

Relationships among physical activity, motor skill competence, cardiovascular fitness,
perceived competence, and cognition in preschool children

A Dissertation
SUBMITTED TO THE FACULTY OF
UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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June 2018

Acknowledgments

I would like to express my gratitude to the individuals who have provided me with their invaluable support and guidance throughout my doctoral studies. To begin, I would like to acknowledge my advisor, Dr. Zan Gao, for his exceptional mentorship during my graduate career. Working with Dr. Gao has provided me with countless opportunities and priceless experiences that have allowed me to become who I am today. I thank him for his continued assistance with my ongoing development as a professional in the field of physical activity and health. Second, I would like to thank my committee members, Dr. Thomas Stoffregen, Dr. Daheia Barr-Anderson, and Dr. Senlin Chen for serving on the committee and their expertise and contributions toward the completion of this dissertation. I am grateful for their support and thank them for their advice in the making this research better. Third, I would like to extend my sincerest appreciation to the research assistants of the Physical Activity Epidemiology Laboratory, as well as to the School of Kinesiology for fostering my development in a very supportive and team-oriented environment. Fourth, thank you to all the teachers, Jeff Sanders, Amy Strickland Johnson, Tyron Dombeck, and Kyle Foster from Ann Sullivan and Nancy Duwenhoegger, Elizabeth Saemann, Renee Benecke from Loring Elementary school. Last but not least, I would like to thank all my family, my wife, mother, and father for their undivided and unconditional support of my academic aspirations, continuous belief in my ability, and endless encouragement in my times of despair.

Dedication

This dissertation is dedicated to my wife, my mother, and my father.

Abstract

Early childhood is marked as one of the most critical and intensive periods of development in the human lifespan. Physical activity is a crucial contributor to health and cognition in early childhood, and therefore is considered to be a vital part of development. In this cross-sectional study, my purpose was to examine relationships among physical activity, motor skill competence, perceived physical competence, cardiovascular fitness, and cognition in preschool children, including possible gender differences in all variables. I recruited 65 preschool children (4-6 years old) from two local elementary schools in Minneapolis, Minnesota. Children's 3 days physical activity during school time was assessed via Actigraph Link; motor skill competences was measured via Test of Gross Motor Development–Second Edition; perceived physical competence was assessed via Pictorial Scale of Perceived Competence and Social Acceptance; cardiovascular fitness was assessed via a modified YMCA 3-Minute Step Test; and cognition was assessed via the computer-administered NIH Toolbox. Using IBM-SPSS 25.0 (IBM, Inc., Armonk, NY), I computed Pearson Product-Moment Correlation Coefficients to determine the relationships among all outcomes. I used independent samples t-test to detect gender differences in all measures. I found that preschool children's moderate-to-vigorous physical activity (MVPA) during school time was not significantly related to their motor skills competence ($r = 0.182, p > 0.05$), perceived competence ($r = 0.121, p > 0.05$), cardiovascular fitness ($r = -0.141, p > 0.05$), cognition ($r = -0.095, p > 0.05$), but their step counts were significantly positively related to motor skills competence ($r = 0.282, p < 0.05$), with preschool children's motor skill competence was a significant predictor of step counts [$F(4, 63) = 4.65, \beta = 0.12, p <$

0.05, $R^2 = 0.24$] after age, gender, and BMI were controlled. In addition, I found that perceived competence was significantly positively correlated with motor skills competence ($r = 0.366, p < 0.01$), and was a significant predictor of motor skills competence [$F(4, 63) = 2.66, \beta = 0.26, p = 0.04, R^2 = 0.15$] in preschool children. Meanwhile, I observed that children's cognition was significantly positively correlated with motor skills competence ($r = 0.266, p < 0.01$) and cardiovascular ($r = 0.372, p < 0.01$), respectively, but only cardiovascular fitness seemed to be a significant predictor of cognition [$F(2, 62) = 4.52, \beta = 0.35, t = 2.73, p = 0.01, R^2 = 0.14$]. I observed significant mean differences in preschool children's MVPA, with boys spending more time in MVPA as compared to girls (Mean: 41.72 mins vs. 36.87 mins, $t = -2.04, p < 0.05$, Cohen's $d = 0.51$). I also found that boys took more steps per minute than girls (Mean: 22.26 vs. 19.11, $t = -3.96, p < 0.01$, Cohen's $d = 0.98$). Last, I found that boys demonstrated higher motor skill competence than girls (Mean: 33.16 vs. 29.88, $t = -2.13, p < 0.05$, Cohen's $d = 0.53$). The current study supports the need for effective strategies that simultaneously promote motor skill competence, cardiovascular fitness, cognition, and physical activity behaviors in early childhood. Future research with larger and more diverse samples is necessary to further explore the relationships of preschool children's physical activity patterns (inside and outside of school) with other health-related fitness.

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Chapter One

Introduction

Regular physical activity participation of moderate and/or vigorous intensity (e.g., walking, cycling, or playing competitive sports) has been shown to promote significant health benefits among all populations. In fact, the health benefits of physical activity participation for school-aged children and youth have been well documented (Janssen et al., 2010; Strong et al., 2005), with children and youth regularly participating in physical activity (e.g., walking, cycling, sports, etc.) tend to have significant health benefits such as stronger muscles and bones, leaner body, lower blood pressure and blood cholesterol levels (Goldfield, Harvey, Grattan, & Adamo, 2012). In addition, evidence-based guidelines for youth physical activity were developed based empirical research indicating that participation in physical activity at recommended levels has a positive influence on children and adolescents with regard to developing and maintaining healthy cardiovascular system (i.e., heart and lungs), neuromuscular awareness (i.e., coordination and movement control), body weight (World Health Organization: [WHO], 2015), psychological well-being, and academic performance (i.e., academic behavior, achievement, and grades) (Centers for Disease Control and Prevention: [CDC], 2015).

Current physical activity guidelines suggest that children and adolescents (6-17 years) should do 60 minutes or more of moderate or vigorous intensity aerobic physical activity daily. As part of their 60 or more minutes of daily physical activity, muscle/bone strengthening activities are also recommended at least 3 days of the week (U.S. Department of Health and Human Services, 2008; WHO, 2010). However, the fact that 81% school children are not sufficiently active to achieve health benefits globally (WHO,

2017), In the U.S., only 25% of children and adolescents (12-15 years) meet the recommendations for 60 minutes of daily moderate-to-vigorous physical activity (MVPA) (Fakhouri, Hughes, Burt, Song, Fulton, & Ogden, 2014).

In addition, recommended amounts of physical activity for preschool children (i.e., those aged 4-6 years who have yet to start school) have been operationalized into public health guidelines (Hnatiuk, Salmon, Hinkley, Okely, & Trost, 2014; LeBlanc et al., 2012; Timmons et al., 2012). Specifically, the National Association for Sport and Physical Education (NASPE) in the U.S. has recommended that preschool-aged children should participate in at least 60 minutes of structured and 60 minutes of unstructured physical activity each day and should not be sedentary for more than 60 minutes at a time except when sleeping (National Association for Sport and Physical Education, 2002). In other countries such as Australia, the United Kingdom, and Canada, endorsed guidelines suggest preschool children should: (1) be physically active for at least 180 minutes every day (accumulated throughout the day including light, moderate, and vigorous intensity physical activity); (2) spend less than 60 minutes per day using electronic entertainment media; and (3) not be sedentary, restrained, or kept inactive for more than 60 minutes at a time (with the exception of sleeping) (Australian Department of Health and Ageing, 2008; Canadian Society for Exercise Physiology, 2012a, 2012b; UK Department of Health, 2011).

However, the evidence shows that preschool children only spend a small proportion of their time being physically active (Trina Hinkley, Salmon, Okely, Hesketh, & Crawford, 2012; Tucker, 2008). In detail, the proportion of time preschool children (2-6 years) spent sedentary ranged from 34% to 94%, while the time spent in light intensity

physical activity and MVPA ranged from 4% to 33% and 2% to 41%, respectively (Hnatiuk et al., 2014). Notably, preschool children engage in a mean sedentary time of approximately 10 hours/day—with inactivity higher among girls than boys (American Heart Association, 2013; Soini et al., 2014; Van Cauwenberghe et al., 2011). That is, compliance with physical activity recommendations in preschool children is low (Beets, Bornstein, Dowda, & Pate, 2011; Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012).

Resulting from this physical inactivity lifestyle, the U.S. has experienced a dramatic increase in chronic diseases such as obesity, diabetes, developmental disabilities, among others in children and youth (Torpy, Campbell, & Glass, 2010). Today, childhood obesity is a serious problem in the U.S., putting children at risk for poor health. Despite recent declines in the prevalence among preschool-aged children, obesity among all children is still high (CDC, 2016). Indeed, the prevalence of obesity is approximately 17% and affects about 12.7 million children and adolescents age 2-19 years (Ogden, Carroll, Fryar, & Flegal, 2015). In addition to influencing health consequences, overweight and obesity significantly increase medical costs and pose a staggering burden on the U.S. medical care delivery system (Office of Disease Prevention and Health Promotion, 2015). Therefore, there is an emerging need to promote children's physical activity and reduce sedentary behavior by identifying and understanding the factors that may influence physical activity for our young generation.

Rationale

Over the past few decades, scholars have attempted to determine the correlates of children's physical activity. One potential behavioral correlate of children's physical activity is motor skill competence. Evidence has suggested that motor skill acquisition in

early childhood is an important prerequisite for the child physical activity participation and engagement in physical activity later in life (Loprinzi, Davis, & Fu, 2015; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Thus, the development of motor skill competence is vital during early childhood. Available studies examining the relationship of preschool children's physical activity and motor skill competence present little consensus, with motor skill competence weakly (Hume et al., 2008; Williams et al., 2008) to moderately (Foweather et al., 2015; Lubans et al., 2010; Okely, Booth, & Patterson, 2001) positively associated with physical activity. Reasons for the mixed findings are partially attributable to differences in physical activity assessment applied (parental report vs. objective measurement). Further, despite the use of objective measures such as accelerometers, the cut-off points chosen to quantify physical activity have varied among studies (Hnatiuk et al., 2014). Given the mixed findings and design limitations in previous studies, more research is warranted to understand the relationship between objectively measured physical activity and motor skill competence in young children.

Perceived competence appears to influence intrinsic motivation in physical education, and to be a deciding factor affecting children's physical activity participation (Sollerhed, Apitzsch, Rastam, & Ejlertsson, 2007). Therefore, perceived competence is also an important correlate as it has been suggested to more directly affect motivation towards physical activity (Barnett, Ridgers, & Salmon, 2015). Notably, perceived competence can vary across domains, children may perceive themselves as having high competency in the social domain but low competency in the physical domain (Shapiro, Lieberman, & Moffett, 2003). In addition, it was concluded that children who are skill

proficient may develop a high perceived competence leading to greater participation in physical activity and higher fitness levels, whereas children with poor skill proficiency tend to develop low perceived competence leading to less participation in physical activity in adolescence (Barnett, Morgan, van Beurden, & Beard, 2008). Although previous research has shown that perceived competence is positively associated with adolescent physical activity (Biddle, Whitehead, Donovan, & Nevill, 2005; Sallis, Prochaska, & Taylor, 2000), the association between preschool children's perceived competence and objectively measured physical activity remains undetermined thus far. Therefore, there is also a necessity to look at the relationship between motor skill competence and perceived competence in preschool children.

It is usually assumed that physical activity is related to cardiovascular fitness and that physically active children will, therefore, be in better health condition. If a kid is generally unfit now, then he/she is more likely to develop conditions like heart disease later in life (American Heart Association: [AHA], 2013). Despite high cardiovascular fitness during childhood and adolescence is linked to a healthier cardiovascular profile during adulthood (Ruiz et al., 2006), the fact that preschool children are most physically inactive (AHA, 2013; Soini et al., 2014; Van Cauwenberghe, Gubbels, De Bourdeaudhuij, & Cardon, 2011), which may result in children are at risk of cardiovascular disease. Therefore, it is also necessary to understand the relationship between objectively measured physical activity and cardiovascular fitness in this population.

Finally, along with the alarming health risks associated with being physically inactive, another critical factor to consider is the development of executive functioning.

Early childhood is a stage in human development, which is the most crucial time for creating the foundation that will set them up for success related to life-long learning. It has been shown that executive functioning is not innate, but is rather developed throughout the early years of lives, specifically during the ages of 3-6 (Center on the Developing Child, 2012). In fact, there are many physiological benefits of exercise on brain. Specifically, exercise has been shown to increase neurochemical production of two important neurotransmitters that regulate mood and behavior, dopamine and norepinephrine. In addition, Exercise is believed to aide in the upregulation of growth factors and neurotrophins, specifically the upregulation of brain-derived neurotrophic factor (BDNF) and the formation of new blood vessels (Vazou, Pesce, Lakes, & Smiley-Oyen, 2016).

Although interest in the correlation between physical activity and cognition has grown over the past decade, the literature has focused mainly on patients and older adults' rehabilitative outcomes. Conversely, research investigating the relationship between young children's physical activity and cognition has received less attention. While a recent systematic review by Donnelly et al. (2016) concluded that there were positive associations among 5-13 years old children's physical activity and cognition, these findings were inconclusive. Therefore, the relationship between physical activity and cognition in preschool children still needs to be further explored.

Theories and Models of Physical Activity

Understanding of why people are physically active or inactive contributes to evidence-based planning of public health interventions, because effective programs will target factors known to cause inactivity (Bauman et al., 2012). Thus, promoting and

sustaining health-enhancing physical activity and subsequent physical and psychological health in children and adolescents is a global pursuit. Over the past few decades, a wealth of research has been conducted attempting to alleviate the disturbing trends in these health domains. Regrettably, present evidence indicates that these interventions have had limited success (Robinson et al., 2015). That is, the understanding of how the development of multiple health-related variables may synergistically impact each other to promote physical activity and overall health remains largely unexplored.

In fact, research into correlates (factors associated with activity) or determinants (those with a causal relationship) of physical activity and sedentary behavior has burgeoned. However, most research mainly focused on individual level factors. It has been concluded that factors that may impact physical activity levels include, but are not limited to: health-related physical fitness (set of physical attributes achieved over time), motor skill competence (ability to execute motor tasks), perceived competence (perception of ability to perform motor tasks), enjoyment, self-efficacy, socioeconomic status, etc. Notably, ecological models take a broad view of health behavior causation, with the social and physical environment included as contributors to physical inactivity, particularly those outside the health sector, such as urban planning, transportation systems, and parks and trails (Bauman et al., 2012). New areas of determinants research have identified genetic factors contributing to the propensity to be physically active, and evolutionary factors and obesity that might predispose to inactivity, and have explored the longitudinal tracking of physical activity throughout life (Bauman et al., 2012).

To date, some comprehensive theoretical models have been proposed to address the correlates of physical activity (Eccles & Harold, 1991; Sallis et al., 2006; Stodden et

al., 2008; Trost et al., 1997; Welk, 1999). For instance, a model developed by Welk (1999) classified the five most commonly reported correlates of physical activity for children into: (1) demographic characteristics (e.g., age, gender); (2) biological characteristics (e.g., body mass index); (3) psychological characteristics (e.g., self-efficacy, beliefs about activity, interest/benefits of activity, benefits-barriers differential, enjoyment, intentions); (4) social/cultural characteristics (e.g., parental influence, friend and family support); and (5) environmental characteristics (e.g., access to an appropriate environment). This conceptual model suggests that direct effects of biological factors leading to increased persistence in physical activity are possible, while indirect effects through the child's perceived competence are perhaps more likely (Welk, 1999). Although this model has contributed greatly to literature regarding the underlying factors of physical activity, which focused more on expectancy-value-based and/or social-cognitive approaches.

Notably, Stodden et al. (2008) suggested that previous theoretical models failed to consider the dynamic and synergistic role of motor competence (e.g., motor proficiency, motor performance, fundamental movement/motor skill, motor ability, and motor coordination) in the initiation, maintenance, or decline of physical activity while suggesting that young children's physical activity might drive their development of motor skill competence. That is, increased physical activity could provide more opportunities to promote neuro-motor development, which in turn promotes fundamental motor skill development. As such, Stodden and associates proposed a conceptual model that addresses the potential role of motor skill competence in promoting either positive or negative trajectories of physical activity (Figure 1).

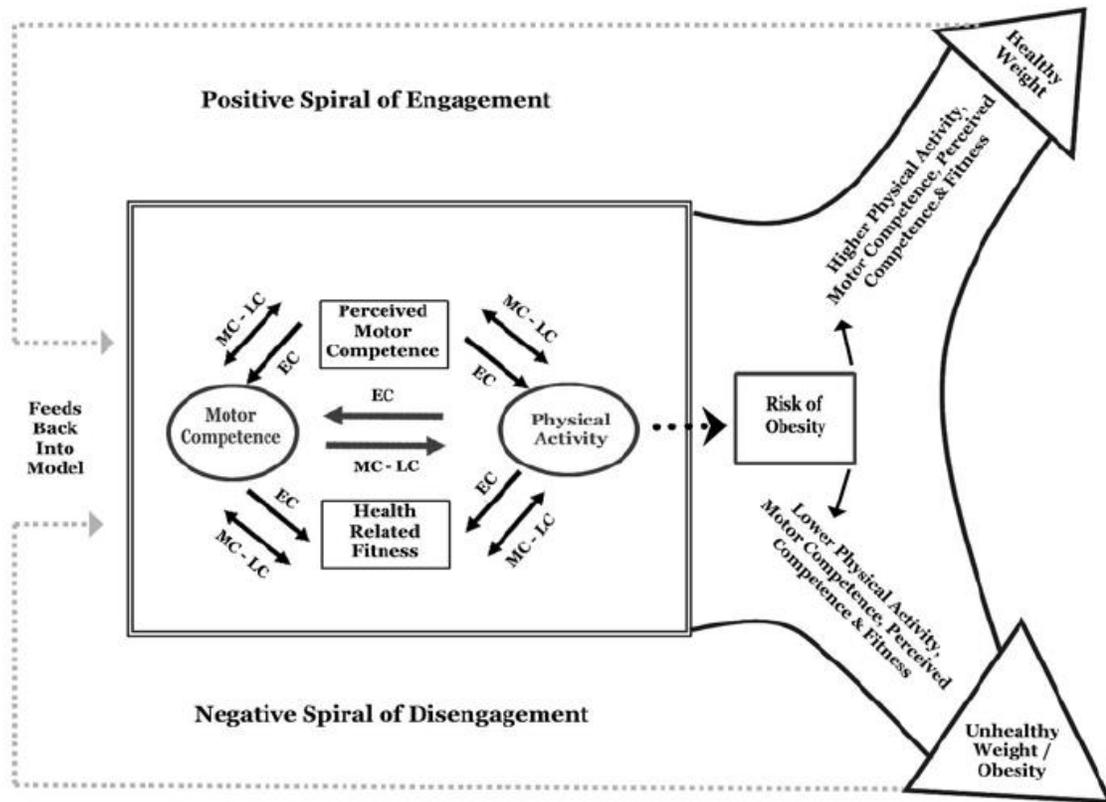


Figure 1 Developmental Mechanisms Influencing Physical Activity Trajectories of Children

In this model, Stodden et al. (2008) suggested that young children (early childhood: 2-6 years) will demonstrate varying physical activity levels and motor skill competence, with these two variables being weakly related at this point in development. Later, as children transition to middle and late childhood (6-12 years), the relationship between physical activity and motor skill competence strengthens, with higher levels of motor skill competence offering a greater motor repertoire—positioning these children to participate in a wider variety of physical activities. During middle and late childhood, the moderately to highly skilled children will be expected to self-select higher levels of physical activity, whereas those who possess less proficient levels of motor skill competence will engage in lower levels of physical activity. That said, one’s motor skill

competence might be driven by physical activity levels. In addition, Stodden et al. (2008) proposed that perceived motor competence, health-related physical fitness, and obesity could play a mediating role that might interact with and promote/demote the dynamic relationship between motor skill competence and physical activity across childhood and into adolescence. Overall, this theoretical model represents a testable framework focusing on multiple individual, behavioral, psychological, and translational variables.

Physical activity is vital to integrate into the lives of children and adolescents and set the foundation for facilitating and maintaining healthy active living through adulthood (Tucker, 2008). Regular physical activity participation is associated with important short- and long-term health benefits for children and adolescents in physical, cognitive, emotional, and social domains (Sallis et al., 2000). Specifically, regular involvement in physical activity enhances physical fitness, with several benefits to the cardiovascular and musculoskeletal system. In addition, the physiological stress resulting from regular physical activity participation can result in cognitive functioning improvements. In fact, research has indicated that physical activity enhances learning and memory in adults (Hillman, Erickson, & Kramer, 2008), while significant positive associations between physical activity and cognition has been observed in children 6-13 years (Sibley & Etnier, 2003). It stands to reason that physical activity might be even more important when the brain is still developing rapidly, as is the case in preschool-aged children. Notably, longitudinal studies have indicated preschool children's physical activity behaviors to remain relatively stable during their preschool years and on into childhood (Pate, Baranowski, Dowda, & Trost, 1996). Therefore, establishing healthy and age-appropriate

physical activity behaviors is crucial to promote long-term beneficial health effects for young children.

While Stodden et al. (2008)'s model represents the important concepts identified in the literature, scant research has utilized this model to investigate why such a large proportion of 4-6 year olds children are physically inactive. Additionally, it is suggested that physical activity can lead to neurochemical and morphological changes in brain regions associated with executive functioning in children 4-12 years old (Best, 2010; Diamond & Lee, 2011). Thus, adding cognition into Stodden et al. (2008)'s theoretical model as one of physical activity correlates appears to be applicable (Figure 2). In this sense, Stodden et al. (2008)'s theoretical model provides the rationale for the current study. That is, further research is warranted to extend and validate this model and document the relationships among objectively measured physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition, with the ultimate goal of understanding the correlates of physical activity in preschool children.

