FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida.

# THE RELATIONSHIP BETWEEN AEROBIC FITNESS, GROSS AND FINE MOTOR SKILLS, AND ACADEMIC ACHIEVEMENT AMONG FIRST GRADE STUDENTS IN URBAN SCHOOLS AND THE ROLE THE RELATIVE AGE EFFECT MAY HAVE ON THESE VARIABLES

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by

Alberto Peláez

2019

To: Dean Michael R. Heithaus
College of Arts, Sciences, and Education

This dissertation, written by Alberto Peláez, and entitled The Relationship between Aerobic Fitness, Gross and Fine Motor Skills, and Academic Achievement among First Grade Students in Urban Schools and the Role the Relative Age Effect May Have on These Variables, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Date of Defense: February 4, 2019

The dissertation of Alberto Peláez is approved.

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Florida International University, 2019

## DEDICATION

I dedicate this dissertation and any good that comes out of it to my mother, Maria Magdalena and my father, Ignacio. You came to this country so that my brother, my sister, and I could have a better life and live out our dreams. I will always be grateful for the hard work you endured for us and the love and passion for knowledge and the truth that you instilled in us. I love you both.

I would also like to dedicate this to my brother Iggy for never losing hope in me and always being there for me, thank you; and to my sister, Rebe, for her ability to persevere no matter what she is faced with. You are both a blessing to me.

I would also like to dedicate this to the children and young adults I met throughout this journey from the Miami Dade County Public School System, the city of Progreso/San Pedro, and the Miami Dade County Juvenile Detention Center. You have awoken a giant in me. I will never forget you.

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ABSTRACT OF THE DISSERTATION

THE RELATIONSHIP BETWEEN AEROBIC FITNESS, GROSS AND FINE MOTOR SKILLS, AND ACADEMIC ACHIEVEMENT AMONG FIRST GRADE STUDENTS IN URBAN SCHOOLS AND THE ROLE THE RELATIVE AGE EFFECT MAY HAVE ON THESE VARIABLES

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This non-experimental design, cross-sectional, and retrospective study (N=79) examined the relationship among aerobic fitness, gross motor skills, fine motor skills, and academic achievement; aerobic fitness and reaction time; relative age effect and aerobic fitness, gross motor skills, and academic achievement. The Bruininks-Oseretsky Test of Motor Proficiency (BOT-2), Yo-Yo Aerobic Test, Diery Liewald Reaction Time Task, and Stanford Achievement Test 10 were administered to heterogeneous, non-randomized, first grade students. Hypotheses were examined using correlational analysis and independent T-tests.

The results indicated that aerobic fitness and academic achievement were not correlated with mathematics scores,or reading scores. Regarding gross motor skills and their correlation to academic achievement, only manual dexterity and bilateral coordination correlated positively with academic achievement. On the other hand, all fine motor skills correlated positively with academic achievement. When analyzing reaction

time and aerobic fitness, only simple reaction time correlated positively with aerobic fitness.

With regards to the relative age effect and aerobic fitness, no relationship was identified. However, a relative age effect was identified in the gross motor subcategories of upper limb coordination, bilateral coordination, and strength. Furthermore, there was a relative age effect observed with academic achievement. When taking gender into account, males demonstrated a higher mean difference in several subcategories of gross motor skills, specifically, upper limb coordination, manual coordination, body coordination and strength and agility. There was no group mean difference between males and females in fine motor skills. Lastly, with regards to handedness and footedness, right handedness demonstrated a relationship with the gross motor skill subcategories of upper limb coordination, manual coordination, running speed and agility, strength and strength and agility. However, footedness did not reveal a relationship with gross motor skills.

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# CHAPTER 1

# INTRODUCTION

This chapter begins with the background to the problem, problem statement, purpose of the study, and research hypothesis. Next, the conceptual framework and the terminology are discussed.

