | .637\* | .703\* | .151\* | .137\* | .183\* | 0.058 | .123\* |
| **Avg Ht** |  | 1 | .862\*\* | 0.055 | -.292\* | .842\* | .692\* | .800\* | .590\* | .679\* | 0.099 | .186\* | .228\* | .135\* | .188\*\* |
| **Avg Wt** |  |  | 1 | .546\* | -0.023 | .836\* | .561\* | .768\* | .425\* | .510\* | 0.059 | .172\* | .188\* | .139\* | .163\*\* |
| **BMI** |  |  |  | 1 | .433\* | .266\* | -0.011 | .231\* | -0.086 | -0.093 | -0.051 | 0.041 | 0.01 | 0.056 | 0.022 |
| **%BF** |  |  |  |  | 1 | -.253\* | -.405\* | -.242\* | -.400\* | -.438\* | -.193\* | -.308\* | -.292\* | -.260\* | -.254\*\* |
| **PP** |  |  |  |  |  | 1 | .912\* | .983\* | .823\* | .594\* | .130\* | .184\* | .219\* | .138\* | .183\*\* |
| **PP/kg** |  |  |  |  |  |  | 1 | .928\* | .975\* | .579\* | .174\* | .178\* | .215 | .128\* | .177\*\* |
| **MP** |  |  |  |  |  |  |  | 1 | .896\* | .558\* | .120\* | .161\* | .207\* | .126\* | .180\*\* |
| **MP/kg** |  |  |  |  |  |  |  |  | 1 | .515\* | .166\* | .138\* | .186\* | 0.101 | .159\*\* |
| **TM Time** |  |  |  |  |  |  |  |  |  | 1 | 0.068 | .155\* | .173\* | 0.101 | .131\* |
| **HRR60** |  |  |  |  |  |  |  |  |  |  | 1 | .236\* | .227\* | .232\* | .224\*\* |
| **Avg MVPA** |  |  |  |  |  |  |  |  |  |  |  | 1 | .936\* | .967\* | .908\*\* |
| **Avg VPA** |  |  |  |  |  |  |  |  |  |  |  |  | 1 | .913\* | .981\*\* |
| **Per MVPA** |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 | .935\*\* |
| **Per VPA** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |

**Table 22.** Year 2 Bivariate Correlations

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Age** | **Avg Ht** | **Avg Wt** | **BMI** | **%BF** | **PP** | **PP/kg** | **MP** | **MP/ kg** | **TM time** | **HRR 60** | **Avg MVPA** | **Avg VPA** | **Per MVPA** | **Per VPA** |
| **Age** | 1 | .775\*\* | .566\*\* | -0.008 | -.331\*\* | .641\*\* | .571\*\* | .675\*\* | .569\*\* | .692\*\* | -0.066 | 0.017 | 0.047 | -0.045 | 0 |
| **Avg Ht** |  | 1 | .854\*\* | .208\*\* | -.119\* | .836\*\* | .588\*\* | .822\*\* | .510\*\* | .626\*\* | -.101\* | 0.082 | .127\* | 0.046 | 0.1 |
| **Avg Wt** |  |  | 1 | .678\*\* | .185\*\* | .889\*\* | .493\*\* | .824\*\* | .357\*\* | .389\*\* | -.119\* | 0.072 | 0.095 | 0.058 | 0.085 |
| **BMI** |  |  |  | 1 | .517\*\* | .494\*\* | .123\* | .402\*\* | -0.02 | -.143\*\* | -0.081 | 0.022 | 0.003 | 0.048 | 0.022 |
| **%BF** |  |  |  |  | 1 | -0.016 | -.276\*\* | -0.089 | -.357\*\* | -.429\*\* | -.252\*\* | -.272\*\* | -.239\*\* | -.220\*\* | -.200\*\* |
| **PP** |  |  |  |  |  | 1 | .827\*\* | .980\*\* | .711\*\* | .526\*\* | -0.061 | .134\* | .145\*\* | .120\* | .134\* |
| **PP/kg** |  |  |  |  |  |  | 1 | .879\*\* | .964\*\* | .548\*\* | 0.035 | .170\*\* | .161\*\* | .154\*\* | .148\*\* |
| **MP** |  |  |  |  |  |  |  | 1 | .814\*\* | .568\*\* | -0.041 | .132\* | .141\*\* | .112\* | .127\* |
| **MP/kg** |  |  |  |  |  |  |  |  | 1 | .555\*\* | 0.066 | .152\*\* | .141\*\* | .126\* | .121\* |
| **TM Time** |  |  |  |  |  |  |  |  |  | 1 | -0.002 | .168\*\* | .181\*\* | .120\* | .145\*\* |
| **HRR60** |  |  |  |  |  |  |  |  |  |  | 1 | .218\*\* | .183\*\* | .188\*\* | .159\*\* |
| **Avg MVPA** |  |  |  |  |  |  |  |  |  |  |  | 1 | .938\*\* | .967\*\* | .914\*\* |
| **Avg VPA** |  |  |  |  |  |  |  |  |  |  |  |  | 1 | .910\*\* | .980\*\* |
| **Per MVPA** |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 | .936\*\* |
| **Per VPA** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |