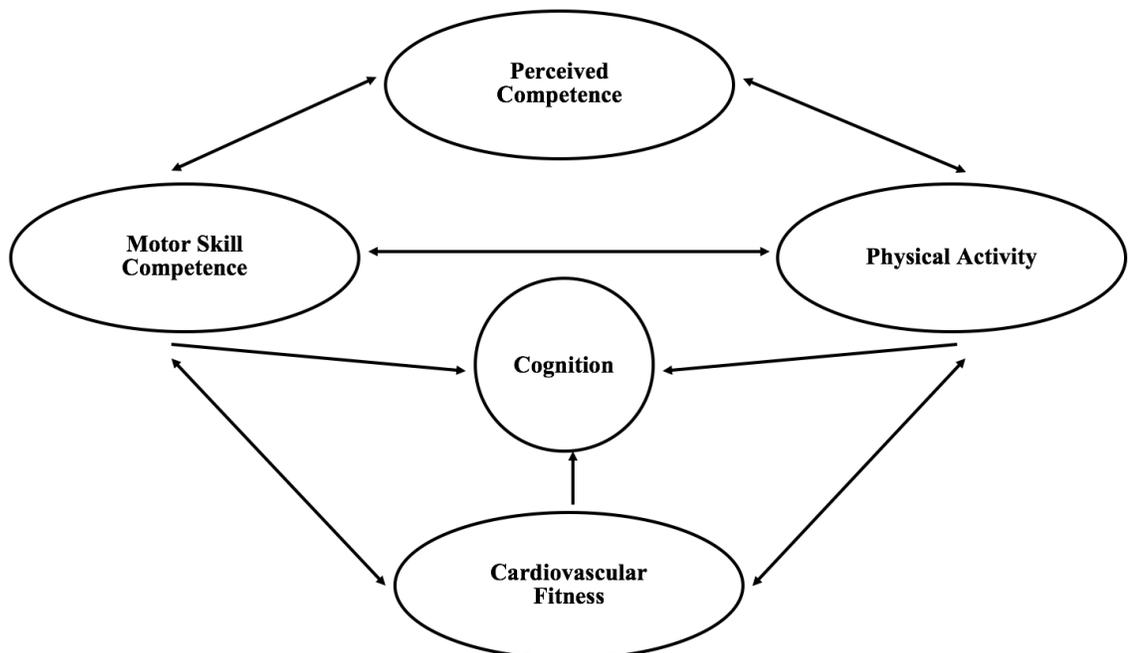


Figure 2 A New Theoretical Model Built on Stodden et al. (2008) Theory

Building upon the Stodden et al. (2008) model, the new model integrates cognition into the framework. In this model, I proposed significant relationships among physical and cognitive outcomes during the early childhood (ages 4-6). To begin, perceived physical competence along with motor skills play an essential role in children's motivation to learn and their engagement in current and future physical activity behaviors. Children who perceive themselves as having greater physical competence and demonstrate a high level of motor skills will engage in more levels of physical activities. That is, motor skill competence and self-perceptions influence motivation and persistence to engage in play, movement, and physical activities, or vice versa. Further, the children's motor skill competence may correlate with their perceptions of competence. For example, children who perceive themselves to be highly competent at a skill or task will demonstrate persistence and attempt to master a skill, whereas those with low competence will lose interest in that task.

Second, cardiovascular fitness during early childhood may affect participation in active recreation and physical activities directly, thereby influencing children's motor skill development indirectly. Specifically, children who have a greater level of cardiovascular fitness will tend to participate in a wider variety of physical activities and exhibit higher levels of motor skill competence, or vice versa.

Finally, as physical activity/movement can stimulate neurochemical and morphological changes in brain regions linked with certain aspects of cognitive development (Best, 2010), children's cognition might be facilitated by physical activities and motor skills. In detail, children who participate in more levels of physical activities or

have better motor skill proficiency are expected to have a higher level of cognitive development. Notably, previous research has suggested that cardiovascular fitness play a mediator role to explain the relationship between physical activity and improved cognitive performance (Aberg et al., 2009; North, McCullagh, & Tran, 1990). In this model, therefore, I proposed that children with better cardiovascular fitness level tending to have a greater level of cognition. To summarize, this new theoretical model focuses on multiple physical and cognitive outcomes and represents a testable framework illustrating development mechanisms influencing physical activity trajectories of preschool children.

Summary

As physical activity is considered to be a vital part of children development (King et al., 2003), there is growing interest in determining the nature of children's activity profiles. Participation in physical activity positively influences the development of skills and competencies, social relationships, and long-term physical health (King et al., 2006). Recently, the importance of motor skill competence and perceived physical competence towards lifetime participation in movement and physical activity has gained increased attention (Robinson, 2011). Two important mechanisms appear to be at play. The first mechanism is a direct relationship between motor skill competence and participation in active recreation and physical activity (Crane, Naylor, Cook, & Temple, 2015; Temple, Crane, Brown, Williams, & Bell, 2016). Learning to move is a necessary skill underlying physical activity. Motor skill competence, as Seefeldt (1980) suggested, is necessary to break through a hypothetical "proficiency barrier" that would allow individuals to apply these motor skills to sports and games. Clearly, motor skill competence is an important stepping-stone to motor development and lifelong physical activity participation (Stodden

et al., 2008). Seefeldt (1980) also stated that there might be a “critical threshold” of motor skill competence, above which children may be more likely to be active and successfully apply fundamental movement skills competence to lifetime physical activities, but below which they would be less successful and ultimately drop out of physical activities at higher rates. The second mechanism is an indirect relationship between motor skill competence and physical activity participation via perceptions of physical competence (Stodden et al., 2008). That is, children with high levels of perceived and actual competence may be more likely to engage in physical activity (Slykerman, Ridgers, Stevenson, & Barnett, 2016).

Research has shown the importance of understanding the correlates that may influence children’s physical activity participation such as movement skill competence, physical fitness, and a positive perception of capabilities (Babic et al., 2014). Stodden et al. (2008) described this process as a positive spiral of engagement. In detail, children’s physical activity participation influences their motor skill development, and in turn their movement competence influences their physical activity engagement. Perceived competence and health-related fitness were described as mediators that also influence physical activity level. As children age, the perceptions of their abilities better reflect their actual motor competence (Slykerman et al., 2016). Therefore, Stodden et al. (2008)’s conceptual model purported that relationships between the constructs will increase in strength as children age. Additionally, it was suggested that physical activities that challenge executive function can facilitate cognitive development in children 4-12 years old (Diamond & Lee, 2011). As a logical extension of Stodden et al. (2008)’s

model, therefore, including cognitive function as a physical activity correlate in this model is feasible.

Regrettably, scant literature is available using (Stodden et al., 2008)'s model to examine the relationships among these variables in preschool children (4-6 years old) and to understand why so many young children are physically inactive. To date, no research has been conducted to extend and validate Stodden et al. (2008)'s model in preschool children. Therefore, I proposed a new theoretical model that builds upon Stodden et al. (2008)'s theory and added the cognition as one of preschool children's physical activity correlates. Although the causal relationships cannot be inferred due to the correlational nature of the current study, understanding the factors that influence preschool children's physical activity behavior is important in the design of intervention programs targeted at young children. My main purpose was to inform future physical activity interventions of how preschool children's motor skill competence, cardiovascular fitness, perceived competence, cognitive functions, and objectively determined physical activity related to each other—setting the stage for the development of experimental trials seeking to promote improvements in preschool children's physical and cognitive health.

Purpose of Study

In this study, I investigated: (1) the relationships among physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognitive function in preschool children. Specifically, I examined how MVPA/step counts related to the preceding outcomes; (2) whether preschool children's motor skill competence, cardiovascular fitness, and perceived competence can predict their MVPA/step counts; (3) whether preschool children's MVPA/step counts, cardiovascular fitness, and motor

skill competence can predict their cognition; (4) whether preschool children's perceived competence can predict their motor skill competence; (5) whether preschool children's motor skill competence can predict their cardiovascular fitness; and (6) whether gender differences exist among all measures.

Specific Aims and Hypotheses

I proposed the following specific aims and hypotheses:

Aim 1. Determine the relationships among 3 days of objectively measured daily MVPA/step counts (measured by research-grade Actigraph Link accelerometer), motor skill competence, cardiovascular fitness, perceived competence, and cognition in preschool children.

Hypothesis 1a. I hypothesized that there are significant, positive associations among all variables (i.e., MVPA/step counts, motor skill competence, cardiovascular fitness, perceived competence, and cognition) in preschool children.

Hypothesis 1b. I hypothesized that motor skill competence, cardiovascular fitness, perceived competence, and cognition are significant predictors of preschool children's MVPA/step counts.

Hypothesis 1c. I hypothesized that MVPA/step counts, motor skill competence, and cardiovascular fitness are significant predictors of preschool children's cognition.

Hypothesis 1d. I hypothesized that perceived competence is a significant predictor of preschool children's motor skill competence.

Hypothesis 1e. I hypothesized that motor skill competence is a significant predictor of preschool children's cardiovascular fitness.

Aim 2. Determine whether gender differences exist among all measures in preschool children.

Hypothesis 2. I hypothesized that boys will demonstrate higher MVPA/step counts, motor skill competence, cardiovascular fitness level, and perceived competence than girls, but that no significant gender difference in cognition.

Definitions of Terms

The following terms and definitions are provided to clarify the constructs which may influence this study:

Physical activity: refers to “any bodily movement produced by skeletal muscles that requires energy expenditure” (WHO, 2016), including activities undertaken while working, playing, doing household chores, travelling, and engaging in recreational pursuits.

Motor skill competence: a global term regarding the development and performance of human movement, has been defined as proficiency in common fundamental motor skills (Stodden et al., 2008). Fundamental motor skills are “building blocks” that lead to specialized movement sequences and sport skills required for adequate participation in physical activity for children, adolescents, and adults (Gallahue & Ozmun, 2012), consisting of locomotor skills (e.g., running, hopping, leaping, jumping, crawling, walking, galloping and skipping) and object control skills (e.g., kicking, striking, throwing, catching, bouncing and dribbling) (Haywood & Getchell, 2014).

Cardiovascular fitness: refers to the ability of the heart, blood cells and lungs to supply oxygen-rich blood to the working muscle tissues and the ability of the muscles to

use oxygen to produce energy for movement (National Physical Activity Guidelines, 2009). Simply stated, cardiovascular fitness is a direct marker of physiologic status reflecting the overall capacity of the cardiovascular and respiratory systems, and the ability to carry out prolonged physical exercise (Taylor, Buskirk, & Henschel, 1955).

Perceived competence: as a component of physical self-perception, reflects the self-perception an individual possesses regarding her/his capability to control and accomplish certain tasks resulting from cumulative interactions with the environment and situation (Harter, 1985). In the current study, perceived competence refers to what a child believes to be his/her motor ability (Robinson, 2011).

Cognition: refers to the set of mental processes that contribute to perception, memory, intellect, and action (Donnelly et al., 2016), which has been defined as “cerebral activities that lead to knowledge, including all means and mechanisms of acquiring information” (Jung, 1971, p. 123). Cognitive functions encompass reasoning, memory, attention, and language and lead directly to the attainment of information and, thus, knowledge (Jung, 1971).

Chapter Two

Review of Literature

Relationship between Physical Activity and Motor Skill Competence

Motor skill competence is hypothesized to be an important factor that determines how physically active or inactive a child is (Stodden et al., 2008). As mastery of motor skills in childhood is likely to be a key determinant of later adolescent motor skill mastery, childhood motor skill proficiency may thus be an important factor in subsequent adolescent physical activity levels (Branta, Haubenstricker, & Seefeldt, 1984). In fact, evidence has shown that motor skill acquisition in early childhood is an important prerequisite for children to participate in physical activity and maintain physically active lifestyle (Loprinzi et al., 2015; Lubans et al., 2010). As physically active lifestyles start at a young age and track into adulthood, adolescents and young adults with proficient motor skills in sport-related activities are more likely to have a physically active lifestyle (Trudeau, Laurencelle, Tremblay, Rajic, & Shephard, 1999). Therefore, the development of motor skill competence is vital during early childhood.

Over the past two decades, scientific evidence has grown regarding the importance of motor skill competence on physical activity participation in children and adolescents, with some studies have found these two variables weakly (Fisher et al., 2005; Hume et al., 2008; Laukkanen, Pesola, Havu, Sääkslahti, & Finni, 2014; Williams et al., 2008) to moderately (Foweather et al., 2015; Lubans et al., 2010; Okely, Booth, & Patterson, 2001) positively associated with physical activity in children and adolescents, while light-to-moderate physical activity (Laukkanen et al., 2014); moderate intensity

physical activity (Bürgi et al., 2011); and MVPA (Iivonen et al., 2013; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006) were found to be positively associated with motor skills.

Several studies have investigated the relationship between physical activity and motor skills in preschool children. Lin, Cherng, and Chen (2017) examined the relation of gross motor performance and physical activity for preschool children in Taiwan ($N = 264$). The Movement Assessment Battery for Children-Second Edition (MABC-2) and the modified Preschool-aged Children's Physical Activity Questionnaire were used to assess motor skills and physical activity. The findings suggested that children with motor difficulties tended to spend less time on physical activity than did typically developing children. Similarly, Williams et al. (2008) investigated the relationship between motor skill performance and physical activity participation in preschool children ($N = 264$). The Children's Activity and Movement in Preschool Study (CHAMPS) Motor Skill Protocol was used to assess locomotor and object control skills, while the ActiGraph accelerometer was used to measure physical activity. This study suggested that preschool children with better developed motor skills may find it easier to be active and engage in more physical activity than those with less developed motor skills. Iivonen et al. (2013) evaluated the relationship between objectively measured physical activity and fundamental motor skills in preschool-aged children ($N = 37$). Physical activity was monitored over 5 consecutive days (3 days at preschool and 2 days at home). The findings suggested that total skill score was significantly associated with physical activity. Notably, motor skills assessment included sliding, galloping, jumping, balancing, throwing and catching.

In addition, Fisher et al. (2005) tested the relationships between objectively measured habitual physical activity and fundamental movement skills in a relatively large and representative sample of preschool children ($N = 394$). Physical activity was measured by the Computer Science and Applications (CSA) accelerometer for 6 days, while fundamental movement skills were assessed via the MABC-2. It was concluded that fundamental movement skills were significantly but weakly associated with habitual physical activity. Similarly, Sääkslahti et al. (1999) examined the relationships between physical activity and fundamental motor skills during a single weekend among 105 normal preschool children. The results suggested that physical activity is weakly related to fundamental motor skills at an early age. Notably, physical activity was measured by self-reported questionnaire in this study. Interestingly, Foweather et al., (2015) examined associations between fundamental movement skills and weekday and weekend physical activity among preschool children ($N = 99$) living in deprived communities. Locomotor and object control skills were presented as children's fundamental movement skills while physical activity was measured via hip-mounted accelerometers. The results suggested that total skill score was positively associated with weekend MVPA but not weekday physical activity.

Generally, young children's motor skill competence appears to be positively associated with an active lifestyle. Nevertheless, limitations have also been noted in the literature. To begin, different definitions and assessments of motor skill competence were seen. For example, Fisher et al. (2005) assessed children's fundamental motor skills using a set of tasks: jumps, balance, skips, ball exercises. Additionally, Williams et al. (2008)'s assessment included a battery of tests: run, jump, slide, gallop, leap, hop, throw, roll,

kick, catch, strike, and dribble. Therefore, inconsistent measures may lead to misunderstanding regarding the relationship between physical activity and motor skill competence. Second, some studies used self-reported measures of physical activity (Lin et al., 2017; Sääkslahti et al., 1999) while others employed objective physical activity measurements (Fisher et al., 2005; Foweather et al., 2015; Iivonen et al., 2013; Williams et al., 2008). Therefore, the findings should be taken with caution as self-reported instruments are not recommended to be used with children younger than 10 or 11 years as these children lack the required cognitive skills to accurately report their physical activity levels (Sallis, 2010). Moreover, despite the use of objective measures such as accelerometers to assess preschool children's physical activity, the cut points chosen to quantify physical activity levels have varied among studies (Bürge et al., 2011; Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014).

Resulting from the preceding limitations, study findings regarding the relationship of physical activity to motor skill competence in preschool children are inconclusive. Given the limitations and mixed findings in previous studies, it is clear that further research is warranted to understand this relationship in young children using objectively measured physical activity and motor skill competency scores derived from a nationally- and/or internationally-recognized motor skill competence assessment.

Relationship between Physical Activity and Perceived Competence

Physical self-perception has been identified as an important psychosocial correlate of physical activity in youth and has been associated with physical activity participation in cross-sectional studies (Crocker, Eklund, & Kowalski, 2000; Fox & Corbin, 1989; Hagger, Ashford, & Stambulova, 1998; Raudsepp, Liblik, & Hannus,

2002; Roberts, Kleiber, & Duda, 1981; Sallis, Prochaska, & Taylor, 2000). Perceived competence is a multidimensional, dynamic, and interactional concept that influences both the initiation of mastery attempts in the physical, social, or cognitive domains and the development of such achievement behaviors as effort and persistence (Bell, 1997; Kosma, Cardinal, & Rintala, 2002; Sherrill, 1998). It was suggested that perceived competence could be considered more directly influence motivation towards physical activity (Barnett et al., 2015), with high perceptions of physical competence may contribute to increased physical activity (Babic et al., 2014).

Over the past two decades, the relationship between perceived physical competence and physical activity has been examined. In detail, Bell, (1997) found a significant positive relationship between perceptions of competence and amount of physical activity in 7th grade children ($N = 43$). Notably, the children's physical activity in this study was measured by direct observation. Gao (2008) investigated the predictive strength of perceived competence and enjoyment on students' physical activity and cardiorespiratory fitness among 7th and 8th graders ($N = 307$). Physical activity was estimated via pedometers. The results showed enjoyment and perceived competence accounted for significant variance of 20.7% of physical activity. In addition, Carroll and Loumidis (2001) found that children ($N = 922$) with high perceived competence participated in significantly more physical activity (self-reported) outside school than those with low perceived competence.

On the other hand, Fairclough (2003) assessed the levels of physical activity, perceived competence and enjoyment in English secondary school children ($N = 73$).

Physical activity was captured using heart rate telemetry. It was concluded that perceived competence was not related to children's MVPA.

The conflicting findings from previous research illustrate the necessity for continued research into the relationships between psychological outcomes and physical activity in children and adolescents. Notably, a systematic review conducted by Sallis et al. (2000) indicating that perceived physical competence could be considered a potential correlate of youth physical activity. Nevertheless, the authors also pointed out that some variables such as perceive physical competence have been studied too few times to draw a definite conclusion. That is, these variables should not be targeted for change in interventions until additional research warrants it. Another review revealed that the evidence for the associations between physical activity, intention, and perceived competence in youth was inconclusive (Van der Horst, Paw, Twisk, & Van Mechelen, 2007).

It is also worth noting that the aforementioned studies mainly focus on children and adolescents. Of studies to include preschool aged children, findings regarding the relationship of perceived competence to physical activity has been mixed. For instance, Morgan et al. (2008) found perceived competence to not be significantly related to young obese children's physical activity (measured by accelerometers and values were calculated for % of monitored time spent in MVPA and steps/minute). Similarly, a recent study indicated that young children's perceived ball skill competence was not associated with their MVPA (measured for eight consecutive days using hip-mounted ActiGraph GT3X accelerometers) (Barnett et al., 2015). While Robinson (2011) reported a moderate positive relationship between perceived competence and physical activity in preschool-

aged children, the author also indicated that children in this study exhibited low perceived competence scores in comparison to other similar populations. This is a concern as children with low self-perceptions may lose motivation and interest in movement-related tasks, leading to lower levels of physical activity (Robinson, 2011). Interestingly, the findings from Robinson, Wadsworth, and Peoples (2012) study rejected a relationship between preschool children's perceived physical competence and physical activity (quantified by steps).

In summary, the evidence regarding the relationship between physical activity and perceived competence in children has been inconclusive, with some studies reporting a significant positive association between perceived competence and their physical activity, while other studies suggesting no relation exists. Nevertheless, researchers stated that children with proficient motor skills may tend to develop a high perceived competence leading to greater participation in physical activity and higher fitness levels, whereas children with poor motor skills may possess low perceived competence causing less engagement in physical activity in adolescence (Barnett, Morgan, et al., 2008). That said, the relationship between perceived competence and motor skill competence in preschool children needs to be further determined.

Relationship between Physical Activity and Cardiovascular Fitness

Empirical evidence has shown that high cardiovascular fitness during childhood and adolescence is associated with a healthier lifestyle during these years and also later in life (Pate et al., 2012; Ruiz et al., 2007; Twisk, Kemper, & van Mechelen, 2002). However, the fact that children's cardiovascular fitness is currently declining worldwide. Globally, children today are roughly 15 percent less fit from a cardiovascular standpoint

than their parents were as children. In the U.S. children's cardiovascular endurance performance declined about 6 percent per decade between 1970 and 2000 (Tomkinson, Annandale, & Ferrar, 2013). Declines in cardiovascular endurance performance among young children are likely caused by social, behavioral, environmental factors, among others. It is a well-known that physical activity is strongly related to physical fitness in children and adults (Monyeki & Kemper, 2007; Ortega, Ruiz, Castillo, & Sjöström, 2008; Ruiz et al., 2006), with a physically active lifestyle in childhood and adulthood associated with lower risks of obesity, cardiovascular disease, high blood pressure, diabetes, cancer, and premature death (CDC, 2015a). As physical activity patterns in childhood are maintained throughout adulthood (Twisk, Kemper, & van Mechelen, 2000), understanding the relationship between physical activity and cardiovascular fitness in early childhood is crucial for developing and managing a healthier lifestyle.

The existing evidence regarding the relationship between physical activity and cardiovascular fitness in children mainly focus on the effects of physical activity on children's physical fitness. It was commonly concluded that more active children will have higher levels of physical fitness and this relationship is causal (Rauner, Mess, & Woll, 2013). Scant research, however, is available examining the direct relationship between physical activity and cardiovascular fitness. For example, Ortega, Ruiz, Hurtig-Wennlöf, and Sjöström (2008) examined the relationship of objectively measured physical activity to cardiorespiratory fitness among adolescents (14-16 years old). The findings supported that those who devote at least 60 minutes moderate and/or vigorous physical activity participation daily had greater cardiovascular fitness. Notably, cardiovascular fitness in this study was presented as VO_{2max} assessed via a cycle

ergometer. Similarly, Martínez-Vizcaíno & Sánchez-López (2008) stated that only vigorous intensity physical activity (≥ 6 METs) can improve physical fitness, including cardiorespiratory capacity, strength, and agility.