## Background to the Problem

Physical education classes are slowly fading from the American education system (Walker, 2014). As of 2012, only 6 states require physical education classes in grades K-12 (Shape of the Nation, 2012). In particular, physical education programs have been disappearing from urban schools (Halpern, 2003). Urban schools are characterized as "having a higher concentration of low-income or students in poverty, higher concentrations of special education students, higher percentage of discipline issues; with many limited financial or physical resources to properly accommodate and/or educate the students" (Holman, 2011, p. 13). Several of these urban schools receive Title 1 funding, a federal grant that provides monetary funds to schools that have a high number of children from low socioeconomic backgrounds (Department of Education, 2015).

The disappearance of physical education in urban schools may be a result of the No Child Left Behind agenda (No Child Left Behind, 2002), initiated in 2008 by former President George W. Bush. Part of the agenda included teaching the Common Core State Standards (McKloskey, 2010). The Common Core State Standards dictate that education throughout the United States must be standardized (Common Core, 2016). In other words, all curriculum should follow a standard model and content should be consistent across states. The Common Core State Standards dictate that students are required to successfully complete an examination at the end of the school year from kindergarten to the twelfth grade in order to advance to the next grade level (Common Core, 2016). The pressure on schools to raise standardized test scores resulted in a lack of support for physical education. School systems feel that time expended in physical education could instead be spent on refining academics (Patterson, 2013).

Academic performance is an important means with which schools obtain monetary funds. The No Child Left Behind Act mandated that schools meet certain academic criteria in subjects such as reading and mathematics in order to continue to receive funding (Klein, 2015). Since physical education is not a subject that is examined through standardized testing, most schools do not make it a priority to place funding to support this subject because federal funding is determined by how well or poorly a school scores on standardized testing, a number of low performing urban schools across the United States have had to endure the burden of either eliminating physical education or providing a sub-par version of the course (Heim, 2012).

Physical education programs should not be absent from the curriculum, nor should they fail to provide essential components of physical activity. Physical education programs should include a variety of components focused on fitness and the development of motor skills. In particular, physical education programs should expose children to weekly aerobic activities that would allow them to develop their aerobic fitness. Aerobic fitness is “the capacity of the cardiorespiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs” (Kowatch, 2012, p.1.). Aerobic fitness has shown a positive correlation with cognition (Haapala, 2013). The notion that aerobic fitness can improve cognition has been attributed to the changes that are occurring at the cerebral level, specifically within the basal ganglia and hippocampus (Chaddock et al., 2010). Aerobically fit children often have increases in hippocampal and basal ganglial volume, through a neuronal increase, compared to children that are not aerobically fit (Chaddock et al., 2010). These are areas responsible for components of cognition, such as memory and attention. In addition, another component of cognition, reaction time, is augmented by aerobic fitness (Geersten et al., 2016). Reaction time is defined as "how quickly someone can respond to a stimulus" (Geersten, et al., 2016, p. 7). Reaction time plays an important part in how quickly a child learns a particular task in subjects such as reading and mathematics (Gold et al., 2013).

In addition to aerobic fitness, physical education classes should also be a time to develop gross motor and fine motor skills. Motor skills are defined as an "activity or task that has a specific purpose or goal to achieve," (Magill & Anderson, 2014, p. 5). Motor skills may play a significant role in the development of cognitive processes used to achieve in subjects such as reading, language, and mathematics (Son & Meisels, 2006; Dinehart & Manfra, 2013; Viholainen et al., 2006). Much like aerobic fitness, certain motor skills may be correlated to cognition (Diamond, 2000).

Gross and fine motor skills are examples of motor skills that may be co-developing in accordance with cognition and within an "equally protracted developmental timetable" (Diamond, 2000, p. 44). A gross motor skill is "a motor skill that requires the use of large musculature to achieve the goal of the skill" (p. 11) and can consist of walking, jumping, hopping, running, skipping, throwing, and catching (Magill & Anderson, 2014; Lerner & Kline, 2006). Additionally, gross motor skills require large and whole body movements.