**Appendix F: Characteristics of Participants Stratified by Changes in PA**

**Table 23.** Differences in Participant Characteristics based on **Δ** MVPA Groups

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Girls** | | | **Boys** | | |
|  | Decreased | Maintained | Increased | Decreased | Maintained | Increased |
|  | **YEAR 1** | | | | | |
| **Age** | 4.7±1.1 | 4.6±0.9 | 4.8±1.0 | 4.7±0.9 | 4.6±0.8 | 4.5±0.9 |
| **Height** | 108.4±9.2 | 107.2±7.7 | 106.8±7.2 | 107.7±6.4 | 108.0±7.1 | 107.9±8.6 |
| **Weight** | 18.3±5.6 | 18.2±3.3 | 17.4±2.4 | 17.9±2.4 | 18.5±3.1 | 18.6±3.8 |
| **BMI** | 15.4±1.2 | 15.8±1.35 | 15.3±1.3 | 15.4±0.8 | 15.8±1.3 | 15.8±1.4 |
| **Height %ile** | 63.5±25.1 | 64.3±25.4 | 56.9±25.2 | 56.7±30.6 | 63.8±27.9 | 66.5±27.3 |
| **Weight %ile** | 53.5±25.2 | 60.4±25.3+ | 49.4±23.9# | 52.1±30.2 | 59.6±29.1 | 58.7±30.7 |
| **BMI %ile** | 48.6±29.7 | 57.7±26.5 | 46.8±30.6 | 24.5±6.1 | 29.4±2.7 | 31.5±4.8 |
| **%BF** | 25.0±4.5 | 26.4±3.3+ | 24.4±4.0# | 20.0±3.03 | 20.5±3.6 | 20.2±3.8 |
|  | **YEAR 2** | | | | | |
| **Age** | 20.5±3.8 | 20.8±4.2 | 19.7±2.5 | 5.7±0.8 | 5.6±0.9 | 5.5±0.9 |
| **Height** | 115.7±9.0 | 114.1±9.7 | 113.6±7.2 | 114.4±6.1 | 115.0 | 7.2 |
| **Weight** | 20.5±3.8 | 20.8±4.2 | 19.7±2.5 | 20.3±2.8 | 20.8±3.8 | 21.0±4.5 |
| **BMI** | 15.2±1.1 | 15.8±1.6 | 15.2±1.2 | 15.4±0.8 | 15.6±1.4 | 15.7±1.5 |
| **Height %ile** | 64.9±24.3 | 62.5±26.0 | 54.9±26.3 | 56.8±29.4 | 64.0±28.3 | 56.7±27.2 |
| **Weight %ile** | 53.0±22.4 | 60.0±25.9+ | 48.7±22.8# | 52.0±27.8 | 56.8±29.2 | 58.4±28.8 |
| **BMI %ile** | 44.2±24.9 | 57.6±27.6 | 47.2±28.6 | 48.5±23.1 | 49.2±28.4 | 49.7±30.3 |
| **%BF** | 22.9±4.6 | 24.4±3.6+ | 22.1±4.0# | 18.6±3.2 | 18.6±3.8 | 18.5±3.9 |
|  | **Δ (Y2-Y1)** | | | | | |
| **Height** | 7.3±0.7 | 6.9±1.1 | 6.8±1.0 | 6.8±0.9 | 7.0±1.1 | 7.0±1.1 |
| **Weight** | 2.2±0.9 | 2.5±1.2 | 2.4±0.6 | 2.4±1.0 | 2.3±0.9 | 2.4±1.1 |
| **BMI** | -0.2±0.6 | 0.05±0.7 | -0.04±0.4 | 0.03±0.6 | -0.2±0.5 | -0.08±0.52 |
| **Height %ile** | 1.4±3.6 | -1.7±6.6 | -2.1±6.5 | 0.1±5.2 | 0.2±5.1 | -0.8±4.2 |
| **Weight %ile** | -0.5±9.5 | -0.5±7.9 | -0.6±7.7 | -0.07±9.9 | -2.8±7.3 | -0.4±7.8 |
| **BMI %ile** | -4.4±16.1 | -0.3±12.7 | 0.4±10.2 | 2.8±13.7 | -2.2±11.7 | 1.1±11.5 |
| **%BF** | -2.1±1.3 | -2.0±1.9 | -2.5±1.7 | -1.4±2.15 | -2.0±1.7 | -1.8±1.7 |