The preceding assertion is founded as Gutin et al. (2002) observed increased cardiovascular fitness not during moderate intensity activity, but only during vigorous intensity physical activity in obese adolescents. Moreover, Dencker et al. (2006) suggested that the relationship between physical activity and physical fitness (cardiovascular fitness as one of physical fitness components) is only weak or moderate among 8-11 years old children. In this study, cardiovascular fitness was defined as VO_{2max} and via bicycle ergometer exercise test while physical activity was assessed by accelerometers for 4 days. Notably, a systematic review by Monyeki and Kemper (2007) confirmed Dencker et al. (2006)'s findings in youth 5-14 years, indicating some studies found this relationship to be non-significant. Recently, Hsieh et al. (2014) conducted a cross-sectional study and found that physical activity was significantly correlated with cardiorespiratory fitness levels in children aged 12 years old ($N = 2419$). Of note, children's cardiovascular fitness was assessed by an 800m run and physical activity was measured via a questionnaire. A more recent systematic review by Larouche, Saunders, Faulkner, Colley, and Tremblay (2014) suggested that despite the observation of an overall positive association between school children's physical activity and cardiovascular fitness, the evidence was conflicting.

Based upon the previous literature, the relationship between physical activity and cardiovascular fitness in children is less clear. It has been argued that physical activity in children and younger adolescents is unlikely to modify physical fitness since the physical

activity among these age cohorts is largely unpredictable and non-systematic, and occurs in relatively short bursts (Martínez-Vizcaíno & Sánchez-López, 2008). Further, disagreement regarding the relationship between physical activity and cardiovascular fitness in children could be partially attributed to the variety of physical activity and cardiovascular fitness assessments. Therefore, a study investigating the relationship between preschool children's physical activity and cardiovascular fitness is warranted.

Relationship between Physical Activity and Cognitive Function

Kinesiology is a field that advocates a holistic approach to human development. This approach emphasizes that the mind and body are one entity, and that one will affect the other (Sibley & Etnier, 2003). Educators have suggested that movement stimulates cognitive development, particularly in young children (Leppo, Davis, & Crim, 2000; Pica, 1997). Today, advances in neuroscience have led to substantial progress in linking physical activity to cognitive performance and to brain structure and function (Donnelly et al., 2016).

The initial evidence regarding the effects of exercise on brain functions was obtained from animal research, indicating that that exercise is one of the strongest promoters of neurogenesis in the brain of adult rodents (Gomez-Pinilla & Hillman, 2013; Itoh et al., 2011). Subsequently, these animal research led to the neurogenic reserve hypothesis that physical activity in early life may optimize brain networks involved in memory and create a reserve of precursor cells that influence an individual's learning capabilities throughout the life span (Donnelly et al., 2016; Kempermann, 2008). It was suggested that cognitive development can be facilitated by activities that challenge cognition such as executive functioning in children 4-12 years old as physical activity can

lead to both neurochemical and morphological changes in brain regions associated with executive functioning (Diamond & Lee, 2011). That is, regularly physical activity participation in early childhood could stimulate cognitive development (Best, 2010).

To date, numerous mechanisms have been proposed to explain the relationship between physical activity and cognition among various populations, including young/older adults and patients. These mechanisms can be classified into two broad categories—physiological mechanisms and learning/developmental mechanisms (Sibley & Etnier, 2003). The physiological mechanisms, such as increased cerebral blood flow, alterations in brain neurotransmitters, structural changes in the central nervous system, and modified arousal levels, are based on physical changes in the body brought about by exercise (Ide & Secher, 2000; Kamijo et al., 2004; Meeusen & De Meirleir, 1995; Vaynman & Gomez-Pinilla, 2005). The learning/developmental mechanisms state that physical activity and movement provide learning experiences that aid proper cognitive development (Bjorklund & Brown, 1998; Kirk, 2005).

A majority of literature focus on examining the effects of physical activity and exercise on cognitive functioning. For instance, Mahar et al. (2006) revealed that classroom-based physical activity interventions have been proven to be effective in improving on-task behavior during instruction time. Kamijo et al. (2011) indicated that improvements in working memory were found following a 9-month physical activity intervention in children aged 7-10 years. Similarity, Chaddock-Heyman et al. (2013) suggested that children ages of 7-9 participated in 60 minutes of physical activity (5 days per week for 9 months) showed increased cognitive control. Booth et al. (2013) found that higher MVPA was associated with better executive attention performance while light

physical activity was a predictor of lower executive functioning performance in children. Review evidence also indicated that there were significant positive relationships between physical activity, fitness, cognition, and academic achievement, with improvements in executive function and academic achievement were associated with acute bouts of activity and fitness among 5-13 year children. The findings, however, were inconsistent (Donnelly et al., 2016; Sibley & Etnier, 2003; Zeng et al., 2017).

In general, the evidence from intervention studies suggests that MVPA participation would be able to induce improvements in certain aspects of executive function in children (Davis et al., 2011; Fisher et al., 2011), while supporting that prolonged physical activity participation may aid improvements in working memory and its neural underpinnings during tasks requiring more extensive amounts of cognitive control (Chaddock-Heyman, Hillman, Cohen, & Kramer, 2014). These interventions provided a preliminary understanding of the influence of physical activity on cognitive development. In these studies, however, children's physical activity behaviors were stimulated beyond their normal activity by the interventions within which the children were enrolled. Thus, it remains unclear whether children's habitual physical activity (i.e., the typical activity pattern of children in daily life) is related to cognitive development.

Relationship between Motor Skill Competence and Perceived Competence

In Stodden et al. (2008)'s model, the importance of motor skills and perceived competence toward lifetime participation in physical activity was proposed. It was suggested that motor skills and perceived competence were primary mechanisms that were linked with physical activity participation and health-related fitness. Over the past decades, research examining the relationship between motor skills and perceived

competence has been explored. These studies found that children with high perceived competence tend to demonstrate higher self-esteem, exert greater effort and select tasks that challenge their ability (Weiss & Amorose, 2005). In addition, children who perceive themselves to be highly competent at a skill task will exhibit persistence and attempt to master a skill, whereas those with low competence will not persist and lose interest in that task (Sollerhed et al., 2007). Meanwhile, fundamental motor skills along with perceived physical competence could contribute to the health of young children given their potential effects of physical activity participation (Goodway & Rudisill, 1997; McCullough, Muldoon, & Dempster, 2009; Robinson, 2011). That said, perceived competence along with motor skills play an essential role in children's motivation to learn and to participate in current and future motor behaviors (Deci & Ryan, 2000; Robinson, Rudisill, & Goodway, 2009).

Evidence regarding the relationship between perceived physical competence and physical activity participation in children between the ages of 8 and 12 years has been well documented (Bagoien & Halvari, 2005; Barnett, Morgan, van Beurden, & Beard, 2008; Carroll & Loumidis, 2001; Fu et al., 2014; Gao, 2008; Stein, Fisher, Berkey, & Colditz, 2007). Nevertheless, research assessing this relationship in preschool children is scant. For example, Nobre, Bandeira, and Valentini (2016) found that the relationships were weak and not significant between perceived motor competence, perceived competence relative to tasks, and actual motor competence in preschool-aged school children ($N = 75$). In contrast, Goodway and Rudisill (1997) found that that African-American preschoolers' ($N = 59$) object control skill ability significantly predicted their perceived physical competence. Later, Robinson (2011) observed a moderate and

significant correlation between perceived physical competence and fundamental motor skills in preschool children ($N = 119$). Therefore, inconsistent findings appeal a most recent investigation to confirm this relationship in preschool children.

Relationship between Motor Skill Competence and Cognition

Motor skills and cognitive performance are broad concepts and have been defined in a variety of different ways. Generally speaking, motor skills refer to learned sequences of movements that are combined to produce a smooth, efficient action in order to master a particular task (Davis et al., 2011). Different categories of motor skills are distinguished: (1) gross motor skills, which require the use of large muscle groups of the body to perform tasks including crawling, walking, running, jumping, sprinting, swimming, etc. (Stallings, 1973). Moreover, all underlying physical abilities like strength, agility, flexibility, and balance that are required to perform a task are included in this category (van der Fels et al., 2015); (2) fine motor skills require the use of smaller muscle groups to perform tasks that are precise in nature, such as playing the piano and video games; picking up objects; using cups, knives and forks; pouring drinks; dressing; holding and using pencils, pens, scissors, etc. (Stallings, 1973); (3) bilateral body coordination, refers to whole body coordination tasks and demands engagement of all body parts and bilateral motor coordination of lower and upper extremities (Planinsec & Pisot, 2006); and (4) locomotor skills (e.g., running, hopping, leaping, jumping, crawling, walking, galloping and skipping) and object control skills (e.g., kicking, striking, throwing, catching, bouncing and dribbling) (Haywood & Getchell, 2014). Of note, above categories are not exclusive so that motor skills from one category may include elements of other categories.

In addition, cognitive performance refers to the mental actions or processes relating to acquiring knowledge and understanding through thought, experience, and the senses in brain. A well-functioning brain controls a range of voluntary and involuntary actions (Davis et al., 2011). Different aspects of cognitive performance are described in previous literature: (1) executive functions are described as higher order cognitive performance that enable self-control and include the following metacognitive functions: response inhibition, planning, attention, and working memory (Gazzaniga, Ivry, & Mangun, 2009); (2) visual processing is described as a path that information taken in through eyes (visual sensors) to cognitive processing (Boden & Giaschi, 2007); (3) short-term memory denotes the capacity to hold the temporary of information in mind in the absence of external stimulation over a short period of time, whereas long-term memory is described as information retained for a significant time (Gazzaniga et al., 2009); (4) intelligence quotient is a measure to calculate a person's intelligence; and (5) academic achievement is a student's success in meeting short- or long-term goals in educational settings.

Historically, there have been different perspectives with regard to the relationship between motor skills and cognitive development in children. On one hand, motor skills and cognition have been seen as entirely different processes, developing independently, and involving different brain regions (Hertzberg, 1929). On the other hand, Piaget (1952) believed that motor skills and cognitive development are related closely, given that children will learn from observable motor actions with objects. Some reasons can explain this possible relationship between motor and cognitive skills in children. To begin, research has shown co-activations among the prefrontal cortex, the cerebellum, and the

basal ganglia during multiple motor and cognitive tasks, especially when a task is demanding, a quick response and concentration is required to perform that task (Desmond, Gabrieli, Wagner, Ginier, & Glover, 1997; Diamond, 2000). Second, it was suggested that motor and cognitive skills might have a similar developmental timetable with an accelerated development between the ages of 5 and 10 years (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001). Finally, both motor skills and cognitive development have several common underlying processes, including sequencing, monitoring, and planning (Roebbers & Kauer, 2009). Therefore, these evidence highlights a necessity to further explore how motor skills associate with cognition in children.

Over the past few decades, the relationship between motor skill competence and cognition among children and adolescents has been widely investigated. For example, Son and Meisels (2006) assessed the relationship between motor skills at the beginning of kindergarten and reading and mathematics achievement at the end of first grade in children ($N = 12,583$). Results demonstrated that early kindergarten motor skills, especially visual motor skills, add a small but unique amount of variance to achievement in reading and mathematics at the end of first grade. The study highlighted the important role of motor skills in developing an early school achievement battery. Moreover, Davis et al. (2011) examined the relationship between cognitive and motor skills in typically developing children ($N = 248$; 4-11 years old). Motor skills were measured via The Bruininks-Oseretsky Test of Motor Proficiency-2nd Edition (BOT-2: Bruininks & Bruininks, 2005, Pearson Assessments), and cognitive abilities were assessed via The Kaufman Assessment Battery for Children-2nd Edition (KABC-II: Kaufman & Kaufman,

2004, Pearson Assessments). Results indicated a significant and moderate relationship between cognitive abilities and motor scores across all participants.

Moreover, Rigoli, Piek, Kane, and Oosterlaan (2012) examined whether the relationship between motor coordination and academic achievement is mediated by working memory in 93 adolescents aged 12-16 years. The MABC-2 provided three indicators of motor coordination (i.e., manual dexterity, aiming and catching, and balance), the working memory Index of the Wechsler Intelligence Scale for Children-IV and the N-back paradigm provided two indicators of working memory, and the Wechsler Individual Achievement Test-II provided three indicators of academic achievement (word reading, spelling, and numerical operations). The findings suggested that the relationship between motor coordination and academic achievement in adolescents may be explained by motor coordination. Specifically, aiming and catching skills, have an indirect impact on academic outcomes via working memory. Similarly, Haapala et al. (2014) investigated the relationships between motor performance and academic skills in children 6-8 year olds ($N = 341$). Motor performance was assessed via the shuttle run test time, the errors in balance test, and the number of cubes moved in box and block test, while academic skills were evaluated using reading fluency, reading comprehension, and arithmetic skill tests. Findings suggested that poorer motor performance was associated with worse academic skills, especially among boys. A recent study by Beck et al. (2016) revealed that children who performed poorly in motor skills tests tend to have lower reading and arithmetic test scores in first through third grades, whereas children with better performance in motor tests scored higher in reading and arithmetic tests.

On the other hand, Jenni et al. (2013) examined the relationship between motor skills and intellectual function in 252 healthy children. Children's motor skills and intellectual functions were assessed via the Zurich Neuromotor Assessment and standardized intelligence tests, respectively. The results indicated that neuromotor and intellectual scores were only weakly correlated with each other. In other words, specific connections between motor and intellectual functions may exist. However, motor and intellectual domains in healthy children might be largely independent. Notably, a recent literature review confirmed this premise indicating there was weak to strong relationships between motor skills and cognitive development in 4-16 year children (van der Fels et al., 2015).

Despite the positive relationships between motor skills and cognitive development were observed from previous studies, there is still insufficient evidence to support the existence of such relationship in children. Notably, there is scant literature investigating this relationship in early childhood. Therefore, more research is needed.

Relationship between Motor Skill Competence and Cardiovascular Fitness

It is widely believed that the performance of children and adolescents on aerobic fitness tests has declined over the past few years (Tomkinson, Léger, Olds, & Cazorla, 2003). Children are spending more time engaging in sedentary behaviors (Hills, King, & Armstrong, 2007; Lopes, Santos, Pereira, & Lopes, 2012), and less time being physically active (Strong et al., 2005). Subsequently, a decline in children's motor skill competence and health-related fitness has been reported (Hardy, Barnett, Espinel, & Okely, 2013; Tomkinson et al., 2003). To be physically active, children need the combined attributes of both health-related fitness (e.g. cardiorespiratory endurance, heart rate and blood

pressure responses to exercise and body composition) and performance-related fitness such as motor skill proficiency (Haga, 2008).

The theoretical model developed by Stodden et al. (2008) proposes a reciprocal and developmentally dynamic relationship between motor skill competence and health-related fitness with the strength of this relationship increasing over time. It was suggested that children with poor motor skill proficiency are more likely to choose a sedentary lifestyle to avoid the movement difficulties they possess (Milne, Leong, & Hing, 2016), and thus decreasing physical activity and worsening states of fitness, including cardiorespiratory fitness. Therefore, it is reasonably hypothesized that a child with good motor skills would be more likely to possess enhanced health-related fitness (e.g. higher cardiorespiratory fitness, greater muscular strength, lower body composition, etc.). Notably, a recent study found that the correlation between gross motor skills and health-related fitness increases over time, indicating that these skills may play a role in the relationship between motor skills and health-related fitness (Stodden, Gao, Goodway, & Langendorfer, 2014). Meanwhile, a review by Robinson et al. (2015) supported Stodden et al. (2008) model that motor skill competence could be related to multiple aspects of health in children and adolescents (i.e., physical activity, cardiorespiratory fitness, muscular strength, muscular endurance, and a healthy weight status).

To date, few studies have examined the relationship between motor skill competence and cardiovascular fitness in children. Milne and colleagues (2016) found that elementary children's motor skill proficiency is significantly related to a number of health-related measures (i.e., body mass index, waist circumference and cardiorespiratory fitness). Farhat et al. (2015) examined the effects of an 8-week motor skill training on

cardiorespiratory fitness and endurance performance in children with developmental coordination disorder (DCD). The results showed that the DCD group improved their cardiorespiratory fitness as measured by power, perceived exertion, and VO_{2max} . In other words, a causal relationship between motor skill and cardiorespiratory fitness in children with DCD has been proven.

A recent systematic review by Cattuzzo et al. (2016) assessed the scientific evidence on relationships between motor competence and components of health-related physical fitness in children and adolescents. Of 44 included studies, 12 investigated the cardiorespiratory fitness separately while 6 studies gauging cardiorespiratory fitness as part of a composite health-related fitness assessment. The authors concluded that there was strong evidence for a positive relationship between cardiorespiratory fitness and motor skill competence in children and adolescents. However, the authors stated no studies have examined this relationship in preschool children. Therefore, there is an emerging need to investigate the motor skill competence and cardiorespiratory fitness in typically developing preschool children.

Relationship between Cardiovascular Fitness and Cognition

It has been recognized that regular physical activity participation enhances cognitive functioning (DeWeerd, 2011). Physical exercise, as indexed by cardiovascular fitness, is a factor that strongly impacts brain plasticity (Hillman et al., 2008). The cardiovascular fitness hypothesis proposes that cardiovascular fitness is the physiological mediator that partially explains the mental health benefits of physical activity (North et al., 1990). As applied to cognitive performance, this hypothesis interprets that the gains in cardiovascular fitness achieved through regular physical activity participation may lead

to cognitive benefits (Barnes, Yaffe, Satariano, & Tager, 2003; Chodzko-Zajko & Moore, 1994; Van Boxtel et al., 1997; Voss, 2016). Meanwhile, it was suggested that participating in at least moderate intensity physical activity could result in an increase in the ability of the heart to deliver oxygen to the working muscles and is indicative of an increase in cardiovascular fitness (American College of Sports Medicine, 2000), and these gains in cardiovascular fitness are believed to be connect with changes in underlying physiological mechanisms such as cerebral structure (Colcombe & Kramer, 2003), cerebral blood flow (Endres et al., 2003), and brain-derived neurotrophic factor (Vaynman & Gomez-Pinilla, 2005), which of them have been shown to be associated with cognitive performance (Bjorklund & Brown, 1998; Moss, Franks, Briggs, Kennedy, & Scholey, 2005). Therefore, the cardiovascular fitness hypothesis proposes that changes in cognition might be caused by increased cardiovascular fitness.

Previous research has demonstrated significant relationship between cardiovascular fitness and improved brain functions in adults. For example, Aberg et al. (2009) investigated the relationship between physical activity and cognitive performance, as well as the specific interactions of cardiovascular fitness and muscular strength on cognitive performance in young adulthood. Results showed that cardiovascular fitness was positively associated with intelligence. However, muscle strength was not associated with cognitive performance. In addition, Dupuy et al. (2015) assessed fitness level, cerebral oxygenation changes and cognitive performances in younger and older women. The authors found that higher fit individuals tend to demonstrate better cardiorespiratory functions and show faster reaction times and greater cerebral oxygenation in the right inferior frontal gyrus than women with lower fitness levels. The findings suggested that

good cardiorespiratory functions may have a positive impact on cognition. Notably, meta-analyses also demonstrated a positive relationship between cardiovascular fitness and cognitive performance (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Etnier, Nowell, Landers, & Sibley, 2006), indicating that higher levels of cardiovascular fitness were linked with increased hippocampal volume and better memory function in older adults (Erickson et al., 2009; Jonasson et al., 2017).

While the relationship between cardiovascular fitness and cognition has been well explored in adults, evidence regarding this relationship in young children is scant. California Department of Education (2001) indicated that achievement in standardized tests of mathematics and reading was positively related to physical fitness scores that measured by the progressive cardiovascular endurance run test in school-aged children. Notably, muscle strength and flexibility fitness were unrelated to academic achievement, and therefore, this relationship might be selective to cardiovascular fitness (Castelli, Hillman, Buck, & Erwin, 2007). Moreover, a systematic review by Keeley and Fox (2009) suggested there were positive relationships between physical activity/fitness (including cardiovascular fitness) and academic achievement/elements of cognitive function in school children.

Based upon the previous findings, the evidence regarding the relationship between cardiovascular fitness and cognition in children is favorable. However, there is a knowledge gap about this relationship in preschool children. Therefore, future research is warranted.

Gender Difference in Physical Activity

Epidemiological studies of youth physical activity have consistently reported that boys are more active than girls (using both research-grade accelerometers and self-report methods), and that physical activity declines with age (Oliver, Schofield, & Kolt, 2007). In detail, Tucker (2008) conducted a thorough systematic review to present research on the physical activity levels of preschool-aged children (aged 2-6 years). Thirty-nine primary studies (published 1986–2007) representing a total of 10,316 participants (5236 male), from seven countries were included. Upon review of the evidence, it is apparent that nearly half of preschool-aged children do not engage in sufficient physical activity. Of note, boys participate in considerably more physical activity than girls. In addition, Pate, McIver, Dowda, Brown, and Addy (2008) described physical activity levels of children ($N = 490$) attending preschools by Observational System for Recording Physical Activity in Children-Preschool (OSRAC-P). Researchers found that children engaged in MVPA during less than 3%, and were sedentary during more than 80% of the observation intervals. Notably, boys were more likely than girls to engage in MVPA, while 3 years old boys were more active than 4 and 5 years old boys.

More recently, Soini et al. (2014) sought to determine physical activity levels and how these vary across gender in Finland preschool children ($N = 81$). A modified version of the OSRAC-P was used to measure children's physical activity levels. Findings indicated that children were mostly sedentary in nature, only engaging in 2% MVPA of all observations. The results further showed a significant difference in gender with boys showed significantly higher physical activity levels than girls. Furthermore, Hesketh, Griffin, and van Sluijs (2015) assessed the in-care and out-of-care activity patterns of 202

(51% female) preschool-aged children in UK and explored differences in physical activity level measured by an Actiheart activity monitor. The study found that boys accumulated more MVPA in care compared to at home, and thus concluded that boys were less sedentary and more active compared to girls.

Interestingly, Kambas et al. (2015) investigated ambulatory activity using Omron HJ-720IT-E2 pedometers for 10 consecutive days in Greece preschool children ($N = 250$). The study found significant differences between normal and obese children's step counts on weekdays, weekend days, during school, after school and in weekly steps. No gender differences, however, were observed. Although the study did not use research-grade accelerometers to assess children's physical activity, step count is also promoted as a useful indicator of the level of physical activity for an individual (Strath et al., 2013).

It appears that most literature supporting gender difference in preschool children's physical activity, with boys are more active than girls. Nevertheless, a consensus is not reached yet. Therefore, it is necessary to further confirm gender difference in preschool children's physical activity using the most advanced objective measurement tool.