A fine motor skill is “a motor skill that requires control of small muscles to achieve the goal of the skill; it typically involves eye-hand coordination and requires a high degree of precision of hand and finger movement” (Magill & Anderson, 2014, p. 11). “These skills include learning to eat with utensils; dressing; and manually using buttons, zippers, pencils and crayons (Lerner & Kline, 2006). Unlike gross motor skills, fine motor skills do not involve gross movements, large muscles, or the whole body to be effectively put to use. However, fine and gross motor skills may correlate to certain forms of handedness (Giagazoglou, 2001).

Handedness is “the natural or biological preference for using one hand more than the other in performing special tasks depending on which hemisphere is dominant for the task” (Ghayas & Adil, 2007, p. 85). Handedness can be observed as early as two years of age; however, the stable use of handedness whether right, left, or mixed handed may vary within the years of early childhood development (Michel et al., 2006). Similarly, during early child development, between the ages of 4 and 10, gross and fine motor skills begin to develop (Gabbard, 2008). Early child development is also a period of time when motor development occurs as girls typically demonstrate proficiency in fine motor skills, whereas boys typically demonstrate proficiency in gross motor skills (Junaid & Fellows, 2009).

Until recently, motor development in gross and fine motor skills and cognitive development have often been treated and studied as two different entities that have little to do with one another (Diamond, 2000). Motor development is defined as “human development from infancy to old age with specific interest in issues related to either motor learning or motor control” (Magill and Anderson, 2014, p.5). Both motor and cognitive developments have been “viewed as independent phenomena” (Diamond, 2000, p.1). However, there has been a reemergence of attention in the role motor development may play in the cognitive, social, and emotional development of a child (Piek et. al, 2007). Motor development is currently being considered to be a “control parameter” and “prerequisite” (Bobbio et al., 2009, p.3) for the development of cognition; moreover, both may fundamentally be interrelated (Diamond, 2000). A number of studies demonstrated a positive correlation between motor development in fine and gross motor skills and overall cognition (Piek, Dawson, Leigh & Smith, 2008; Bobbio et al., 2009; Dinehart & Manfra, 2013). With regards to handedness, data indicate that mixed handed children show a low level of cognition (Tan, 1985; Crow, Crow, Done, & Leask, 1998; Corballis, Hattie, & Fletcher, 2008). Cognition plays an important role when considering a child’s success in school through academic achievement (Kaufman et al., 2011).

Academic achievement represents “increased grades in core academic classes or increasing tests scores on standardized tests” (Podulka, et al., 2006, p.1). Children who excel academically through the development of their reading, writing and math skills “are less likely to fail in school and more likely to develop the thinking skills they need to graduate from high school and posts-secondary school” (Regier, 2011, para. 3). Although socioeconomic status and ethnicity were not taken into consideration in these correlational studies, certain children who have demonstrated that they are aerobically fit or proficient in gross or fine motor skills have shown higher performance in English and Math (Geertsen et al., 2016; Dinehart & Manfra, 2013; Piek, Dawson, Smith, & Gasson, 2008). Therefore, academic achievement may be affected by aerobic fitness and motor skill development (Geertsen et al., 2016; Son & Meisels, 2006; Haapala et al., 2014).

In addition, aerobic fitness, motor skills and academic achievement may be affected by the relative age effect (Roberts, Boddy, Fairclough, & Stratton, 2012; Muller et al., 2015; Lin, Freeman & Chu, 2009). The relative age effect refers to "the selection and performance differentials between children and youth who are categorized in annual-age groups" (Romann & Cobley, 2015, p.1). The relative age effect displays itself when, for example, a child is born earlier in the year and another child is later, within the same year. The same year age difference could signify substantial physiological and cognitive differences between the two children (Dixon, Horton & Weir, 2011). A physical education program that implements aerobic fitness and motor skill development may be implemented as an intervention to improve the academic achievement scores of those children that are born later in the year.