Note: \* different than 1, # different than 2, +different than 3, based on p<0.05

**Table 24.** Differences in Fitness based on **Δ** MVPA Groups

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Girls** | | | **Boys** | | |
|  | Decreased | Maintained | Increased | Decreased | Maintained | Increased |
|  | **YEAR 1** | | | | | |
| **PP** | 97.2±43.8 | 95.4±39.1 | 89.4±26.9 | 97.2±37.9 | 100.2±33.7 | 106.4±44.1 |
| **MP** | 90.9±36.9 | 87.5±31.2 | 78.1±24.0 | 93.0±28.0 | 86.1±28.4 | 93.5±36.6 |
| **TM Time** | 8.9±2.7 | 9.3±2.0 | 9.7±1.9 | 9.9±2.0 | 9.8±2.3 | 9.8±2.6 |
| **60-sec HRR** | 62±25 | 63±14 | 63±16 | 70±13 | 67±14 | 66±13 |
|  | **YEAR 2** | | | | | |
| **PP** | 128.1±41.1 | 124.5±38.6 | 120.1±26.9 | 123.4±29.7 | 130.1±45.0 | 134.6±47.0 |
| **MP** | 112.1±39.0 | 107.8±33.9 | 106.0±26.1 | 107.9±28.0 | 112.9±29.1 | 115.6±40.3 |
| **TM Time** | 11.7±1.6 | 11.6±1.9 | 12.1±2.3 | 12.1±2.2 | 12.2±2.3 | 12.2±3.1 |
| **60-sec HRR** | 58±9 | 59±13 | 62±13 | 67±17 | 67±12 | 70±13 |
|  | **Δ (Y2-Y1)** | | | | | |
| **PP** | 30.9±8.9 | 30.5±16.7 | 30.7±16.2 | 26.2±17.1 | 32.0±18.5 | 30.7±18.3 |
| **MP** | 29.1±6.5 | 25.7±15.0 | 29.0±17.0 | 19.8±13.0 | 30.0±17.3 | 27.1±16.3 |
| **TM Time** | 2.8±1.6 | 2.4±1.3 | 2.5±1.1 | 2.2±1.0 | 2.4±1.6 | 2.3±1.7 |
| **60-sec HRR** | -34±21 | -4±14 | -1±14 | -2±15 | 0±12 | 3.4±13 |

Note: \* different than 1, # different than 2, +different than 3, based on p<0.05