Gender Difference in Motor Skill Competence

Early childhood is a critical period for the development of fundamental movement skills. Children who do not master fundamental motor skills are more likely to experience failure in the motor domain and less likely to participate in sport and games during childhood and adolescence (Hardy et al., 2010). Over the past decades, scientific evidence has grown on the importance of motor skill competence for physical activity participation in preschool children. Today, empirical studies investigating gender differences in children's motor skills has burgeoned in academia. For instance, Goodway

and Rudisill (1997) examined the relationship between perceived physical competence and actual motor skill competence in African American preschool children ($N = 59$) at risk of school failure and/or developmental delay, while gender differences across these variables were determined. Actual motor skill competence was measured by the Test of Gross Motor Development-2 (TGMD-2; Ulrich, 2000). The results indicated that the object control component of actual motor skill competence differed from gender, with boys had actual object control motor skill than girls did.

Similarly, Robinson (2011) examined the effect of sex on fundamental motor skills in preschoolers ($N = 199$, 65 boys). The TGMD-2 (Ulrich, 2000) was used to assess fundamental motor skills. As a result, gender differences were observed, with boys had more proficient motor skills compared to girls. Specifically, boys demonstrated higher total score and object control score. Unlike Goodway and Rudisill (1997)'s work, however, the authors found that boys' locomotor score were higher than girls'. In addition, Goodway, Robinson, and Crowe (2010) examined the influence of gender and region on object control and locomotor skill development in preschool children. Participants were 275 Midwestern African American and 194 Southwestern Hispanic preschool children. The study found that there was no significant region effect for object control skills, indicating children from both regions had statistically similar skills. There was, however, a significant difference between genders with boys outperformed girls on object control skills in both regions.

Moreover, Hardy et al. (2010) conducted a cross-sectional study of 425 (171 boys) preschool children in the Sydney, Australia to assess gender differences in fundamental movement skills. The TGMD-2 (Ulrich, 2000) was used including

locomotor (run, gallop, hop, horizontal jump) and object control (strike, catch, kick overhand throw) skills. The study observed that total locomotor score was higher among girls compared with boys, but only the hop was significantly different. Notably, boys had higher total and individual object control scores compared with girls, except the catch. In addition, the prevalence of mastery differed across each skill. Specifically, girls generally had higher mastery of locomotor skills and boys performed higher mastery of object control skills. Recently, Foulkes et al. (2015) conducted a cross-sectional study to examine fundamental movement skill among underserved preschool children ($N = 168$) in Northwest England while exploring gender differences. Six locomotor (run, jump, leap, hop, gallop, and slide) and six object control (overarm throw, stationary strike, kick, catch, underhand roll, and stationary dribble) skills were assessed using the TGMD-2 (Ulrich, 2000). The study reported that boys had significantly better object control skills than girls, with greater competence observed for the kick and overarm throw, whereas girls were more competent at locomotor skills in run, hop, and gallop.

The evidence appears to support boys are more proficient than girls. However, a definite conclusion cannot be drawn yet given the conflicting findings still remain. Therefore, more research is warranted.

Gender Difference in Cardiovascular Fitness

Physical fitness is a condition that permits an individual to carry out his or her daily activities without undue fatigue and with adequate reserve to enjoy active leisure pursuits (Malina & Katzmarzyk, 2006). Physical activity and physical fitness have similar influence on physical and psychological health outcomes, and physical fitness is a strong indicator of present and future health in children and adolescents (Mess, et al.,

2013). Over the past several years, research has been conducted to assess gender differences in preschool children's physical fitness, and it was believed that boys tend to have better physical fitness level than girls (Riddoch et al., 2004). For example, Ergun, Tunay, and Baltaci (2006) conducted a study to assess gender differences in health-related physical fitness in Turkish kindergarten children ($N = 16$). Each child completed a battery of health-related physical fitness tests including skinfold thickness for body composition, sit ups and pull-ups for muscular strength and endurance, sit and reach test for flexibility, standing broad jump test for power, flamingo test for balance, and 10-meter running (cardiovascular fitness). Results indicated girls had better performance in flexibility and balance tests, but no significant differences in other tests. Krombholz (2006) investigated whether gender differences exist in preschool children's physical fitness. A total of 1194 kindergartens in the city of Munich, Germany were recruited. Children's physical fitness was measured by standing broad jump, 4-meter shuttle run (cardiovascular fitness), and hanging task. The findings indicated that boys significantly exceeded on all measures except arm hanging than girls did. In addition, Román et al. (2016) sought to determine the physical fitness among preschool children ($N = 3868$, 1961 boys) in southern Spain. Results demonstrated significant differences were found between genders, with boys showing a greater performance on cardiorespiratory endurance, reaction time, strength and running speed.

Conversely, a recent study by Cadenas-Sánchez et al. (2014) examined gender differences in cardiorespiratory endurance in preschool children ($N = 130,77$ boys). The 20-meter shuttle run test, and the maximum heart rate were used to assess children's

cardiorespiratory fitness. The findings suggested no significant gender differences were observed.

To summarize, although gender differences in preschool children's cardiorespiratory fitness are evident, the findings from available literature are still inconsistent. Namely, more research is needed.

Gender Difference in Perceived Competence

As the need to increase physical activity levels during childhood being urgent, researchers have investigated the potential correlates of physical activity, with perceived physical competence considered a critical one among others (Afthentopoulou, Venetsanou, Zounhia, & Petrogiannis, 2018). Children's positive perceptions regarding their physical competence are a key increased physical activity as positive perceptions may affect motivation towards participation in physical activity (Babic et al., 2014; Craven & Marsh, 2008). In other words, higher levels of perceived physical competence might be positively linked with increased physical activity participation in children.

A considerable number of studies have investigated gender differences in children's perceived competence. For instance, Granleese, Trew, and Turner (1998) examined gender difference in children's perceived competence. The Perceived Competence Scale for Children was completed by 102 boys and 88 girls aged 11 years. Finding suggested that girls were significantly lower on physical and general competence than boys. In addition, Piek, Barrett, Smith, Rigoli, and Gasson (2010) probed the relationships among enjoyment, perceived competence, fundamental movement skills, and physical activity engagement in 7th graders ($N = 404$), while examining gender differences in all assessed variables. The results revealed that boys perceived higher

levels of physical competence than girls. In addition, Robinson (2011) investigated the effect of gender on perceived physical competence in preschoolers ($N = 199$). The Pictorial Scale of Perceived Competence and Social Acceptance (Harter & Pike, 1984) was used to evaluate perceived physical competence. As a result, gender difference was seen, with boys perceiving higher physical competence compared to girls. Similarly, Slingerland et al. (2014) investigated gender difference in children's perceived competence ($N = 216$, 90 girls, aged 11-15). The study found that girls' perceived competence was lower than boys'. Notably, a recent longitudinal cohort study by Noordstar, van der Net, Jak, Helders, and Jongmans (2016) found that boys from kindergarten to second grade tend to report higher levels of perceived physical competence and were more physically active than girls as they age.

Interestingly, Afthentopoulou et al. (2018) examined perceived movement competence differences between boys and girls ($N = 142$, 65 boys, aged 6-9). Children's perceived movement competence was assessed via the Pictorial Scale of Perceived Movement Skill Competence-Greek version. The study observed that boys had higher perceived object control skills than girls, whereas there were no gender differences in children's perceived locomotor skills. It was concluded that between 6 and 9 years, gender differences in perceived movement competence were small and located only in object control. Conversely, a study by LeGear et al. (2012) revealed that girls aged 4-6 years reported higher perceived motor competence than their male peers. In addition, studies indicated no gender difference in perceived competence in children between age 6-7 years, with girls and boys presenting the same level of perceived physical competence (Mantzicopoulos, 2006; Planinšec & Fošnarič, 2005).

Overall, the research findings regarding gender differences in children's perceived competence are contradictory, with most studies suggesting that boys tend to report higher perceptions of physical competence compared to girls, but small portion of research suggested girls may perceive themselves to be more competent than boys, and no gender differences exist in perceived competence in this population. That being said, more research is warranted.

Gender Difference in Cognition

Preschool age is a period of rapid growth along with a number of cognitive development. Across this time period, children learn how to use symbolic thought, the hallmarks of which are language and symbol use, as well as imitate adult's behaviors (Piaget, 1964). Children at this age present centration of thought, and their own ways of categorizing, reasoning, and problem solving (Piaget, 1964). Research investigating children's cognitive development has burgeoned in the past decade. Of note, identifying gender difference in preschool children is of particular interest. For instance, Dobbs, Arnold, and Doctoroff (2004) examined gender differences in misbehavior and specific types of non-disciplinary teacher attention in preschool children ($N = 153$). The study found that girls received more positive interactions than boys, indicating girls receive more attention from their teachers compared to boys. In addition, Kaushanskaya, Gross, and Buac (2013) investigated gender differences in word learning and referent familiarity in children ($N = 69$, 30 girls, ages 5-7). Children learned phonologically-familiar or phonologically-unfamiliar novel words in association with pictures of familiar referents (animals) or unfamiliar referents (aliens). Findings revealed stronger phonological and referent familiarity effects in girls than in boys, suggesting that girls tend to have better

learning and memory than boys. Similarly, Rescorla, Nyame, and Dias (2016) examined effects of language, gender, and age on vocabulary size, lexical composition, and late talking in Portuguese and U.S. children. A total of 387 preschool children participated and learned European Portuguese ($n = 181$) and English ($n = 206$). The Language Development Survey (Rescorla, 1989) was used as measurement tool. Results suggested that girls had higher vocabulary scores than boys and vocabulary scores increased with age in both languages, indicating that girls may have better ability in language learning than boys.

On the other hand, some studies observed mixed findings on some aspects of cognitive function. For example, Wei and Hendrix (2009) investigated whether competitive and noncompetitive educational mathematics computer games influence children's (4-7 years old) recall of game playing experience. The study found that boys tend to first recall the consequence of "winning and losing", whereas girls focused on "friendship among animated characters" in the game. The results suggested that selective attention or selective recall might be partially influenced by gender. Moreover, Matthews, Ponitz, and Morrison (2009) examined gender differences in self-regulation and academic achievement (i.e., math, general knowledge, letter-word identification, expressive vocabulary, and sound awareness) in kindergarten ($N = 268$). Results indicated no significant gender differences were found on the 5 academic achievement outcome variables. In a recent study, Yamamoto and Imai-Matsumura (2017) examined gender differences in preschool children' ability for behavioral self-regulation and executive function. A total of 107 children (5 years old) were assessed on behavioral self-regulation, inhibitory, and working memory tasks (direct measurement). The findings

demonstrated that there were no significant gender differences in behavioral self-regulation and executive function. Given the previous literature, it appears that findings regarding gender difference in preschool children's cognition are mixed. Therefore, more research is needed.

Summary

I have summarized the scientific research on the relationships among physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition in children. Meanwhile, I reviewed gender differences in these outcome variables. Overall, evidence regarding multiple relationships among these variables are inconclusive, and gender differences are mixed. Notably, limitations also are noted in the previous literature. Resulting from the mixed findings, a definite conclusion has yet to be drawn. Therefore, more research is warranted.

Chapter Three

Methodology

Subjects

To achieve statistical significance, I calculated the sample size by G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf), indicating that 80 participants would be sufficient for 80 % power ($\alpha = 0.05$, effect size = 0.30). I recruited the participants from two public schools in Minneapolis, Minnesota for the current study. Inclusion criteria were (1) children aged 4-6 years; (2) children without diagnosed physical and/or mental disabilities according to school records; (3) provision of parental consent forms. Conversely, exclusion criteria were: (1) greater than 6 years of age or younger than 4 years of age; (2) school record diagnosed physical/mental disability; (3) did not provide informed consent forms.

Research Design

To address my study aims, I implemented a cross-sectional study (i.e., non-experimental design) with convenience sample recruitment. I collected multiple variables from each child in the sample. I collected data at a single point in time and analyzed as a single group.

Research Setting

Two schools participating in the study were within Minneapolis Public Schools that offered high-five classes. Two classes (AM and PM) with approximately 25-30 children in each class from each school were involved in the current study. All the data collection occurred in school setting and no any tests were conducted outside school. If the kid was absent on testing day, he/she was given a makeup test next day. Prior to data

collection, I contacted the physical education instructors and preschool teachers to request class schedule and then arranged the testing sessions.

Data Collection

Demographic and anthropometric measurements

First, I obtained demographic information of children whose parents have consented to participate in this study from school records, including: date of birth, gender, race/ethnicity, and disability status. Afterwards, I measured participants' height to the nearest half-centimeter using a Seca stadiometer (Seca, Hamburg, Germany) and gauged weight using the Tanita BC-558 IRONMAN® Segmental Body Composition Monitor (Tanita, Tokyo, Japan) digital weight scale (Appendix A).

Outcome measures and instruments

Primary Outcomes

Physical Activity Levels. I used ActiGraph GT9X Link accelerometers (Actigraph Corps., Pensacola, FL) to capture preschool children's physical activity levels. The ActiGraph GT9X Link is lightweight and resembles a watch. The ActiGraph monitor has been proven to be a valid and reliable measure of physical activity in preschool children at school settings and free-living settings (Johansson, Larisch, Marcus, & Hagströmer, 2016; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004; Sirard, Trost, Pfeiffer, Dowda, & Pate, 2005; Van Cauwenberghe et al., 2011). I instructed participants to wear the accelerometers on the dominant wrist at all times during school time for 3 consecutive school days. In detail, prior to data collection, I assigned each child an identification number that matched up with the number on his/her accelerometer. During the data collection, I visited the school 10-15 minutes before the school started. Once children

arrived at school, I helped equip the accelerometer on each child. I also asked preschool teachers to oversee and ensure the accelerometers were worn correctly all the time during school. Notably, if anyone left or removed the accelerometers earlier, he/she was asked to wear the accelerometers one more day. As such, the reactivity effect was minimized. The accelerometers were collected at the end of the school. For each child, I recorded the time for placement and removal of the accelerometers after receiving the equipment.

Afterwards, accelerometry data were downloaded into ActiLife 6.0 (Actigraph Corps., Pensacola, FL, USA) for data sorting and processing. Data from accelerometers were truncated and matched to the initial time frames when physical activity occurred for each participant. Finally, all the data were imported into a SPSS data file for descriptive statistical analyses.

Activity counts were set at 1-second epoch given the sporadic nature of children's physical activity and short duration of school time (Troost, Mciver, & Pate, 2005). Counts then were interpreted using empirically-based cut points that define different physical activity intensities for preschool children (i.e., Sedentary: 0-799 count per minute; Light: 800-1679 count per minute; Moderate: 1680-3367 count per minute; Vigorous: ≥ 3368 count per minute) (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006), with children's percentage of time spent on MVPA as the primary outcome variable (Appendix B). Notably, I also calculated step counts as another primary outcome given they are useful indicator of physical activity levels (Strath et al., 2013). Physical activity data were only considered valid if accelerometer data is present for at least 3 observed days (Lee, Macfarlane, & Cerin, 2010; Troost et al., 2005). Compliance with wearing accelerometers were facilitated according to Troost recommendations (Troost et al., 2005). Notably, in the

current study, the ActiGraph monitors were not allowed to take home given the following considerations: 1) additional burden in underserved families; 2) lost or stolen device; 3) incomplete and inaccurate measurements. Therefore, I only used physical activity data during school time for the current study. That is, the exclusion of preschool children's outside school physical activity could be a limitation of the study given it does not represent the complete daily physical activity levels for a child.

Secondary Outcomes

Motor Skill Competence. I used The Test of Gross Motor Development-2 (TGMD-2) (Ulrich, 2000) to assess preschool children' motor skill competence. The TGMD-2 is a qualitative measure to assess the gross motor skills of children aged 3-10 years, which is made up of 12 skills (six for each subtest): (1) Locomotor: run, gallop, hop, leap, horizontal jump, slide; (2) Object Control: striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll. The current study selected 5 skills tested are run, hop, jump, kick and throw, with children executing each skill twice. To evaluate skill performance, qualitative performance criteria were scored, with 1 indicating presence of a performance criteria for a given motor skill and 0 indicating the absence of the performance criteria. If a skill is assessed using three performance criteria, the raw scores can therefore vary between 0-6. The highest raw total subtest score for the locomotor as well as the object control skills is 20 (Appendix C).

Cardiovascular Fitness. I used a modified YMCA 3-Minute Step Test (Golding, Meyers, & Sinning, 1998) to assess preschool children's cardiovascular fitness. Specifically, children stepped up and down for three minutes on a 6-inch riser to a metronome beat set at 96 beats per minute (each beep corresponding to one movement of

the leg with 4 beeps representing one up-down cycle). After the test, I measured children's heart rates immediately via palpation of the radial artery, with the child's one minute heart rate recorded, which was used to represent children's cardiovascular fitness. Children were encouraged to do their best while performing the tests (Appendix D).

Perceived competence. I used the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984) to assess children's perceived competence. More specifically, I used the subscale of perceived physical competence to assess children's perceptions of physical competence. I selected the scale as the following reasons: (1) the scale has strong psychometric properties for children 4 years and older (e.g., $\alpha > .70$) (Harter, 1985, 1999); (2) the scale is developmental in nature, reflecting children's changing perception of self (Harter, 1999); and (3) the scale has been widely used and accepted in the literature (Harter, 1985, 1999; Harter & Pike, 1984). Children responded to a 5-item perceived physical competence survey using a 4-point Likert-type scale (1: not too good to 4: really good). I calculated the item mean and used it as a measure of children's perceived physical competence (Appendix E).

Cognition. I used the computer-administered NIH Toolbox to assess children's attention and executive functioning (Mungas et al., 2013; Weintraub et al., 2013). In detail, I asked children to complete The Flanker Test (a measure of inhibitory control and attention) on an iPad (Rueda et al., 2004). The Flanker test requires the child to focus on a given stimulus while inhibiting attention to stimuli (i.e., fish) flanking it. Sometimes the middle stimulus is pointing in the same direction as the "flankers" (congruent) and sometimes in the opposite direction (incongruent). Twenty trials were conducted. If a participant's scores $\geq 90\%$ on the fish stimuli (with no more than one congruent and one

incongruent trial incorrect), then 20 additional trials with arrows were presented (Appendix E).

Scoring of children's attention and executive functioning is based on a combination of accuracy and reaction time. A 2-vector scoring method is employed that uses accuracy and reaction time, where each of these "vectors" ranges in value between 0 and 5, and the computed score, combining each vector score, ranges in value from 0-10. For any given individual, accuracy is considered first. If accuracy levels for the participant are less than or equal to 80%, the final "total" computed score is equal to the accuracy score. If accuracy levels for the participant reach more than 80%, the reaction time score and accuracy score are combined. Specifically, the accuracy score varies from 0 to 5 points. For every correct behavioral response, a participant receives a value of 0.125 (5 points divided by 40 trials) added to his/her score for Flanker: *Flanker Accuracy Score = 0.125 * Number of Correct Responses*. Like the accuracy score, the reaction time score ranges from 0 to 5 points. One issue regarding reaction time data is that it tends to have a positively skewed distribution. A log (Base 10) transformation is therefore applied to each participant's median reaction time score from the Flanker, creating a more normal distribution of scores. Based on data from a validation study of the NIH Toolbox Cognition Battery, the minimum median reaction time for scoring is set to 500 ms and the maximum reaction time for scoring is 3,000 ms. Participants with median reaction times that fall outside this range but within the allowable range of 100 ms – 10,000 ms are truncated (i.e., reaction times between 3,000 ms and 10,000 ms are set equal to 3,000 ms) for the purpose of score calculation.

Scoring of the validation data indicates that this truncation does not introduce any problems with regard to ceiling or floor effects. Log values are algebraically rescaled from a log (500)-log (3,000) range to a 0-5 range. Note that the rescaled reaction time scores are reversed; smaller reaction time log values are at the upper end of the 0-5 range while larger log values are at the lower end of the range. The formula for rescaling is: $Reaction\ Time\ Score = 5 - \{5 * [\log RT - \log(500) / \log(3000) - \log(500)]\}$ (U.S. Department of Health and Human Services, 2016). This engaging game-like task are appropriate for the age range specified in this study. Notably, these assessments are individually-administered and require an environment that is reasonably quiet and distraction-free. As such, behavior observations during testing were recorded throughout and any distractions during testing that could impact assessment validity documented.

Procedures

After obtaining the approval from Institutional Review Board at the University of Minnesota Twin Cities, I contacted two local elementary schools (A and B) in Minneapolis. I also acquired the permission for conducting the research at these two schools from the school district, school principals, high-five program teachers, and physical education teachers. I delivered the consent forms that explain the purpose and procedures of the study to parents with the assistance of the class teacher. I initiated the study after which parents or guardians have provided the informed consent forms that allow their children to participate in the current study.

Prior to data collection, I explained the purpose and procedure of the study to all children and teachers. Further, I informed children and teachers that participation in the study was voluntary and that they had the right to decline and withdraw from the study at

any time. To begin, I equipped each child with an ActiGraph Link to assess his/her habitual physical activity once she/he arrived at school. I helped children to wear the accelerometers on the dominant wrist. Notably, I also encouraged children to do their best while performing all assessments. I offered the stickers to each child based upon successful completion of each assessment as a reward to recognize her/his effort, and most importantly, to avoid testing withdrawal. I collected the accelerometers before the class was finished. Specifically, I helped children attending AM class at School A to wear the accelerometers from 8:30 am to 11:30 pm, while attending PM class to wear the accelerometers from 12:30 pm to 2:20 pm (Appendix F); I also equipped children attending AM class at School B with the accelerometers from 8:30 am to 11:30 pm, while attending PM class with the accelerometers from 12:10 pm to 2:50 pm (Appendix G).

I measured children's height and weight in private, and assessed their cardiovascular fitness using a modified YMCA 3-Minute Step Test (Golding et al., 1998). Data collection took place in a quiet area and approximately 5 minutes per child. Following the YMCA 3-Minute Step Test, I administered motor skill competence tests to all participants using the TGMD-2 (Ulrich, 2000). During the administration of the TGMD-2, I first demonstrated each test skills to ensure each child understand how to perform the tests correctly. Notably, each child's test was videotaped to facilitate later coding of each test and accurate data analysis. The test took place in the school gymnasium and approximately 3-5 minutes per child.