## Problem Statement

A review of the literature has indicated that there may be a correlation between aerobic activity and academic achievement and between gross and fine motor skill development and academic achievement (Castelli, Hillman, Buck & Erwin, 2007; Bobbio, Gabbard, & Cacola, 2009; DaSilva, Gabbard, Ries, & Bobbio, 2014). However, currently, there is limited literature on the simultaneous assessment of aerobic activity, gross and fine motor skill development with academic achievement (Geersten et al., 2016; Haapala, 2013).

Aerobic activity and motor development in physical education classes may play an important role in academic achievement among urban schools. Some research has demonstrated that gross and fine motor skills, may have a significant role on academic achievement because of the role both play in cognitive development (Bobbio et al., 2009;

Dinehart & Manfra, 2013). Similarly, aerobic activity may play a role in academic achievement because of its effects on cognition, specifically memory, attention, and reaction time (Geersten et al., 2016). Therefore, as students develop their aerobic fitness, and gross and fine motor skills in physical education, they may then be developing cognitive skills, such as memory, attention, and reaction time; as well as academic achievement.

Although literature on aerobic fitness, motor skills and academic achievement (Haapala, 2013; Piek, Dawson, Leigh & Smith, 2008; Bobbio et al., 2009; Dinehart & Manfra, 2013) exists, it is limited and does not address urban children in the United States. The literature also fails to address the significance that a quality physical education program, which includes aerobic activity and motor skill development, may have in improving the academic scores of urban schools.

## Purpose of the Study

The purpose of the study was to examine if there is a positive correlation between aerobic fitness, gross and fine motor skills, a component of cognition, reaction time, and academic achievement; and the impact the relative age effect may have on aerobic fitness, gross and fine motor skills, and academic achievement. The study also identified the effect that gender and handedness had on gross and fine motor skills and academic achievement.

## Research Hypotheses

$H_1$: There is a positive correlation among aerobic fitness and academic achievement.

*$H_2$:* There is a positive correlation among gross motor skills and academic achievement.

*$H_3$:* There is a positive correlation between fine motor skills and academic achievement.

*$H_4$:* There is a positive correlation between aerobic fitness and a component of cognition, reaction time.

*$H_5$:* There is a relative age effect on aerobic fitness.

*$H_6$*: There is a relative age effect on gross motor skills.

*$H_7$:* There is relative age effect on academic achievement.

*$H_8$:* There is a significant group mean difference by sex in gross motor skills.

*$H_9$:* There is a significant group mean difference by sex in fine motor skills.

*$H_{10}$:* There is a significant group mean difference in left handedness, footedness and gross motor skills.

## Conceptual Framework

### Aerobic Fitness and Cognitive Skills

Low levels of aerobic fitness are "associated with declines in academic achievement, cognitive abilities, brain structure and brain function" (Chaddock, Pontifex, Hillman & Kramer, 2011, p. 1). Structural brain imaging through Magnetic Resonance Imaging (MRI) has been used to identify these physiological differences in brain structure and function between aerobically fit and unfit individuals. The MRI instrument has  shown that aerobic fitness may be considered a tool with which to enhance brain structure and function in order to improve cognition and positively affect academic achievement (Chaddock, Pontifex, Hillman, & Kramer, 2011).

Compared to unfit children, aerobically fit children display cortical differences within the basal ganglia, an area of the brain considered to play a role in cognition; the hippocampus, an area of the brain also associated with cognition, particularly memory, and the prefrontal cortex, an area of the brain associated with attention and reaction time (Chaddock et al., 2012; & Chaddock et al., 2010).