**Table 25.** Differences in Participant Characteristics based on **Δ**VPA Groups

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Girls** | | | **Boys** | | |
|  | Decreased | Maintained | Increased | Decreased | Maintained | Increased |
|  | **YEAR 1** | | | | | |
| **Age** | 4.9±0.8 | 4.6±0.9 | 4.7±1.0 | 4.9±0.7 | 4.6±0.8 | 4.4±0.9 |
| **Height** | 109.4±6.6 | 107.2±7.4 | 106.4±8.1 | 108.7±6.0 | 108.6±6.8 | 106.9±8.5 |
| **Weight** | 19.1±2.8 | 18.1±3.0 | 17.6±3.4 | 18.2±2.3 | 18.8±3.1 | 18.1±3.7 |
| **BMI** | 15.9±1.3 | 15.7±1.2 | 15.5±1.5 | 15.4±0.9 | 15.9±1.4 | 15.7±1.3 |
| **Height %ile** | 65.1±21.1 | 65.4±24.5 | 57.2±27.1 | 54.2±31.2 | 67.4±25.7 | 61.8±29.6 |
| **Weight %ile** | 62.0±22.4 | 59.8±24.8 | 52.2±26.2 | 50.2±30.5 | 62.5±28.2 | 55.8±30.7 |
| **BMI %ile** | 60.4±26.8 | 55.8±26.2 | 50.6±30.7 | 45.6±24.6 | 53.4±30.2 | 47.1±29.7 |
| **%BF** | 25.4±3.2 | 26.3±3.5 | 25.2±3.9 | 19.2±2.9 | 20.6±3.7 | 20.5±3.5 |
|  | **YEAR 2** | | | | | |
| **Age** | 5.94±0.8 | 5.6±0.9 | 5.7±0.9 | 5.9±0.7 | 5.6±0.8 | 5.4±0.9 |
| **Height** | 116.5±6.7 | 114.0±7.3 | 113.3±8.2 | 115.2±9.1 | 115.5±6.9 | 113.9±8.6 |
| **Weight** | 21.6±3.3 | 20.6±3.6 | 20.0±4.1 | 20.5±2.8 | 21.1±3.7 | 20.5±4.5 |
| **BMI** | 15.8±1.4 | 15.7±1.4 | 15.5±1.6 | 15.4±1.0 | 15.7±1.4 | 15.6±1.5 |
| **Height %ile** | 64.8±21.1 | 63.1±25.3 | 56.1±28.0 | 53.4±30.1 | 67.6±26.1 | 61.6±29.4 |
| **Weight %ile** | 61.4±21.6 | 59.7±25.5 | 51.2±25.4 | 49.5±28.0 | 59.5±28.2 | 55.0±30.0 |
| **BMI %ile** | 57.7±25.1 | 56.2±27.7 | 50.1±29.2 | 47.9±23.9 | 50.9±29.0 | 47.3±28.9 |
| **%BF** | 23.6±3.7 | 24.4±3.6 | 22.8±4.2 | 17.8±2.9 | 18.7±4.0 | 18.6±3.7 |
|  | **Δ (Y2-Y1)** | | | | | |
| **Height** | 7.1±0.6 | 6.9±1.1 | 6.9±1.1 | 6.6±0.9 | 7.0±1.0 | 7.0±1.2 |
| **Weight** | 2.5±0.7 | 2.5±1.1 | 2.3±1.1 | 2.3±0.9 | 2.3±0.8 | 2.4±1.1 |
| **BMI** | -0.0±0.4 | 0.1±0.75 | -0.1±0.6 | 0.0±0.6 | -0.2±0.5 | -0.1±0.6 |
| **Height %ile** | -0.3±3.8 | -2.3±6.7 | -1.1±6.8 | -0.8±4.8 | -/2±5/0 | -0.2±4.9 |
| **Weight %ile** | -0.7±5.7 | -0.1±8.3 | -1.0±7.9 | -0.7±8.0 | -3.0±7.0 | -0.8±8.5 |
| **BMI %ile** | -2.7±8.2 | 0.3±13.3 | -0.5±11.7 | 2.3±11.6 | -2.5±10.9 | 0.2±13.3 |
| **%BF** | -1.8±1.5 | -2.0±1.9 | -2.4±1.8 | -1.5±1.8 | -1.9±1.7 | -2.0±1.8 |

Note: \* different than 1, # different than 2, +different than 3, based on p<0.05

**Table 26.** Differences in Fitness based on **Δ**VPA Groups

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Girls** | | | **Boys** | | |
|  | Decreased | Maintained | Increased | Decreased | Maintained | Increased |
|  | **YEAR 1** | | | | | |
| **PP** | 109.3±36.3 | 92.7±35.9 | 91.1±36.7 | 102.8±31.6 | 101.8±33.1 | 100.4±43.9 |
| **MP** | 94.9±33.7 | 86.1±28.4 | 80.7±30.2 | 92.6±24.3 | 87.3±28.4 | 89.0±36.1 |
| **TM Time** | 10.0±2.0 | 9.1±2.1 | 9.5±1.9 | 10.2±2.1 | 9.8±2.2 | 9.6±2.7 |
| **60-sec HRR** | 60±14 | 64±13 | 62±17 | 68±14 | 68±13 | 65±13 |
|  | **YEAR 2** | | | | | |
| **PP** | 140.3±34.3 | 122.9±36.7 | 119.5±34.7 | 130.0±26.6 | 132.4±34.1 | 128.1±45.8 |
| **MP** | 123.0±32.4 | 106.2±32.7 | 105.0±30.5 | 115.0±24.4 | 114.8±28.3 | 110.1±38.9 |
| **TM Time** | 12.07±2.0 | 11.6±2.0 | 11.9±2.0 | 12.5±2.2 | 12.2±2.2 | 12.0±2.9 |
| **60-sec HRR** | 57±8 | 60±13 | 60±15 | 65±13 | 67±13 | 69±12 |
|  | **Δ (Y2-Y1)** | | | | | |
| **PP** | 31.0±9.4 | 31.2±16.9 | 29.6±17.0 | 27.2±16.3 | 31.4±18.5 | 32.2±18.7 |
| **MP** | 28.1±8.5 | 25.9±16.0 | 27.5±16.2 | 24.3±15.1 | 28.9±17.3 | 28.6±17.0 |
| **TM Time** | 2.0±1.0 | 2.6±1.4 | 2.4±1.1 | 2.2±1.4 | 2.4±1.5 | 2.4±1.7 |
| **60-sec HRR** | -4±11 | -4±14 | -2±17 | -3±15+ | -1±11+ | 5±13# |

Note: \* different than 1, # different than 2, +different than 3, based on p<0.05