I used a quiet classroom during the administration of the cognition assessments and perceived competence. First, I took each participating child from the classroom one-by-one after obtaining permission from the class teacher. I used an iPad that downloaded

and installed the NIH Toolbox to administrate The Flanker Test (Mungas et al., 2013; Weintraub et al., 2013) as the assessment of children's cognitive function. After cognition testing, I used the modified Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984) questionnaire to assess children's perceived physical competence. Given the fact that preschool children are largely unable to read, I read each question to all children, with the child's answer to each question recorded. These two tests took approximately 5-7 minutes per child.

Covariates

As height, weight, date of birth, and gender could be penitential confounding variables that may affect the accuracy of regression analyses, age, gender, and BMI percentile, therefore, were considered as covariates. Notably, preschool children's BMI percentile was calculated via BMI Percentile Calculator for Child and Teen English Version (CDC, 2015). This calculator provides BMI and the corresponding BMI-for-age percentile on a BMI-for-age growth chart.

Statistical Analyses

I used IBM-SPSS 25.0 (IBM Inc., Armonk, NY) to analyze the data in the following manner. First, I calculated descriptive statistics including means, standard deviations, and/or frequencies for demographic information (i.e., age, race, height, weight, and body mass index percentile) and each outcome variable (physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition). Of note, I categorized physical activity levels into different intensities and step counts when calculating descriptive statistics (i.e., sedentary behavior, light physical activity, MVPA, and steps). To address question 1, "What is the relationship between MVPA/steps, motor

skill competence, cardiovascular fitness, perceived competence, and cognition in preschool children?”, I calculated Pearson product-moment correlation coefficients. To address question 2, “Whether preschool children’s motor skill competence, cardiovascular fitness, and perceived competence can predict their MVPA/steps”, I used multiple linear regression analyses while controlling for age, gender, and BMI percentile. To address question 3, “whether preschool children’s MVPA/steps, cardiovascular fitness, and motor skill competence can predict their cognition”, I used multiple linear regression analyses while controlling for age, gender, and BMI percentile. To address question 4, “whether preschool children’s perceived competence can predict their motor skill competence”, I used bivariate linear regression while controlling for age, gender, and BMI percentile. To address question 5, “whether preschool children’s motor skill competence can predict their cardiovascular fitness”, I also used bivariate linear regression while controlling for age, gender, and BMI percentile. Finally, to address question 6, “Are there gender differences across outcome measures?”, I conducted a one-way multivariate analysis of variance (one-way MANOVA). Notably, I also partial eta-squared (η^2) as the effect size of MANOVA. I used a p level of 0.05 for all analyses.

Chapter Four

Results

I delivered parents/guardians consent forms three times with the assistance of the high-five teachers. In detail, I brought the study flyers to attend the High Five Open House prior to school begins. I asked the teachers to help promote the study at parent meeting via mouth so that parents were aware of the study while handing out the first round of consent forms. As a result, I received 21 informed consent forms from School A, and 38 informed consent forms from School B. Notably, two consent forms from School B indicated that parents/guardians did not consent their children to participate in the study. After one week of the first round of delivering, I conducted the second round of distribution. Specifically, I asked high-five teachers to put the study flyers and consent forms into children's backpack so that they can bring home on Tuesday and collected the consent forms on Friday. I obtained 3 informed consent forms from School A, and 5 informed consent forms from School B, respectively, in this round. One week later, I administered the last round of delivering with same process and did not receive any informed consent forms. As a result, I recruited 65 preschool children in the current study. The demographic characteristics of participants were presented in Table 1.

Demographic Information

I recruited 24 preschool children from School A (11 girls) and 41 preschool children from School B (22 girls). The mean age of participants was 4.45 years ($SD = 0.46$); the mean height of participants was 108.3 centimeters ($SD = 5.92$); the mean weight of participants was 18.88 kilograms ($SD = 3.35$). I also calculated body mass index percentiles for boys and girls (2-20 years), with mean of 59.05 ($SD = 32.04$). Of

note, the majority of children were African Americans at School A ($n = 16, 66.7\%$), and were White American at School B ($n = 24, 58.5\%$).

Table 1
Demographic Characteristics of Participants

	School A (<i>n</i> = 24)	School B (<i>n</i> = 41)	Total (<i>N</i> = 65)
Gender			
Female	11 (45.8)	22 (53.7)	33 (50.7)
Male	13 (54.2)	19 (47.3)	32 (49.3)
Race			
White	3 (12.5)	24 (58.5)	27 (41.5)
Black	16 (66.7)	5 (12.2)	21 (32.3)
Hispanic	4 (16.7)	6 (14.6)	10 (15.4)
Asian	0 (0)	5 (12.2)	5 (7.7)
Other	1 (4.1)	1 (2.5)	2 (3.1)
Age (y)	4.71 (0.46)	4.29 (0.46)	4.45 (0.46)
Height (cm)	111.39 (5.67)	106.49 (5.33)	108.3 (5.92)
Weight (kg)	20.2 (3.73)	18.09 (2.87)	18.88 (3.35)
BMI (Percentile)	61.83 (33.89)	57.38 (31.21)	59.05 (32.04)

Data are presented as Gender (n/%), Race (n/%), Age (mean/standard deviation), Height (mean/standard deviation), Weight (mean/standard deviation), and BMI Percentile (mean/standard deviation)

Physical Activity Pattern

I measured preschool children's physical activity levels/steps via ActiGraph GT9X Link accelerometers at all times during school time. Specifically, I helped children attending AM class at School A to wear the accelerometers from 8:30 am to 11:30 pm, while attending PM class to wear the accelerometers from 12:30 pm to 2:20 pm. Activities occurred during the school A time including breakfast, morning meeting, gym, small/large groups, etc. (Appendix F). I also equipped children attending AM class at School B with the accelerometers from 8:30 am to 11:30 pm, while attending PM class with the accelerometers from 12:10 pm to 2:50 pm. Activities occurred during the school B time including breakfast, read book, computers, music, art, gym, the listening rules, calendar, skill review, mini lesson, small group, etc. (Appendix G).

On average, preschool children spent 239 minutes (47.93%) in sedentary behaviors during a 3-day school time, while their light physical activity time and MVPA time were 63.84 minutes (12.79%), and 196 minutes (39.28%), respectively. Notably, the time preschool children spent in vigorous intensity physical activity on the 3 school days were zero. In addition, preschool children spent 10,316 steps on average during a 3-day school time, which equals 20.66 steps per minute (Table 2).

Table 2

Minute and Percentage Time Spent in Each Type of Physical Activity and Steps During School Time

Total Steps	10316.17 (1823.19)
Steps/Minutes	20.66 (3.55)
Sedentary Time (mins)	239.11 (62.21)
LPA Time (mins)	63.84 (17.77)
MPA Time (mins)	196.13 (50.94)
VPA Time (mins)	0 (0)
MVPA Time (mins)	196.13 (50.94)
Sedentary Time (%)	47.93 (12.56)
LPA Time (%)	12.79 (3.52)
MPA Time (%)	39.28 (9.89)
VPA Time (%)	0 (0)
MVPA Time (%)	39.28 (9.89)

Abbreviation: LPA = Light Physical Activity; MPA = Moderate Physical Activity; VPA = Vigorous Physical Activity; MVPA = Moderate to Vigorous Physical Activity; Note: Data are presented as mean (standard deviation)

Description of Other Outcome Variables

I also conducted descriptive statistical analyses for preschool children's motor skill competence, perceived competence, cardiovascular fitness, and cognition. In detail, the mean score of participants' motor skill competence was 31.49 ($SD = 6.37$); the mean score of perceived competence was 3.14 ($SD = 0.6$); the mean score of cardiovascular fitness (heart rate) was 111.06 beats per minute ($SD = 11.27$); and the mean score of cognitive function was 106.56 ($SD = 21.89$) (Table 3).

Outliers

Using SPSS 25.0, I first detected the number of missing values for each variable. As a result, the analysis indicated no missing data were presented. Afterwards, I examined the outliers in the data file, three boys and one girls were identified as outliers on MVPA; one boy and one girl were identified as outliers on cardiovascular fitness; two girls were identified as outliers on motor skill competence; one girl was identified as outlier on perceived competence. After identifying the outliers, I went back to data file to inspect these outliers, I found no data were inappropriately scaled and no errors were made on data entry.

In fact, some scholars indicate that removal of extreme scores produces undesirable outcomes, especially when the outliers are illegitimate (Osborne & Overbay, 2004). However, when the data points are suspected of being legitimate, researchers also argue that data are more likely to be representative of the population as a whole if outliers are not removed (Orr, Sackett, & DuBois, 1991). In addition, due to the actual sample size was smaller than the ideal (65 vs. 80), if the outliers were dropped, which may increase the chance of assuming as true a false premise (Faber & Fonseca, 2014). Most

importantly, the data collection procedure was highly controlled and thus no data were inappropriately scaled and no errors were observed on data entry. That is, these outliers were legitimate, which may represent the population as a whole if they were kept. Therefore, I decided to include these outliers in the final analysis.

Table 3
 Descriptive Statistics of Sample for Motor Skill Competence, Perceived Competence,
 Cardiovascular Fitness, and Cognition

Motor Skill Competence	31.49 (6.37)
Perceived Competence	3.14 (0.6)
Cardiovascular Fitness	111.06 (11.27)
Cognition	106.56 (21.89)

Note: Data are presented as mean (standard deviation)

Question 1

I calculated Pearson product-moment correlation coefficients to determine the relationships among preschool children's MVPA/steps, motor skill competence, cardiovascular fitness, perceived competence, and cognitive functions (Table 4). The results indicated that there were no significant relationships of children's MVPA to other variables. Specifically, observed children's MVPA was not significantly linked with motor skill competence ($r = 0.18, p > 0.05$), perceived competence ($r = 0.12, p > 0.05$), cardiovascular fitness ($r = -0.14, p > 0.05$), and cognition ($r = -0.09, p > 0.05$). However, preschool children's step counts were observed to be significantly positively related to their motor skill competence ($r = 0.28, p < 0.05$). While preschool children's perceived competence was not significantly associated with their cardiovascular fitness ($r = 0.02, p > 0.05$) and cognition ($r = 0.02, p > 0.05$), perceived competence was observed to be positively significantly correlated to motor skill competence ($r = 0.37, p < 0.01$). In addition, preschool children's cognitive functioning was observed to be significantly positively associated with their motor skill competence ($r = 0.27, p < 0.01$) and cardiovascular fitness ($r = 0.37, p < 0.01$), respectively.

Table 4
 Relationships among Physical Activity, Motor Skill Competence, Cardiovascular Fitness,
 Perceived Competence, and Cognitive Functions

	1	2	3	4	5	6
1. MVPA	1	<i>0.68**</i>	0.18	0.12	-0.14	-0.09
2. Steps		1	<i>0.28**</i>	0.09	-0.07	-0.01
3. MSC			1	<i>0.37**</i>	0.22	<i>0.27*</i>
4. PC				1	0.02	0.02
5. CF					1	<i>0.37**</i>
6. Cognition						1

Abbreviation: MVPA = Moderate to Vigorous Physical Activity; MSC = Motor Skill Competence; PC = Perceived Competence; CF = Cardiovascular Fitness

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Question 2

To answer research question 2 “whether preschool children’s motor skill competence, cardiovascular fitness, and perceived competence can predict their MVPA/steps”, the multiple linear regression analyses should be applied. However, the fact that there were no significant relationships of preschool children’s MVPA to other health-related outcomes. Therefore, the multiple linear regression may not be appropriate conducted. Nevertheless, preschool children’s steps during school time was observed to be significantly associated with their motor skill competence. As such, I conducted the bivariate linear regression to determine whether preschool children’s motor skills can predict their step counts. The results of bivariate linear regression revealed that the overall regression model was significant $F(4, 63) = 4.65, \beta = 0.12, p < 0.05, R^2 = 0.24$ after age, gender, and BMI were controlled (Table 5), indicating preschool children’s motor skill competence was a significant predictor of step counts as 24% variance can be explained (Figure 3).

Table 5
 Bivariate Linear Regression Analysis Predicting Preschool Children's Steps from Their Motor Skill Competence

DV	Predictor	B	SE	β	t	p	R ²	F	p
Steps							0.24	4.65	0.002
	MSC	22.95	22.91	0.12	0.99	0.03			

Abbreviation: DV = Dependent Variable; MSC = Motor Skill Competence; SE = Standard Error

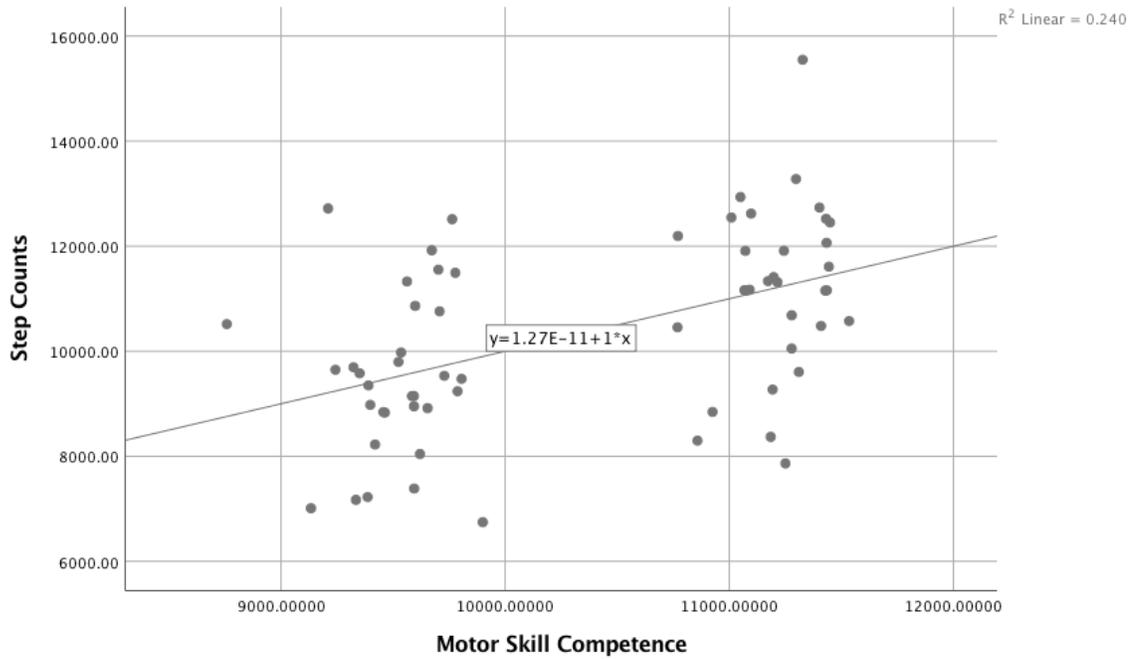


Figure 3 Predicting Preschool Children's Steps from Their Motor Skill Competence

Question 3

To address question 3, “whether preschool children’s MVPA/steps, cardiovascular fitness, and motor skill competence can predict their cognition”, I conducted multiple linear regression analyses. Due to the fact that preschool children’s MVPA/steps were not related to their cognition ($r = -0.09, p > 0.05$; $r = -0.01, p > 0.05$), I used only cardiovascular fitness and motor skill competence to predict cognition. The results suggested that the overall regression model was significant after which age, gender, and BMI were controlled, with 14% variance can be explained by the model $F(5, 63) = 4.52, p < 0.05, R^2 = 0.14$ (Figure 4). However, while children’s cardiovascular fitness was a significant predictor of the cognition ($\beta = 0.35, t = 2.73, p = 0.01$), motor skill competence seemed not to be a valid predictor of the cognition ($\beta = 0.08, t = 0.64, p = 0.53$) (Table 6).

Table 6
 Multiple Linear Regression Analysis Predicting Preschool Children’s Cognition from Their Motor Skill Competence and Cardiovascular Fitness

DV	Predictors	B	SE	β	t	p	R ²	F	p
Cognition							0.14	4.52	0.02
	MSC	0.19	0.29	0.08	0.64	0.53			
	CP	0.66	0.24	0.35	2.73	0.01			

Abbreviation: Dependent Variable = DV; MSC = Motor Skill Competence; CF = Cardiovascular Fitness; SE = Standard Error

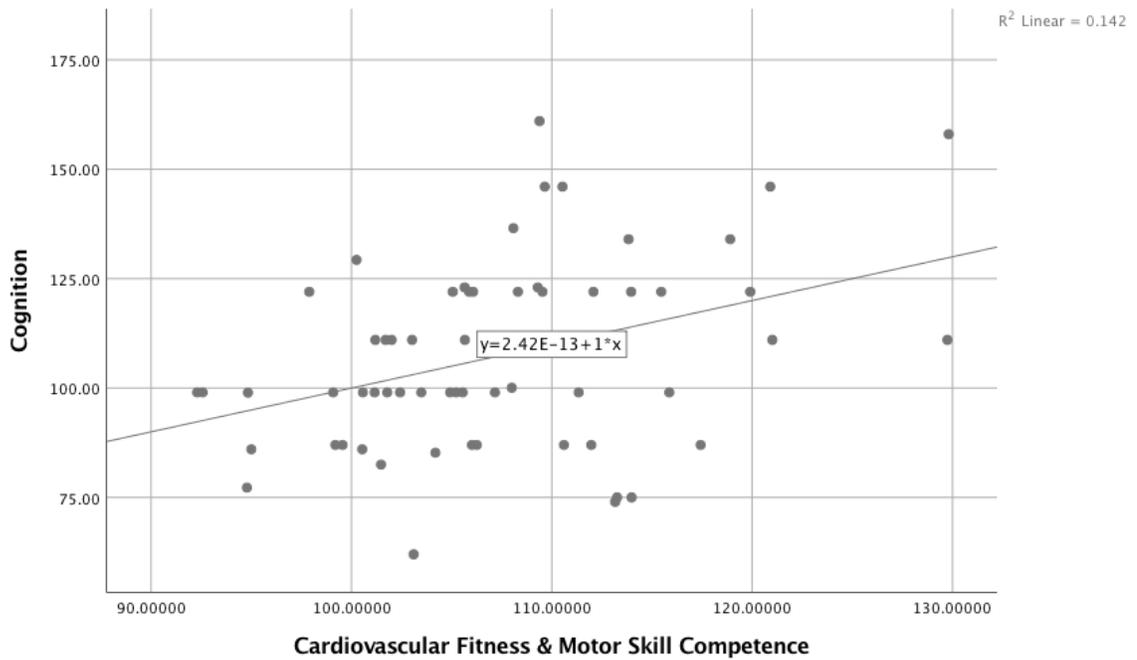


Figure 4 Predicting Preschool Children’s Cognition from Their Motor Skill Competence and Cardiovascular Fitness

Question 4

I used bivariate linear regression analysis to address question 4 “whether preschool children’s perceived competence can be used to predict motor skill competence”. The result demonstrated that preschool children’s perceived competence appeared to be a significant predictor of their motor skill competence $F(4, 63) = 2.66, \beta = 0.26, p = 0.04, R^2 = 0.15$ (Table 7), with the whole model explaining 15% of the variance (Figure 5).

Table 7
 Bivariate Linear Regression Analysis Predicting Preschool Children's Motor Skill Competence from Their Perceived Competence

DV	Predictor	B	SE	β	t	p	R ²	F	p
MSC							0.15	2.66	0.04
	PC	4.73	2.21	0.26	2.14	0.04			

Abbreviation: Dependent Variable = DV; MSC = Motor Skill Competence; PC = Perceived Competence; UC = Unstandardized Coefficients; SC = Standardized Coefficients; SE = Standard Error

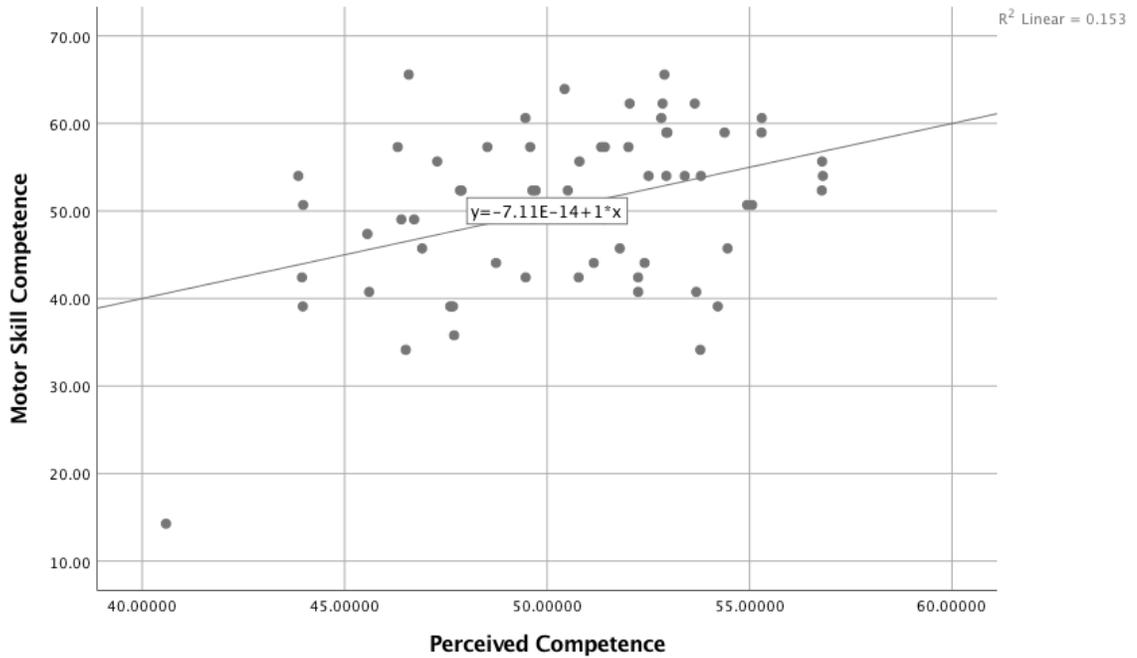


Figure 5 Predicting Preschool Children's Motor Skill Competence from Their Perceived Competence

Question 5

To address question 5, “whether preschool children’s motor skill competence can predict their cardiovascular fitness”, the bivariate linear regression analysis was supposed to be conducted. However, the fact that preschool children’s motor skill competence was not observed to be significant associated with their cardiovascular fitness. Therefore, I did not conduct the analysis.