**Basal ganglia**

The basal ganglia is an area of the brain that has been associated with cognition (Chaddock et al., 2012). The portion of the brain is divided into two structures. The first structure, the dorsal striatum plays an important role in "cognitive flexibility" or the ability to shift from one topic to another; and the execution of learned behaviors (Chaddock et al., 2010, p. 2). Cognitive flexibility can be seen when children are attempting to consider different answers to questions and create alternate answers to problems that are presented to them (Johnco, Wuthree, & Rapee, 2013). When comparing fit and unfit children, a significant lower volume of the dorsal striatum has been observed (Chaddock et al., 2010). The second structure, the ventral striatum, is responsible for the fortification of learning skills and the motivational states of a child (Aron et al., 2009; Casey, Getz, & Galvan, 2008). Overall, aerobic fitness has shown to promote neuronal activity within these two structures (Chaddock et al., 2012).

**Hippocampus**

The second section of the brain that has shown to positively correlate with aerobic fitness activity is the hippocampus (Erickson et al., 2016). The hippocampus is found within the temporal lobe that is an important factor in memory related tasks (Erickson et al., 2016). Memory is a significant component for children in their school setting because it assists a child in a number of different areas in academics, including the ability to focus on a task, remembering instructions and executing steps on a math problem (Klingberg, 2012). Aerobic activity also triggers neurogenesis, or the growth and development of neurons, in the hippocampus (Erickson et al., 2011). The development of neurogenesis through aerobic activity is significant because neurons form the basis through which signals travel within the different structures of the brain, allowing for a swift and effective recall of information within the hippocampus when a child, in this case, is confronted with school work (Erickson et al., 2011).

When unfit children have been compared to fit children a significantly lower hippocampal volume has been observed (Chaddock et al., 2011). In a correlational study observing fit and unfit children, the aerobic children demonstrated higher levels of performance on "cognitive control challenges that involve inhibition, cognitive flexibility, and working memory" (Chaddock et al., 2011, p. 421).

**Prefrontal Cortex**

The third part of the brain that has been shown to positively correlate with aerobic activity is the prefrontal cortex (Chaddock-Heyman et al., 2013; Davis et al., 2011). The prefrontal cortex plays an important role in attention related tasks and reaction time to stimuli (Chaddock-Heyman et al., 2013; Davis et al., 2011). Children require a level of attention throughout their academic endeavors in order to work effectively on different assigned tasks in school. A decrease in attention can cause "distracting thoughts or habitual responses which get in the way of performing the task at hand" within different subjects (Stevens & Bavelier, 2012). For example, in mathematics a child must be able to use the material explained by a teacher to solve a problem. While in reading, a student must consistently pay attention to the passage to be able to comprehend the material. Both subjects require that students concentrate when a teacher is lecturing on a new subject, in an effort to obtain all the details and methods needed to excel in the subject matter. Having delayed reaction time in a class setting "will affect learning in a negative way and be included in factors preventing them to succeed in courses" (Taskin, 2016, p. 206). With regards to reaction time and academics endeavors, reaction time plays a significant role in how quickly a child responds to a problem posed by a teacher or another student.

## Motor and Cognitive Skills

Motor and cognitive skills begin at the brain level. Activation of several areas of the brain allow an individual to engage in motor or cognitive activities. For example, when performing a motor or cognitive activity, these segments of the brain efficiently work to allow a child to execute the particular skill. These segments of the brain that are co-developing and activating are the cerebellum and the prefrontal cortex (Diamond, 2000).

### Cerebellum

One area of the brain that plays a pivotal role in motor and cognitive learning is the cerebellum (Ellerman et al., 1994). The cerebellum is a section of the brain that is responsible for physical coordination as well as cognitive elements such as visuospatial and verbal working memory, attention, and pattern detection (Koziol et al., 2014). The cerebellum is most active or "heavily recruited" when either a motor or cognitive task is unfamiliar, requires concentration, or is about to be performed for the first time (Diamond, 2000, p. 46). Since all forms of learning require the brain to maintain, sustain, and process information, the cerebellum has been taken into account when considering the development of learning a type of motor skill, and other forms of learning, such as cognitive learning (Koziol et al., 2014).