Question 6

Finally, to address question 6, “Are there gender differences across outcome measures?”, a one-way MANOVA might be appropriate used to analyze the data. However, the fact that only two significant relationships were observed (i.e., motor skill competence and perceived competence; motor skill competence and steps) among all outcome measures, which violated one of basic assumptions of MANOVA (i.e., Linearity) that all variables should be significantly related to each other. Therefore, I conducted Independent Samples t-test was applied in this study. Accordingly, I calculated Cohen’s *d* to determine the effect size rather than using partial eta-squared (η^2) to determine the effect size of MANOVA. The Cohen’s *d* uses the standard effect size definition on the basis of mean and standard deviations of difference scores—regardless of whether the statistic employed is parametric or nonparametric. An effect size of 0.2 was considered small, 0.5 medium, and 0.8 large (Faul, Erdfelder, Lang, & Buchner, 2007) (Table 8).

The results indicated that there were three significant gender differences were observed. Specifically, I found significant mean differences in preschool children’s MVPA, with boys spending more time in MVPA as compared to girls (Mean: 41.72 mins

vs. 36.87 mins, $t = -2.04$, $p < 0.05$, Cohen's $d = 0.51$) (Figure 6). In addition, I found that boys took more steps per minute than girls (Mean: 22.26 vs. 19.11, $t = -3.96$, $p < 0.01$, Cohen's $d = 0.98$) (Figure 7). Notably, I found that boys demonstrated higher motor skill competence than girls (Mean: 33.16 vs. 29.88, $t = -2.13$, $p < 0.05$, Cohen's $d = 0.53$) (Figure 8). Notably, I also observed a potential gender difference in cardiovascular fitness as the p value ($p = 0.06$) was close to the significance level of 0.05, with boys tending to have better cardiovascular fitness compared to girls (108.50 vs. 113.55) (Figure 9). Last, I observed no significant gender differences in preschool children's cognition (Figure 10) and perceived competence (Figure 11).

Table 8
Gender Differences Across All Measures in Preschool Children

	Mean (Girls)	Mean (Boys)	Mean Diff	<i>t</i>	<i>p</i>	Cohen's <i>d</i>
MVPA%	36.87	41.72	-4.89	-2.04	0.04*	0.51
SM	19.11	22.26	-3.15	-3.96	0.00*	0.98
MSC	47.48	52.61	-5.12	-2.12	0.03*	0.53
PC	3.10	3.18	-0.08	-0.54	0.59	
CF	113.55	108.50	5.05	1.85	0.06	
Cognition	104.46	108.73	-0.78	-4.26	0.44	

Abbreviation: MVPA = Moderate to Vigorous Physical Activity; SM = Steps per Minute; MSC = Motor Skill Competence; PC = Perceived Competence; CF = Cardiovascular Fitness

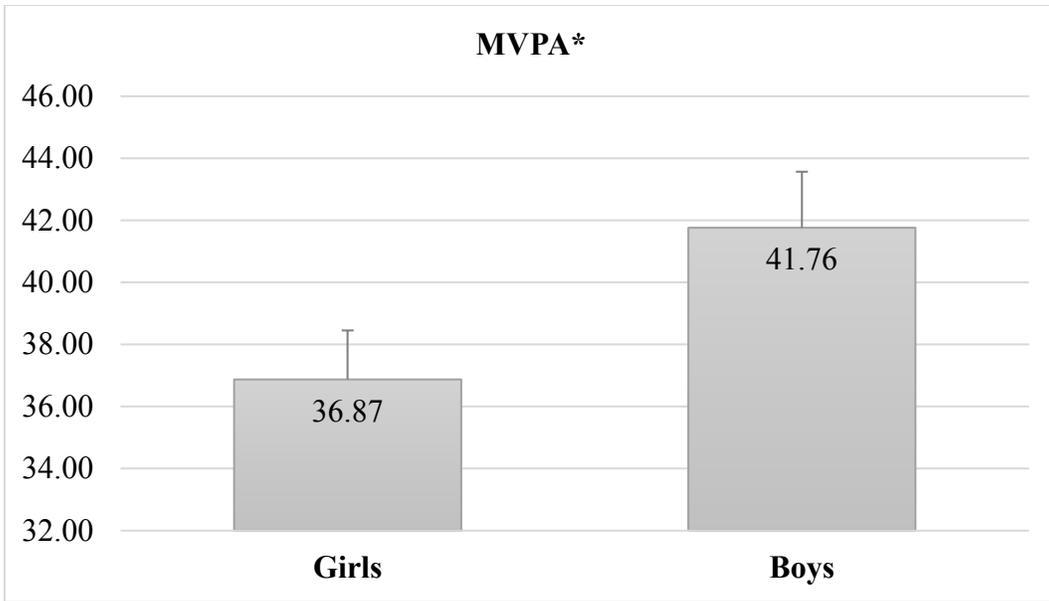


Figure 6 Gender Difference in Moderate-to-Vigorous Physical Activity

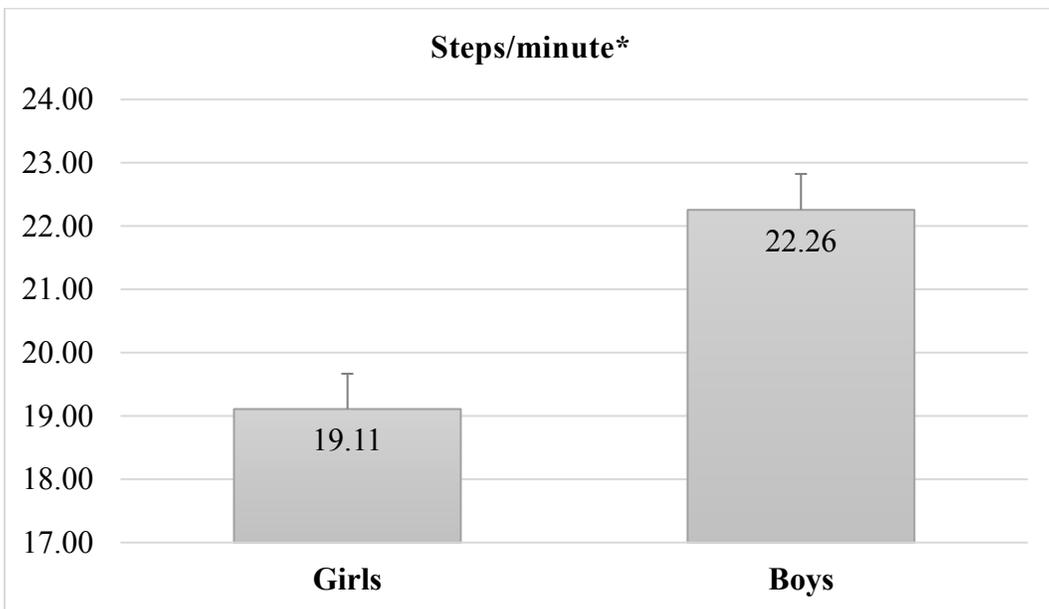


Figure 7 Gender Difference in Steps/minute

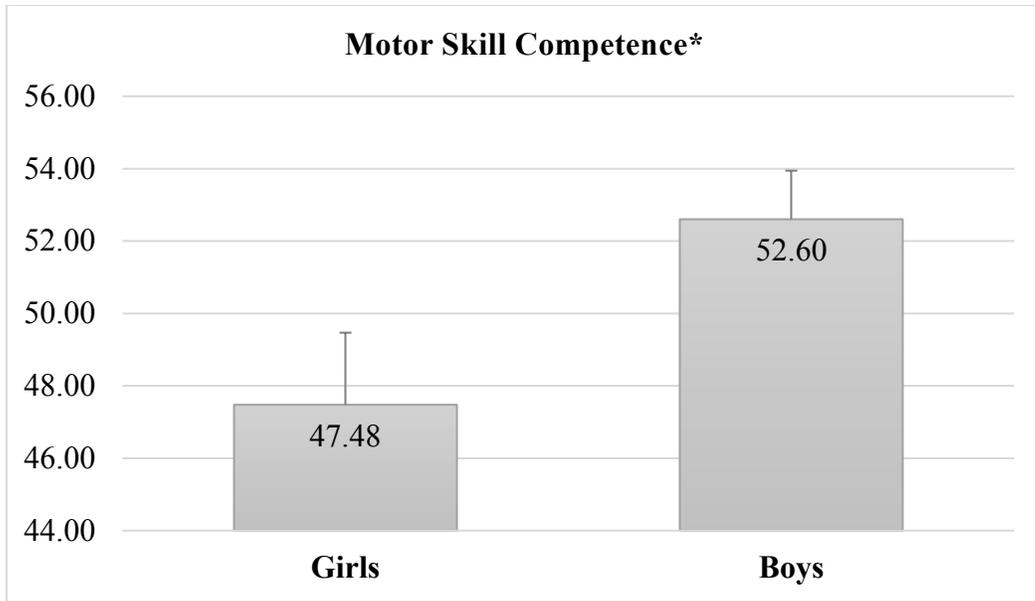


Figure 8 Gender Difference in Motor Skill Competence

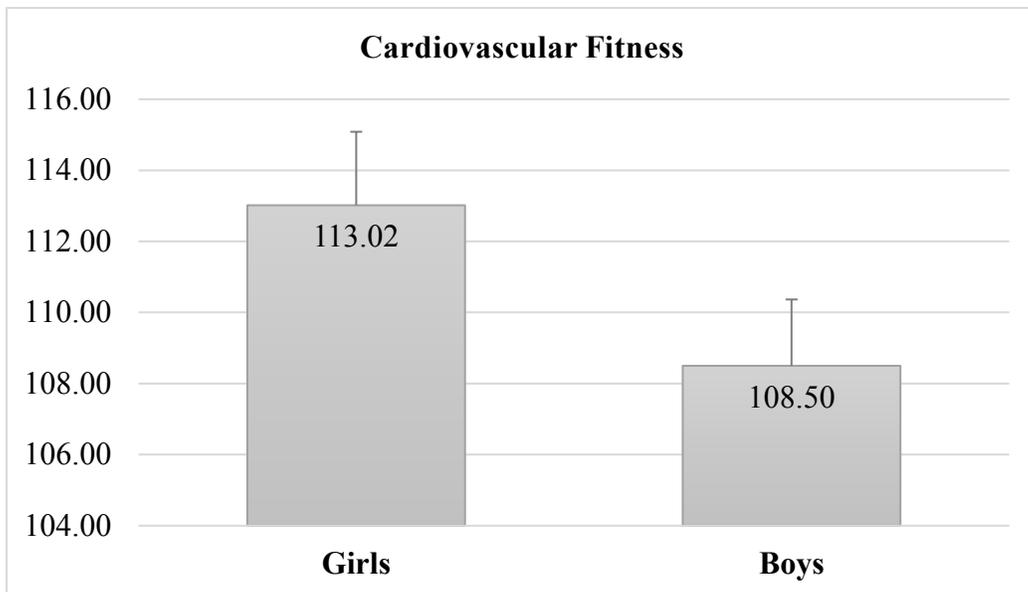


Figure 9 Gender Difference in Cardiovascular Fitness

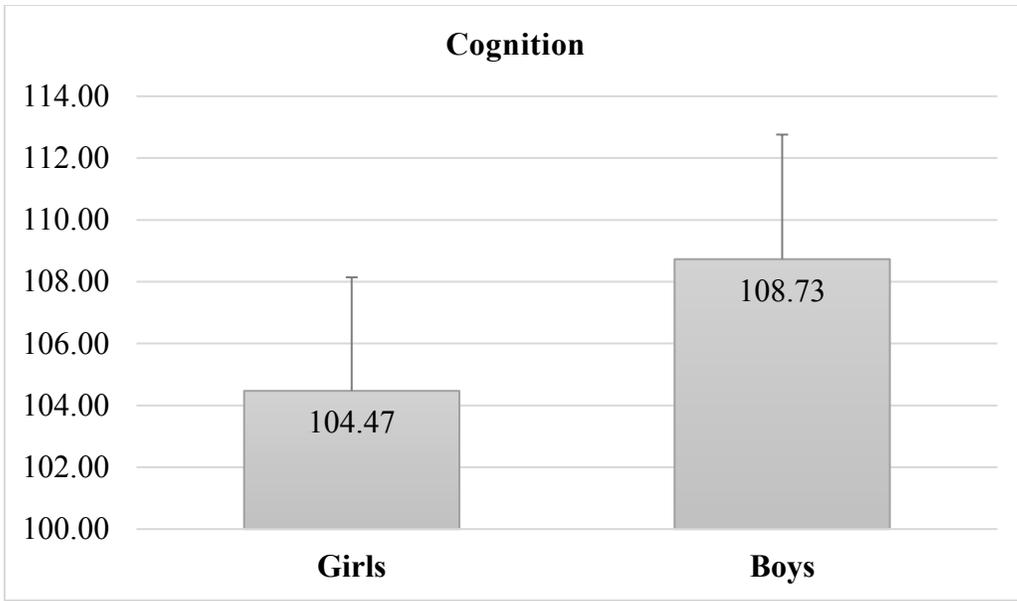


Figure 10 Gender Difference in Cognition

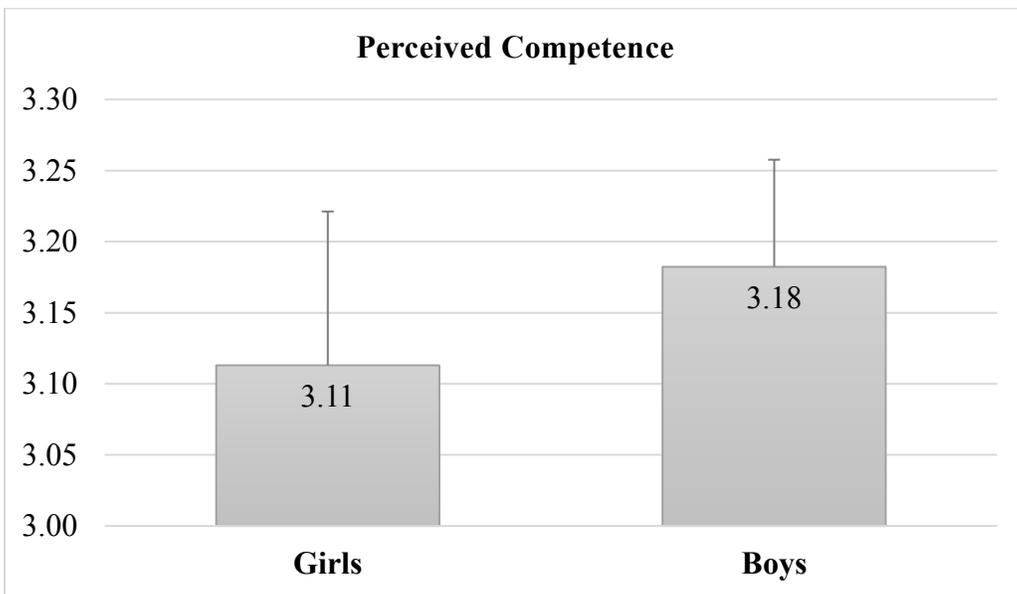


Figure 11 Gender Difference in Perceived Competence

Chapter Five

Discussion

Summary of Findings

Early childhood (e.g., birth to 6 years old) is marked as one of the most critical and intensive periods of development throughout the human lifespan (Khan & Hillman, 2014). Physical activity is a crucial contributor to health in early childhood (Janz et al., 2001; Jiménez-Paán, Kelly, & Reilly, 2010), and therefore is considered to be a vital part of children development (King et al., 2003). While the early years are a critical period for the development of an active lifestyle, it is the period of growth for which we know the least about evidence linking physical activity with health outcomes in this population (Timmons, Naylor, & Pfeiffer, 2007; Tremblay et al., 2012). That is, the questions regarding the correlates of physical activity for the early childhood (i.e., aged 4-6 years) have not been addressed. Thus, the understanding of how the development of multiple health-related variables may synergistically impact each other to promote physical activity and overall health in preschool children remains largely unexplored.

To date, no research has been conducted to extend and to validate Stodden et al. (2008)'s model in preschool children. Although Stodden et al. (2008)'s model represents the important concepts identified in the literature, scant literature is available using this model to examine the relationships among these variables in preschool children (4-6 years old) and to understand why so many young children are physically inactive. As such, I proposed a new theoretical model that built upon Stodden et al. (2008)'s theory and added the cognition as one of correlates of preschool children's physical activity, with the goal of understanding of how preschool children' physical activity related to

their motor skill competence, perceived physical competence, cardiovascular fitness, and cognition, while determining the gender differences in these variables.

Despite the causal relationships cannot be inferred due to the correlational nature of the present study, understanding the factors that influence preschool children's physical activity behavior is important in the design of intervention programs targeting at youth, while aiding in addressing the declining levels of physical activity and fitness along with the increasing rates of obesity across childhood and adolescence. To the best of my knowledge, this is the first study examining the relationships among physical activity and other health-related outcomes in preschool children. I found that: (1) preschool children's MVPA was not significantly associated with their motor skills competence, perceived competence, cardiovascular fitness, cognition, but only their step counts were significantly positively related to motor skills competence; (2) preschool children's motor skills competence was significantly positively correlated with perceived competence; (3) preschool children's motor skills competence were significantly positively linked with cognition; (4) preschool children's cardiovascular fitness were significantly positively related to cognition; (5) boys were more physically active than girls; (6) boys had better motor proficiency than girls.

Relationships among Physical Activity, Motor Skill Competence, Cardiovascular Fitness, Perceived Competence, and Cognition

Physical Activity and Motor Skill Competence

Although previous evidence indicated that preschool children's physical activity tends to be either weakly or moderately related to their motor skill competence (Fisher et al., 2005; Foweather et al., 2015; Iivonen et al., 2013; Lin et al., 2017; Sääkslahti et al.,

1999; Williams et al., 2008), I found that preschool school children's MVPA was not associated with their motor skill competence. The reasons for the inconsistent findings are partially attributable to varied measurements of physical activity and motor skills across these studies. To begin, motor skills assessment tools were varying in previous studies, including the MABC-2, the CHAMPS Motor Skills Protocol, and the TGMD-2. In fact, different assessment tools have different scoring standards. For example, the TGMD-2 (Ulrich, 2000) interprets "run" as: (1) arms move in opposition to legs, elbows bent; (2) brief period where both feet are off the ground; (3) narrow foot placement landing on heel or toe (not flat-footed); (4) nonsupport leg bent approx. 90 degrees (close to buttocks). On the other hand, CHAMPS Motor Skills Protocol assesses "run" as: (1) arms move in opposition to legs, elbows bent; (2) brief period of suspension: both feet off the ground; (3) narrow foot placement; lands on heel or toe; not flat footed; (4) length of stride even; path of movement horizontal; (5) nonsupport leg flexed to approximately 90 degrees; (6) eyes focused forward. Therefore, different scoring standards may lead to different interpretations of motor skills.

In addition, difference in physical activity assessment (parental report vs. objective measurement) may result in inconsistent findings. Despite the objective measures such as accelerometers were seen in most studies, different cut points and epochs may capture varying physical activity levels. For example, in Fowweather et al. (2015) study, children's physical activity was classified into minutes per day spent in sedentary: 0 - 819 counts per minute; light: 820 - 3907 counts per minute; moderate: 3908 - 6111 counts per minute; and vigorous \geq 6112 counts per minute intensities on weekdays and weekend days, and the study used 60 second epochs to quantify children's

physical activity. However, I used Pate Preschool (2006) cut points: Sedentary: 0-799 counts per minute; Light: 800-1679 counts per minute; Moderate: 1680-3367 counts per minute; Vigorous: ≥ 3368 counts per minute (Pate et al., 2006) and 1 second epoch length to detect preschool children's physical activity during school time. Therefore, different cut points and epochs selected will result in different physical activity levels captured. Moreover, most previous studies employed either ActiGraph GT1M or ActiGraph GT3X to measure activity pattern that were tied around the waist by an elastic belt and worn on the right side of hip. I utilized ActiGraph GT9X Link (ActiGraph, Pensacola, FL) to measure children's physical activity in the current study, which is the most advanced wearable sensor and needs to be placed on the dominant wrist to detect activity pattern. Therefore, the different placements of motion sensors may also cause different activity patterns quantified.

It is also worth noting that most previous studies captured children's all day physical activity, including school time and home time, as well as weekdays and weekends. However, due to school policy and safety issue, I was not allowed to quantify children's all day physical activity data, and thus only activity occurring during school time was measured. Notably, in the current study, the school time for preschool children was approximately 150-180 minutes, during the school time, children performed organized/structured activities (story, music, library, fitness, etc.). That is, children's activity patterns tended to be identical, which limits the ability to capture the daily physical activity pattern of preschool children, including outside of school physical activity.

Due to the limitations aforementioned, I also examined the relationship between preschool children's motor skill competence and steps as step counts are useful indicator of physical activity level (Strath et al., 2013). Interestingly, I found that preschool children's steps during school time were positively related to their motor skill competence, which is consistent with previous research by Robinson, Wadsworth, and Peoples (2012) finding that preschool children's locomotor ability (measured via TGMD-2) was moderately associated with their physical activity (quantified by steps). Indeed, the step counts might be more appropriate to represent children's physical activity given the limitations of the current study (i.e., cut points, accelerometer placement and wearing time).

Overall, I observed that preschool children's motor skill competence was not associated with MVPA but related to step counts. Nevertheless, motor skill competence appeared not to be an ideal predictor of step counts as only 8% variance can be explained. Thus, future research is warranted to determine this relationship by quantifying preschool children's daily physical activity pattern, including both structured and unstructured activities that occurring at school and outside school.

Physical Activity and Perceived Competence

I observed that preschool children's perceived competence was neither related to their school day MVPA nor step counts, which is consistent with previous studies indicating preschool children's perceived competence is not related to their physical activity (Barnett et al., 2015; Morgan et al., 2008; Robinson. L et al., 2012). However, it is important to note that perceived competence can vary across domains and individuals. Young children may perceive themselves as having high competency in the social

domain but low competency in the physical domain (Shapiro et al., 2003). In other words, children tend to inflate perception of their physical competence and therefore perceptions are not always accurate when matched with teacher's perceptions (Harter & Pike, 1984; Vedul-Kjelsås, Sigmundsson, Stensdotter, & Haga, 2012). In addition, most previous studies defined children's physical activity as several consecutive days, including school time and home time, but I interpreted children's physical activity as activities only occurring during school times in the current study (i.e., AM 8:30-11:20, PM 11:30-2:10 or 12:10-2:45). Nevertheless, I also used step counts/minute to denote children's physical activity. As a result, there was no relationship between preschool children's step counts and motor skill competence.

In fact, there is a paucity of data with regard to average step counts for preschool-age children, and thus no established recommendation for daily step count. While one research suggested that a daily step count of 13,874 has been equated to 60 min of MVPA in preschool children (Cardon & De Bourdeaudhuij, 2007), the other study stated that a total daily physical activity volume of 10,000-14,000 steps/day is associated with 60-100 minutes of MVPA in preschool children (approximately 4-6 years of age) (Tudor-Locke et al., 2011). Notably, Boldemann et al. (2006) reported average step counts for 4-6 years boys were 21 steps/minute and 18 steps/minute for girls during preschool hours. In the current study, I observed that step counts/minute for boys and girls were 22.26 and 19.11, respectively, which aligns with this finding. That is, the preschool children's steps/minute in the current study clearly meet the recommended levels for physical activity as compared to other preschool samples.

Overall, I observed that preschool children's MVPA and steps during school time were not significantly related to their perceived competence. That is, the proposed positive relationship between perceived competence and objectively measured physical activity was not supported in the current study. Nevertheless, more research with larger and diverse samples is warranted to quantify preschool children's both structured and unstructured activity patterns to further determine this relationship in this population.

Physical Activity and Cardiovascular Fitness

It is important to note that available literature mainly focused on the effects of physical activity on cardiovascular fitness, with few studies examining the relationship between physical activity and cardiovascular fitness in children and adolescents. To the best of my knowledge, this is the first study investigating the direct relationship between physical activity and cardiovascular fitness in preschool children.

I found that objectively measured MVPA and steps/minute during school time were not significantly associated with preschool children's cardiovascular fitness, which is inconsistent with previous studies observing a significant positive weak to strong relationship between physical activity and cardiovascular fitness in children aged 6-14 years (Dencker et al., 2006; Gutin et al., 2002; Martínez-Vizcaíno & Sánchez-López, 2008; Monyeki & Kemper, 2007; Ortega, Ruiz, Hurtig-Wennlöf, et al., 2008). In these preceding literature, however, researchers stated that only vigorous intensity physical activity (≥ 6 METs) were related to physical fitness, including cardiorespiratory capacity, strength, and agility, despite the fact that physically active children tend to have higher level of fitness (Gutin et al., 2002; Martínez-Vizcaíno & Sánchez-López, 2008). In

addition, it was suggested that daily physical activity only explains a small proportion of aerobic capacity (Dencker et al., 2006).

In the current study, I used Pate Preschool (2006)'s cut points to quantify preschool children's physical activity levels, and captured zero vigorous physical activity during school time. While I also used steps/minute to assess this relationship, the calculation of steps was given moderate intensity physical activity, and thus children's steps/minute may not reach vigorous intensity physical activity. In addition, the disagreement between the current study and previous research could be partially attributed to different cardiovascular fitness assessments. For example, cardiovascular fitness testing in previous studies included shuttle run, distance/timed run, cycle ergometer, indirect calorimetry etc. Although VO_{2max} (i.e., the greatest rate at which a person is able to consume oxygen during sustained, exhaustive exercise) is considered the gold standard measure of cardiorespiratory fitness (Pate et al., 2012), it is typically measured while a person performs maximal, graded exercise on a treadmill or cycle ergometer in the laboratory. In fact, the most commonly used field tests for cardiovascular fitness consists of distance/timed runs, shuttle runs, and step tests. In the current study, I used the modified YMCA 3-minute steps test to assess preschool children's cardiovascular fitness, which was different previous research. For instance, a study by Hsieh et al. (2014) used 800m run test to evaluate children's cardiovascular fitness, the total time taken to run 800m was recorded to interpret children's cardiovascular fitness. In contrast, I utilized YMCA 3-minute steps test and assessed the immediate heart rates as the outcome (Bennett, Parfitt, Davison, & Eston, 2016). Despite I carefully conducted and highly controlled study procedures, different assessments and

interpretations of cardiovascular fitness could be a potential reason of why there was no correlation observed in the current study.

To summarize, I found that preschool children's objectively measured MVPA and steps/minute during school time were not significantly linked with their cardiovascular fitness. Due to the disagreements between the current study and previous research, a definitive conclusion cannot be reached yet. Notably, the measurement of cardiorespiratory fitness in preschool children in the educational settings and of its relationship to physical activity and other health outcomes is relatively new to the literature, therefore, more study is warranted.

Physical Activity and Cognition

While the causal relationship between physical activity and cognition has been well documented, a strong reciprocal relationship between physical activity and cognition in preschool children has yet to be determined, which may represent a different paradigm than causality. In the current study, I observed that preschool children's objectively measured MVPA and steps/minute during school time were not significant related to their cognition, namely, attention and executive functioning, which differs previous interventions that MVPA participation would be able to induce improvements in certain aspects of cognitive functioning in children and adolescents (Laura Chaddock-Heyman et al., 2013; Davis et al., 2011; Fisher et al., 2011; Keita Kamijo et al., 2011; Mahar et al., 2006). Although a cross-sectional study by Gapin and Etnier (2010) demonstrating that the time spent in MVPA was a significant predictor of planning ability in boys, the participants included in this study were children with Attention Deficit Hyperactivity Disorder.

It is worth noting that I used the computer-administered NIH Toolbox to assess children's attention and executive functioning (Mungas et al., 2013; Weintraub et al., 2013), whereas other previous studies used math/reading/science scores to interpret children's cognition assessing via Stanford-Binet-Fifth Edition (for children aged 2 to 7 years); Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition (for children aged 2 years and 6 months to 7 years and 7 months). That is, the use of different interpretations of cognition may cause such dissimilarity. In addition, I captured the physical activity levels only when children were in school. During this time, children participated in structured/organized activities led by the teachers, thus their physical activity patterns tend to be alike, which restricts the ability to discern how preschool children's actual daily physical activity levels related to their attention and executive functioning.

I found that objectively measured MVPA and steps/minute during school time were not significantly associated with preschool children's attention and executive function. Further research is needed to confirm this conclusion and should be extended to examining the correlation of daily physical activity to other cognitions, as daily physical activity may represent a different paradigm than that associated with school physical activity.

Motor Skill Competence and Perceived Competence

The importance of motor skill competence and perceived competence towards lifetime participation in physical activity was hypothesized in Stodden et al. (2008)'s model. It was suggested that motor skill competence and perceived physical competence are primary mechanisms that are linked with physical activity participation and health-

related fitness. It is also important for young children to achieve basic competence in motor skills to break through a hypothetical “proficiency barrier” proposed by Seefeldt (1980), thereby resulting in successful engagement in various forms of movement, sport and physical activities (Clark & Metcalfe, 2002). The evidence supports the concept that children who are competent movers tend to be more physically active (Okely & Booth, 2000), and children aged 6-12 years with advanced fundamental motor skills spend more time engaged in non-sedentary behaviors in comparison to their peers with low fundamental motor skills (Houwen, Visscher, Lemmink, & Hartman, 2009). That is, perceived competence is an important determinant of achievement-related behaviors and actions (Deci & Ryan, 2000).

I observed a significant relationship between preschool children’s motor skill competence and perceived competence, which aligns with previous studies that supporting perceived competence along with motor skills serve as an essential role in children’s motivation to learn and to participate in present and future motor behaviors in preschool-aged population (Goodway & Rudisill, 1997; Robinson, 2011). Although the positive evidence has been favored, it is worth noting that at least 80% of the participants from those two previous studies were African American preschoolers. Notably, the preschool children included in the current study were all from underserved families with low socioeconomic status (66% African-American from School A VS. 58.5% White from School B). Therefore, unrepresentative samples of the current and preceding studies may restrict the generality of the findings.

Overall, in the current study, I found that preschool children’s perceived physical competence was significantly positively associated with their motor skill competence,

and perceived competence was a significant predictor of motor skill competence with the whole model explaining 13% of the variance. Nevertheless, more research with a larger and diverse sample is needed in order to generalize this finding to other preschool-aged populations.

Motor Skill Competence and Cognition

Early childhood is considered one of the most critical and intensive periods of brain development throughout the human lifespan (Khan & Hillman, 2014), and habitual physical activity is a key determinant of cognition during childhood (Timmons et al., 2007). It was believed that motor skills and cognitive development are closely related as both motor and cognitive skills have several common underlying processes, including sequencing, monitoring, and planning (Roebbers & Kauer, 2009). The evidence regarding the relationship between motor skill and cognitive performance in children is inconsistent, with relationships varying from moderate to strong. Nevertheless, positive correlations of motor skill and cognitive performance were possible among children and adolescents, indicating the potential of motor skill in eliciting the cognitive development in children.

I found a strong relationship between motor skill competence and cognition (i.e., attention and executive function) in preschool children, which is consistent with previous studies suggesting better motor proficiency may contribute to higher level of cognitive development in children and adolescents (Beck et al., 2016; Davis et al., 2011; Haapala et al., 2014; Rigoli et al., 2012; Son & Meisels, 2006). Of note, a recent systematic review by van der Fels et al. (2015) assessed evidence regarding the relationship between motor skills and cognition in typically developing children (4-16 years). The study stated that

(1) there was insufficient evidence for a correlation between gross motor skills and visual processing, short- and long-term memory, intelligence quotient, academic skills, general knowledge, visuospatial working memory, attention, and cognitive capacity; (2) there was insufficient evidence for a correlation between fine motor skills and executive functions, academic skills, long-term memory, and verbal comprehension, general knowledge, working memory, attention, and visuospatial working memory; (3) there was insufficient evidence for a correlation between bilateral body coordination and visual processing, short-term memory, long-term memory, executive functions, cognitive capacity, and academic skills; (4) there was insufficient evidence for a correlation between object control and executive functions, verbal comprehension, and academic skills, attention, knowledge, and quantitative reasoning.

While my results suggested the existence of a strong relationship between motor skill competence and cognition (i.e., attention and executive function) in preschool children, motor skill competence seemed not to be a valid predictor of the cognition. Therefore, more research is warranted to further confirm this relationship in preschool children as the knowledge gap defined aforementioned. In detail, future studies should extend to investigate other cognitive functions such as general knowledge, visual processing, short- or long-term working memory, intelligence quotient, and academic achievement in addition to attention and executive functioning. Moreover, more specific fundamental movement skills include fine/gross motor skills and locomotor/object control skills should also be examined regarding how each of them related to the children's cognition.

Motor Skill Competence and Cardiovascular Fitness

My correlational analysis suggested that preschool children's motor skill competence was not significantly related to their cardiovascular fitness, which is inconsistent with previous studies supporting motor skill competence might be a good predictor of cardiovascular fitness in children and adolescents (Milne et al., 2016; Robinson et al., 2015). Notably, a recent systematic review by Cattuzzo et al. (2016) confirmed a significant and positive relationship between cardiovascular fitness and motor competence in children and adolescents. The preschool children, however, were not included.

The differences in measurement and sample size may explain the disagreement between the current study and previous research. To begin, the measurement of children's cardiovascular fitness in previous studies included: (1) the Progressive Aerobic Cardiovascular Run (Barnett, Morgan, et al., 2008; Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Erwin & Castelli, 2008; Hands, 2008; Hardy, Reinten-Reynolds, Espinel, Zask, & Okely, 2012; Okely, Booth, & Patterson, 2011; Vandendriessche et al., 2011); (2) the six-minute walk/run test (Haga, 2009; Vedul-Kjelsås et al., 2012); (3) half-mile walk/run test (Reeves, Broeder, Kennedy-Honeycutt, East, & Matney, 1999); and (4) bicycle ergometer test (Hands, Larkin, Parker, Straker, & Perry, 2009). Each of these measurements has different scoring standard. For example, the six-minute walk test records the distance covered in meters or converted measure (i.e., feet) over 6 minutes as the outcome. The Progressive Aerobic Cardiovascular Run measures the number of laps completed in a 20-meter shuttle run to interpret the cardiovascular fitness. In contrast, I used the modified YMCA 3-min step test and took the immediate heart rates as the

outcome to represent preschool children's cardiovascular fitness. Therefore, different measurements of cardiovascular fitness may partially explain the dissimilarity between the current study and previous research. Second, I calculated the sample size using G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf) to ensure to reach statistical significance, the results indicated that 80 participants would be sufficient for 80 % power ($\alpha = 0.05$, effect size = 0.30). However, the fact that I only recruited 65 preschool children for the study. That is, the actual sample size might be too small to achieve a customary level of statistical significance. Therefore, it is highly possible that preschool children's motor skill competence is associated with their cardiovascular fitness if sufficient sample are included.

To summarize, this is the first study examining the direct relationship between motor skill competence and cardiovascular fitness in preschool children. I found no significant relationship between preschool children's motor skill competence and cardiovascular fitness. Nevertheless, more research with larger sample size is needed to further confirm this relationship given the conflicting findings between the current study and previous research.

Cardiovascular Fitness and Cognition

Today, children are becoming increasingly sedentary and physically inactive (Haapala, 2013). Hence, it is important to develop and implement effective interventions to improve children's metabolic, cardiovascular, and cognitive health by understanding how these variables are related to each other. I found that preschool children's cardiovascular fitness was significantly positively related to their attention and executive function, with cardiovascular fitness was a significant predictor of the cognition,

suggesting preschool children with better cardiovascular fitness tend to have higher cognition. This finding aligns well with previous studies that cardiovascular fitness positively impacted third- and fifth-grade students' cognitive performance (Castelli et al., 2007; Keeley & Fox, 2009).

It is important to note that preceding studies defined children's cognitive performance as mathematics and reading scores (Castelli et al., 2007), as well as academic achievement (Keeley & Fox, 2009), whereas I used attention and executive functioning to interpret cognition in the current study. As cognition is a broad concept and has been defined in a variety of different ways, more research, therefore, is warranted to further confirm the relationship of cardiovascular fitness to other elements of cognition, such as visual processing, short- and long-term memory, intelligence quotient, academic achievement in this population.

Gender Differences in Outcome Variables

Physical Activity

Previous scholars have reported that boys were more physically active than girls (Hesketh et al., 2015; Pate et al., 2008; Soini et al., 2014; Tucker, 2008). My results align with previous evidence: I found that there was significant gender difference in preschool children's MVPA, with boys demonstrating more active than girls during their school time. Notably, I also examined gender difference in preschool children's steps/minute as step counts are also promoted as a useful indicator of physical activity level (Strath et al., 2013). Likewise, boys also displayed more step counts than girls during school time.

Notably, existing studies examining preschool children's physical activity levels by either subjective or objective measurements indicating that preschool-aged children do

not engage in sufficient physical activity—nearly half of children are not meeting the recommended physical activity guidelines, with inactivity higher among girls than boys. In the current study, I observed that preschool children spent about 40% of their school time on MVPA. Therefore, more activities during school time may be necessary to promote preschool children’s physical activity.

Motor Skill Competence

According to Berk (2013), boys generally mature ahead of girls in skills that emphasize force and power. That is, boys tend to jump farther, run faster and throw a ball farther than girls by the end of early childhood. My results are consistent with the previous literature, indicating that preschool-aged boys are more motor proficient than girls (Goodway & Rudisill, 1997; Robinson, 2011).

It is worth noting that my sample, as well as those used in previous studies comprised preschool children from underserved families with low socioeconomic status in the U.S. (Goodway & Rudisill, 1997; Robinson, 2011). However, Foulkes et al. (2015) examined gender difference among underserved preschool children in Northwest England and found that girls were more competent at locomotor skills including run, hop, and gallop. This finding raises another interesting question that whether gender difference in motor skill competence exists in different regions. That being said, more research is warranted to further explore the influence of region in preschool children motor skill development.

Cardiovascular Fitness

I found no significant gender difference in preschool children’s cardiorespiratory fitness, which is consistent with Cadenas-Sánchez et al. (2014) study, suggesting that no

gender and age significant differences in cardiorespiratory endurance in Spanish preschool children. Notably, in Cadenas-Sánchez et al. (2014)'s study, children's cardiorespiratory endurance was assessed via 20-meter shuttle run test, whereas I used modified YMCA 3-minute step test in the current study. On the other hand, Krombholz (2006) and Román et al. (2016) applied shuttle run test and indicated that boys had a greater performance on cardiorespiratory endurance than girls in Germany and Spain, respectively. That is, such conflicting may be explained by the different measurements of cardiorespiratory fitness and different preschool-aged populations. In addition, due to the sample size ($N = 65$) in the current study did not reach 80% power calculated by G*Power 3.1 (Heinrich-Heine-Universität Düsseldorf) ($N = 80$), this could be another reason explaining why I failed to observe the gender difference in cardiovascular fitness.

To summarize, I observed no significant gender difference in preschool children's cardiorespiratory fitness. Nevertheless, future research with larger sample is necessary to further confirm this relationship in a diverse population.

Perceived Competence

Children's cultural and social context differences and their impact on the formation of self-perceptions could explain conflicting results (Hagger et al., 1998). In the current study, I found that there was no significant gender difference in preschool children's perceived physical competence. In fact, the evidence regarding gender differences in children's perceived physical competence was contradictory, with most studies indicating that boys tend to report higher perceptions of physical competence compared to girls (Cairney et al., 2012; Noordstar et al., 2016; Piek et al., 2010; Robinson, 2011; Slingerland et al., 2014), but small portion of research suggested girls

may perceive themselves to be more competent and had higher physical self-confidence levels than did the boys (LeGear et al., 2012), and no gender differences existed in perceived competence in this population (Afthentopoulou et al., 2018; Mantzicopoulos, 2006; Planinšec & Fošnarič, 2005).

Researchers have suggested that young children, until the age of 8, tend to have inflated perceptions of their physical competence (McKiddie & Maynard, 1997; Rudisill, Mahar, & Meaney, 1993; Slykerman et al., 2016). Therefore, children might not be accurate at perceiving their physical competence as their cognitive skills make it difficult for them to distinguish between effort and action (Goodway & Rudisill, 1997; Harter & Pike, 1984). That is, children are not capable of comparing their performance with their peers, but they only can support the formation of their self-perception on their own previous performance at these young ages (Afthentopoulou et al., 2018).

I found no evidence of gender differences in preschool children's perceived competence. Since the literature regarding gender difference in preschool children is relatively sparse, a consensus has yet to be reached. More investigations, therefore, on the topic are warranted in this population.

Cognition

Previous literature regarding gender difference in preschool children's cognition is mixed, with research indicating that girls receive more attention from their teachers (Dobbs et al., 2004), and have better learning and memory than boys (Kaushanskaya et al., 2013; Rescorla et al., 2016), but no significant gender differences were found on math, general knowledge, letter-word identification, expressive vocabulary, sound awareness (Matthews et al., 2009), behavioral self-regulation and executive function

(Yamamoto & Imai-Matsumura, 2017). In the current study, I found no gender differences in preschool children's cognition, specifically in attention and executive functioning.

Notably, I used NIH Toolbox to assess children's attention and executive functioning, which is different from any previous research that examined gender difference in children's cognition, including learning, memory, vocabulary, math. etc. In addition, multiple factors could affect children's cognitive functions, such as biological (e.g., heredity, intelligence, sense organs, etc.), environment (e.g., community, school, peer/parental influence, etc.), nutrition, and socioeconomic status (Christensen, Schieve, Devine, & Drews-botsch, 2014; Ford & Stein, 2016). It is important to note that a majority of preschool children in the current study were from underserved families with low socioeconomic status. Indeed, socioeconomic status was found to be associated with cognitive performance as children from better socioeconomic status will get more opportunities and better training to help develop cognition (Christensen et al., 2014). That is, children in the current study might be at risk of poor nutrition and lack of additional training opportunities, all of which affect children's cognitive development. Moreover, children from low socioeconomic status families are more easily influenced by negative parenting, which also may impact young children's executive functioning (Hughes & Devine, 2017).

To summarize, in the current study, I found no gender differences in preschool children's attention and executive function. Nevertheless, this conclusion must be interpreted with caution as cognition is a broad concept and impacted by many factors. As preschool age is a developmental milestone for children's cognitive function, more

research is needed in identifying gender differences in children's cognition, with the ultimate goal of providing scientific evidence for future intervention studies to promote children's cognitive development.

Model of physical activity and health-related outcomes for preschool children

Participation in physical activity positively influences the development of motor skills, physical fitness, cognitive development, and other long-term health-related outcomes (King et al., 2006). Understanding the correlates of physical activity among preschool children is important for future experimental trials seeking to promote improvements in preschool children's physical health and cognitive development. As such, I developed a theoretical model and attempted to illustrate development mechanisms influencing physical activity trajectories of preschool children (Figure 3). While not all proposed hypotheses were validated in this model, I confirmed the relationships of cognition to motor skill competence and cardiovascular fitness in this population, which significantly contributes to the literature and provides preliminary evidence for future youth interventions—setting the stage for the development of experimental trials seeking to promote preschool children's cognition.

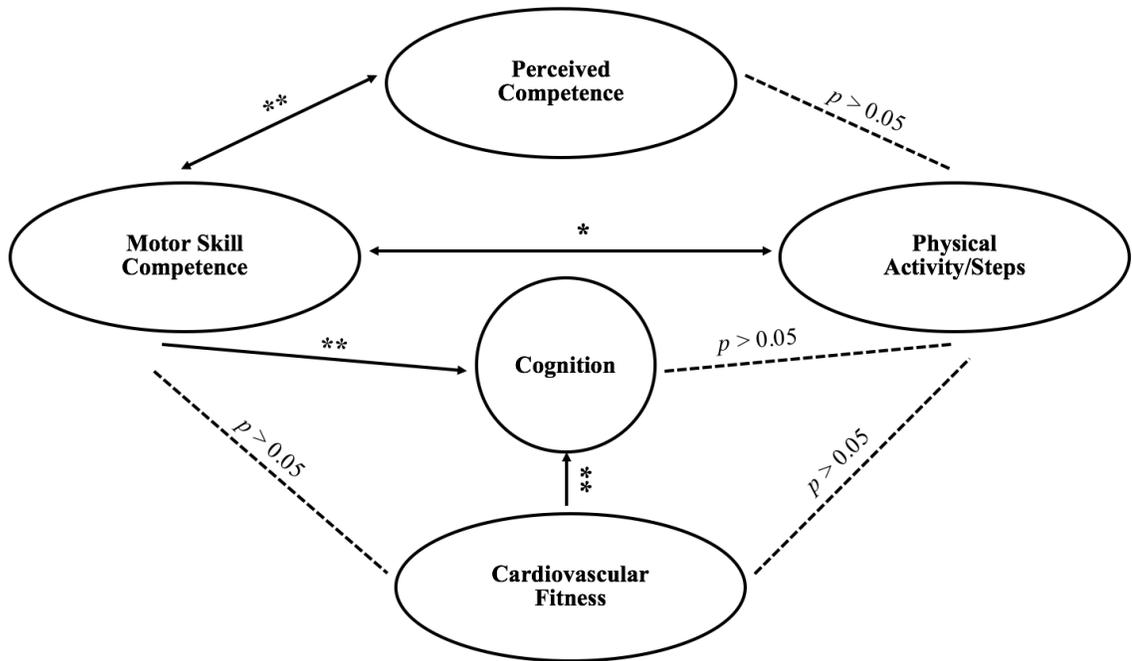


Figure 12 Relationships among Physical Activity, Motor Skill Competence, Cardiovascular Fitness, Perceived Competence, and Cognitive Function in Preschool Children

Study Strengths

The current study systematically reviewed the evidence concerning the relationships of physical activity to motor skill competence, cardiovascular fitness, perceived competence, and cognition, as well as how gender differences exist in these variables in preschool children. Several knowledge gaps and limitations are noted on each relationship in previous study, which help improve future studies that attempt to understand the correlates of preschool children’s physical activity— providing the foundation for experimental trials seeking to investigate the determinants of preschool children’s physical activity.

To the best of my knowledge, this is the first study investigating the relationships among physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition in preschool children. The current study provides preliminary

experimental evidence for future intervention programs aim to promote physical activity and cognitive development in this population. In detail, the study identifies motor skill competence as an underlying correlate of preschool children's physical activity, while confirming motor skill competence and cardiovascular fitness are important correlates of preschool children's cognition, which significantly contributes to the literature regarding how motor skills and physical fitness impact preschool children's cognition. That is, motor skill competence and cardiovascular fitness could be considered appropriate outcomes to evaluate the effectiveness of interventions for the improvement of physical activity and cognitive functions in preschool children.

Study Limitations

Several limitations within this study should be noted when interpreting and building upon the findings. To begin, the samples from the two schools had an uneven distribution of racial backgrounds. Specifically, most children included in the current study were either American-American or White, with other populations such as Hispanic and Asian were scant. In addition, participants from both schools were underserved population. As race, ethnicity, and socioeconomic status are moderating factors in explaining children's physical activity behaviors, they should be taken into consideration. That is, these factors may hamper the generalizability of the findings to other populations.

Second, I computed a sample of 80 participants to reach statistical significance. However, the fact that I recruited only 65 children, which may limit the ability to detect more potential significances. Therefore, future research with larger sample is needed.

Third, the selection of cut points. I used Pate Preschool (2006)'s cut points: sedentary: 0-799 counts per minute; light: 800-1679 counts per minute; moderate: 1680-3367 counts per minute; vigorous: ≥ 3368 counts per minute (Pate et al., 2006) to calculate preschool children's physical activity levels. However, the fact that there are other cut points available such as Freedson Children (2005), which classified children's physical activity into sedentary: 0-149 counts per minute; light: 150-499 counts per minute; moderate: 500-3999 counts per minute; vigorous: 4000-7599 counts per minute; very vigorous ≥ 7600 counts per minute. That is, different cut points will result in different physical activity levels captured, which may affect the results of the analyses. Nevertheless, I also calculated the steps as step count is promoted a useful indicator of physical activity level (Strath et al., 2013).

Fourth, while I used objectively measured physical activity, I only measured children's activities when they were in school (due to school policy and safety consideration, ActiGraph accelerometers were not equipped all time). In other words, I did not capture children's actual physical activity levels including outside of school. This could be considered the major limitation of the study since children performed structured activities during the school time, so their physical activities tend to be identical, which could partially explain why the proposed relationships of physical activity to other health-related outcomes were not observed. Therefore, future studies would be necessary to capture preschool children's all day physical activity data so that we can discern the correlates of actual physical activity behavior in this population.

Fifth, the causal relationships cannot be inferred due to the correlational nature of the current study. Nevertheless, understanding the correlates of preschool children's

physical activity behaviors is important in the design of intervention programs targeted at young children—setting the stage for the development of experimental trials seeking to promote improvements in preschool children’s physical and cognitive health.

Another limitation of this study would be some potential confounding variables such as lesson materials and teaching style. For example, children at School A had physical education class every day for 30 minutes, whereas those at School B only had physical education class 30 minutes per week. It would have been ideal to have children similar lesson plans and physical activity time for both schools in order to increase the internal validity of this study. Each school, however, has its own lesson plans for its own style of physical education classes, which may lead to children from different schools having inconsistent physical activity patterns during school time, as seen that children at School A had more physical activities monitored than their peers at School B.

Practical Implications

Preschool-aged children are an important target for behavioral change strategies, as this age cohort may enhance tracking into the crucial period of adolescence. Research regarding the relationships of objectively measured physical activity to motor skill competence, cardiovascular fitness, perceived competence, and cognitive function for this age group of children has not been adequately documented. In fact, underserved children are a special population as they are different from other normal peers from families with higher socioeconomic status in physical, psychological, and cognition development. My main purpose was to inform future physical activity interventions of how underserved preschool children’s motor skill competence, cardiovascular fitness, perceived competence, cognitive functions, and objectively determined physical activity related to

each other—setting the stage for the development of experimental trials seeking to promote physical, psychological, and cognitive health in this population.

Indeed, as investigated in the present cross-sectional study, components that foster the development of physical and cognition health may have the potential to significantly improve the long-term impact of childhood and adolescent development. I provided scientific evidence supporting the connections between outcomes of motor skill competence, perceived competence, cardiovascular fitness, and cognition in underserved preschool children. The relationships that I observed were sufficiently strong to warrant further investigation aims at examining cause-and-effect relationships.

Since many variables affecting preschool children’s physical activity and cognition, longitudinal designs may be more appropriate to assess dynamic relationships among these variables. My findings support the need for effective strategies that simultaneously promote motor skill competence, cardiovascular fitness, cognition, and physical activity behaviors in early childhood. Considering the observed low levels of physical activity during school time among underserved preschool children, developing a specifically designed movement-oriented intervention would be a strategic step towards improvement. Furthermore, the promotion of autonomous and competence-based activities among physical activity groupings (particularly targeting low active girls) may exist within future interventions.

Conclusion

In this cross-sectional study, I attempted to understand relationships among objectively measured physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition in preschool children, while determining the gender

differences in all study variables. My findings suggested that preschool children's MVPA during school time was not significantly related to their motor skills competence, perceived competence, cardiovascular fitness, cognition, but their step counts were significantly positively associated with motor skills competence. Nevertheless, preschool children's motor skills competence was not an ideal predictor of their step counts. In addition, motor skills competence was positively correlated with perceived competence, despite perceived competence seemed to be a weak predictor of motor skills competence in preschool children. Notably, I observed that preschool children's motor skills competence and cardiovascular fitness were significantly correlated with their cognition, respectively, but only cardiovascular fitness seemed to be a significant predictor of cognition. I also observed gender differences in MVPA/step counts and motor skill competence, with boys demonstrating more active and motor proficient than girls. Future research with larger and diverse samples is necessary to further explore the relationships of preschool children's daily physical activity levels (inside and outside school)/weekday and weekend physical activity patterns to other health-related outcomes.

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Appendices

Appendix A

Testing Protocols for Body Mass Index

Definitions

Body Mass Index

- A measure of body fat that is the ratio of the weight of the body in kilograms to the square of its height in meters

Calibration

- The use of standard test weights and measuring rods to check the accuracy of equipment

Height

- A standing measurement in inches or meters

Mid-Axillary Line

- An imaginary line through the axilla (armpit) parallel to the long axis of the body and midway between its ventral (front or anterior) and dorsal (back or posterior) surfaces (see Figure 4)

Frankfort Horizontal Plane

- Imaginary line passing through the external ear canal and across the top of the lower bone of the eye socket, immediately under the eye (see Figure 5)

Private

- Not openly or in public

Scale

- Instrument for measuring weight Stadiometer: instrument for measuring height

Weight:

- A measurement in pounds or kilograms

Zeroed

- Assuring the scale balances at “0 or 00” before the student steps on the platform

Equipment

Critical Components

- Accuracy and reliability are the two most critical components of height/weight assessment and are to some degree a function of the quality of the equipment. Equipment must also be properly used and maintained. Quality, easily calibrated and well-maintained equipment is a good investment and will provide years of accurate and reliable service
- Accuracy – degree to which a measurement of an individual corresponds to his/her actual weight or stature
- Reliability – degree to which successive measurements of the same child agree with specified limits

Calibration of Equipment and Use of Up to Date Screening Tools

Weight – Scales

- A properly calibrated, high quality balance beam or electronic digital scale should be used to measure children and adolescents

The scale should

- Be used for the purpose for which it was designed
- Be used in a private location
- Weigh in 0.1 kg (100 gm) or ¼ lb increments
- Be stable and have a large enough platform for support for the individual being weighed
- For balance beam scales, is capable of being ‘locked’ in and is at eye level of the measurer
- Can be “zeroed”
- Can be calibrated through professional service or by standard known weight
- Not have wheels attached

Scales should be calibrated regularly to ensure accurate measurements

- Use known weights (a set of standard weights purchased from a sports store) on the scale or a professional service to check accuracy
- Send the scale for professional calibration if the standard weight and the scale weight are off by ¼ pound or more. For a digital scale, change the batteries and if it is still off after checking again with the standard weights, send scales for professional calibration and/or check the owner manual for scale instructions
- Re-calibrate if the scale has been moved to a different surface
- Portable digital scales, frequently moved, should be calibrated monthly
- For scales that are not moved or used excessively, calibrate at least annually

Height – Stadiometers

- A portable or wall-mounted stadiometer should be used

The tool should

- Be used for the purpose for which it was designed
- Not include tapes, yardsticks or graphics attached to the wall
- Measure in 0.1 cm or 1/8 inch increments
- Have an easily moveable horizontal headboard at least 3 inches wide that can be brought into contact with the most superior part of the head
- Should have a wide and stable platform or firm uncarpeted floor as the base
- Not use metal height attachment attached to a scale

Check the stadiometer regularly to be sure the base is stable and measures are accurate

- Length rods, a standard measuring test rod, should be used to verify accuracy at least annually
- Portable stadiometers should be checked more frequently
- If a discrepancy is found in accuracy, contact the manufacturer for advice

Instructions for Measuring Weight

- Set the scale at zero reading
- Have the children remove shoes, heavy outer clothing to extent possible
- Have the children step on the scale platform, facing away from the scale read out, with both feet on the platform, and remain still with arms hanging naturally at side and looking forward
- Read the weight value to the nearest $\frac{1}{4}$ pound or 0.1 (1/10) kilogram
- Have the student step off the scale and take a second measurement, repeating the steps above (measurements should agree within 0.1 kilogram or $\frac{1}{4}$ pound; if not, re-measure until this standard is met)
- For confidentiality and to avoid stigma or harassment, do not call out weight value
- Record the weight value immediately on the student health record or data log
- If using a balance beam scale, return the weights to zero position

Instructions for Measuring Height

- Have the student remove shoes, hat, and hair ornaments /buns/braids to extent possible
- Have the student stand on the footplate or uncarpeted floor with back against stadiometer rule
- Have the student bring legs together (in contact at some point, whatever touches first)
- Assure children's legs are straight, arms are at sides, and shoulders are relaxed
- Assure the back of the student's body touches/has contact with the stadiometer at some point, preferably with heels, buttocks, upper back and head touching the measuring surface
- Assure that the child's body is in a straight line (mid-axillary line parallel to the stadiometer), see Figure 4
- Assure the head is in the appropriate position (Frankfort plane) see Figure 5
- Ask the child to breathe in and hold his/her breath while being measured

Figure 13 Mid-axillary Line

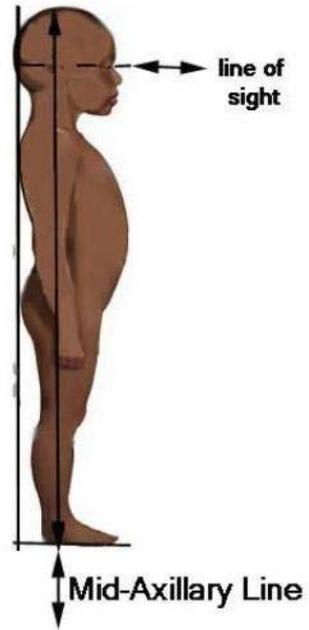
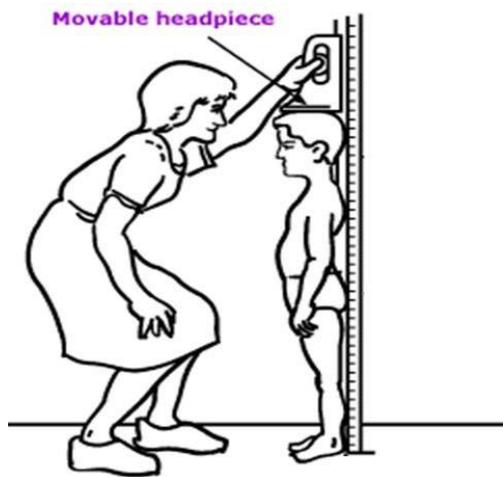


Figure 14 Frankfort Horizontal Plane





- Lower the headpiece until it is touches the crown of the head firmly, compressing the hair
- Position yourself so that your eyes are parallel with the head piece and read the measurement to the nearest 0.1 cm or 1/8 inch, make note of the first measurement
- Move the headboard away, check the posture, and re-measure the child
- Measurements should agree within 1 cm or 1/4 inch, re-measure and select the average of the two measures that agree the most
- Immediately record the results

Appendix B

ActiGraph Link Accelerometers Protocol



Preschool Children's physical activity levels for 3 days will be assessed using ActiGraph Link accelerometers. Children will be instructed to wear the accelerometers on the left wrist during school time.

Preparation of the ActiGraph:

- Label the monitors from #1-70
- Charge all monitors
- Initialize all accelerometers. Test each unit by initializing and wearing it for at least 24 hours. Download and check that the device recorded data and the counts are within a reasonable range (< 16,000 cpm)

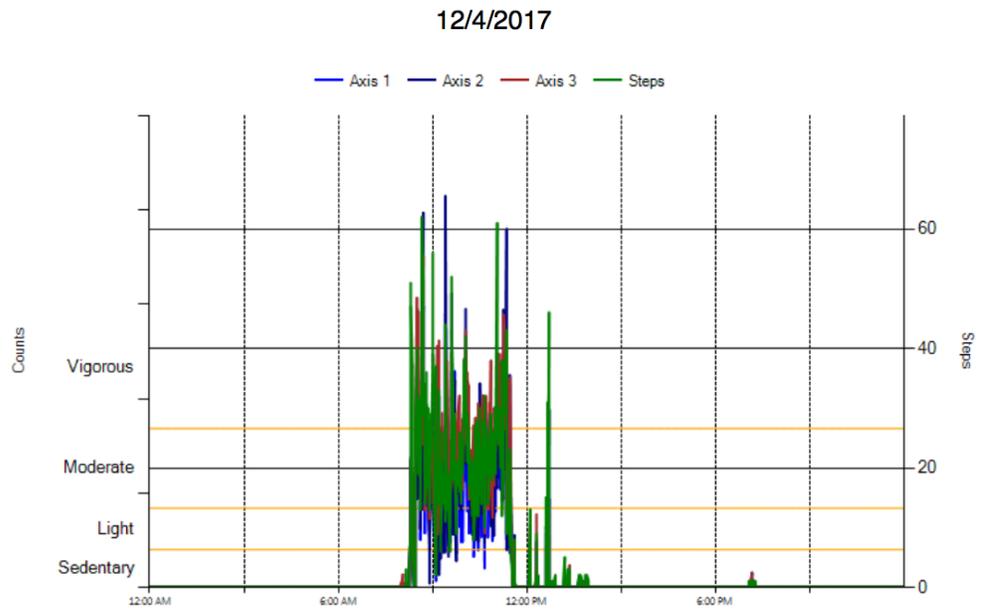
Data Collection

- Assign one number to each student
- Dress professionally and minimize disruption in the classroom
- On the first day of data collection, physically show the students how to place the accelerometers in the classrooms
- Be Early. Go to classrooms before 7:50 am, and distribute the assigned accelerometers to the corresponding students
- Reinforce that the children should put on the accelerometers all the time
- If a child does not wear the accelerometer for 3 school days, go back on another day to collect the make-up data

Data Downloading and Sorting

- Download data to PC after data collection
- Sorting and analyzing

Example of accelerometer data of one day for a preschool child



Appendix C

Motor Skill Competence Protocol

Testing Conditions					
1 = Interfering with Data Collection and 5 = Not interfering with Data Collection					
Noise Level	1	2	3	4	5
Interruptions	1	2	3	4	5
Distractions	1	2	3	4	5
Light	1	2	3	4	5
Temperature	1	2	3	4	5

Run			
Criteria	Trial 1	Trial 2	Total
Arms move in opposition to legs, elbows bent			
Brief period where both feet are off the ground			
Narrow foot placement landing on heel or toe (not flat-footed)			
Nonsupport leg bent approx. 90 degrees (close to buttocks)			

Hop			
Criteria	Trial 1	Trial 2	Total
Nonsupport leg swings forward in pendular fashion to produce force			
Foot of nonsupport leg remains behind body			
Arms flexed and swing forward to produce force			
Takes off and lands 3 consecutive times on preferred foot			
Takes off and lands 3 consecutive times on non-preferred foot			

Jump			
Criteria	Trial 1	Trial 2	Total
Preparatory movement includes flexion of both knees with arms extended behind body			
Arms extend forcefully forward and upward reaching full extension above the head			
Take off and land on both feet simultaneously			
Arms are thrust downward during landing			

Kick			
Criteria	Trial 1	Trial 2	Total
Rapid continuous approach to the ball			
Elongated stride or leap immediately prior to ball contact			
Non-kicking foot placed evenly with or slightly behind ball			

Kicks ball with the instep of preferred foot (shoelaces) or toe			
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Throw			
Criteria	Trial 1	Trial 2	Total
Windup is initiated with downward movement of hand/arm			
Rotates hip and shoulders to a point where the non-throwing side faces wall			
Weight is transferred by stepping with the foot opposite the throwing hand			
Follow-through beyond ball release diagonally across body toward non-preferred side			

Appendix D

YMCA Step Test Protocol

Equipment required:

- 15.25 cm (6 inch) step
- Metronome set to cadence of 96 beats per minute (24 step-ups per minute) –refer to “How to Use a Metronome”
- Stop watch

How to use the Metronome

- Download the free metronome app on iPhone
- Set the pace to 96bpm
- Disable autolock
- Turn metronome from off to on (bottom button)

Prior to starting the test

- Demonstrate to the children how to perform the test by stepping up and down on the step keeping in time with the beat of the metronome
- The children can lead with either foot and is able to change the leading leg during testing, but **MUST** stay in time with the metronome
- The stepping must be up up, down down
- Children should not be holding on to a railing/wall during the test

Conduct testing

- Have the child start testing at the same time as starting the stop watch
- If the child deviates from the beat, instruct her/him a few times
- Record the one minute heart rate after the test

Cease Step Test Immediately if:

- The child is unable to complete the testing (physically and mentally)

Appendix E

Protocols for Survey and Cognition Testing

Perceived Competence

- The Pictorial Scale of Perceived Competence and Social Acceptance (PSPCSA) will be used to examine perceived competence

The test will be individually administered at available locations within the school outside of the classroom in order to protect the privacy of the child

Cognitive Function

- NIH-TB Cognition Battery tests
- NIH-TB Flanker Inhibitory Control and Attention Test (Executive/Attention)

This test is a version of the Eriksen flanker task derived from the Attention Network Test. It tests the ability to inhibit visual attention to irrelevant task dimensions. On each trial, a central directional target (fish for children younger than 8, arrows for ages 8 and older) is flanked by similar stimuli on the left and right. The task is to indicate the direction of the central stimulus. On congruent trials, the flankers face the same direction as the target. On incongruent trials, they face the opposite direction. A scoring algorithm integrates accuracy, a suitable measure in early childhood, and reaction time, a more relevant measure of adult performance on this task, yielding scores from 0 to 10. There are 40 trials and the average time to complete the task is 4 minutes

Appendix F

Example of School A Schedule (Anne Sullivan Communication Center)

AM Class

7:55-8:30 Arrival & Breakfast & Bathroom

8:30-9:00 Morning Meeting (greeting, explicit SEL & games)

9:00-9:30 Gym

10:00 -10:30: Math Choice time/small groups

11:00- 11:15 Clean up & Large group activity

11:15-11:30 Quiet time

11:30-11:35 Lockers

11:40 Buses

PM Class

12:25-1:00 Arrival & Lunch & Bathroom

1:00-1:30 Gym

1:30-2:00 Literacy large group & repeated read aloud

2:00 -2:15 Quiet time

2:15-2:20 Lockers

2:25 Buses

Appendix G

Example of School B Schedule (Loring Elementary School)

AM Class

8:30 Arrival & Check in

- Hang clothes, backpack in locker
- Return folder in necessary
- Sing in
- Read book

8:50 Breakfast

9:15-9:45 Specialist

- A: Computers
- B: Music
- C: Art
- D: Gym

9:50 Group time

- The listening rules
- Daily schedule
- Message
- Calendar
- Skill review
- Mini lesson

10:05 Small group

- Monday: None
- Tuesday-Thursday: 3 groups
- Friday: Journals

10:15 Choice time

11:10 Clean up

11:20 Story

11:40 Dismissal

PM Class

12:10 Arrival & Check in

- Hang clothes, backpack in locker
- Return folder in necessary
- Sing in

Read book

12:20 Lunch

12:45-1:15 Specialist

- A: Computers
- B: Music
- C: Art
- D: Gym

1:20 Group time

- The listening rules
- Daily schedule
- Message
- Calendar
- Skill review
- Mini lesson

1:35 Small group

- Monday: None
- Tuesday-Thursday: 3 groups
- Friday: Journals

1:45 Choice time

2:35 Clean up

2:45 Story

3:07 Dismissal