**Prefrontal Cortex**

The second section of the brain that is associated with motor and cognitive performance is the prefrontal cortex (Diamond, 2000). The prefrontal cortex assists cognitive functions by enabling us to store and organize information, pay attention, and self-regulate behaviors (Diamond 2000). These cognitive functions are important when a child is working on subjects such as reading and math. Reading and math require students to pay attention, organize past information, and self-regulate behaviors. Self-regulation can be defined as "the processes by which the self-alters its own responses, including thoughts, emotions, and behaviors" (Baumeister, 1997, p. 146). These cognitive functions allow students to work on present problems. For example, in mathematics a student must be able to use the material explained by a teacher to solve a problem. While in reading, a student must consistently pay attention to the passage to be able to comprehend the material. Both subjects require that students concentrate when a teacher is lecturing on a new subject, in an effort to obtain all the details and methods needed to excel in the subject matter.

Many of the cognitive functions that the prefrontal cortex is responsible for are also important in motor performance. For example, when executing motor skills, a child must be able to pay attention, organize information on how the movement will be performed, and perform the skill within the appropriate time frame. These factors allow the skill to be carried out effectively.

### Co-activation of the Cerebellum and Prefrontal Cortex

In addition to the motor and cognitive development roles that the cerebellum and prefrontal cortex independently contribute to, there is also a "co-activation" (p.44) of the cerebellum and prefrontal cortex when these sections of the brain are exposed to either a motor or cognitive activity (Berman, et al., 1995; Diamond, 2000).

When a child performs "stimulation in the form of movement" (p.1) during the early developing years, synapses, or the connections located between brain cells, are strengthened (Greenough & Black, 1992; Shatz, 1992; Gabbard & Rodrigues, 2009). Moreover, neurons, or brain cell synapses found in the cerebellum and prefrontal cortex are "enriched" (p.2) by the means of participating in motor activities that stimulate the brain, which may then play a "significant factor in its overall development" (Jones & Greenough, 1996; Kempermann & Gage, 1999). The stimulation of the synapses in the cerebellum and prefrontal cortex occurs when a child is engaged in academic subjects such as reading and mathematics and participates in gross and fine motor activities that include kicking, catching, postural control, coordination, and handwriting (Jones & Greenough, 1996; Kempermann & Guy, 1999; Gabbard & Rodrigues, 2009; Dinehart & Manfra, 2014).

## Significance to the Field

A review of the literature has indicated that there may be a correlation between aerobic activity, gross and fine motor skill development with academic achievement (Castelli, Hillman, Buck & Erwin, 2007; Bobbio, Gabbard, & Cacola, 2009; DaSilva, Gabbard, Ries, & Bobbio, 2014). Some research demonstrated that aerobic fitness and gross and fine motors skills, may have a significant role on academic achievement because of their relevance to cognitive development (Geersten et al., 2016; Bobbio et al., 2009; Dinehart & Manfra, 2013). A quality physical education program can play a vital role in improving aerobic fitness and motor development (Son & Meisels, 2006; McKenzie, Alcaraz, & Sallis, 1998). By highlighting that aerobic fitness and motor skills may have a positive effect in increasing academic achievement, the results of this study may defend the notion that physical education should remain in the American school curriculum. In addition, the identification of a relative age effect on aerobic fitness, motor skills, and academic achievement among children that are born later in the year may serve to promote future research studies that focus on improving academic achievement through an intervention that utilizes physical education programs to develop aerobic fitness and motor skills.

## Assumptions

The researcher's assumptions included: (a) Aerobic fitness will have a positive correlation to academic achievement (b) Aerobic fitness will demonstrate a positive correlation to cognition, specifically reaction time (c) Motor development is an essential component of cognitive development, (d) The Common Core State Standards that have been promoting the exclusion of physical education are not conducive to enhancing academic achievement, (e) Gross and fine motor skills will demonstrate a positive correlation to academic achievement (f) Females will demonstrate a more positive correlation between motor skills and academic achievement than males, (g) Mixed handed children will demonstrate difficulties in motor skills and academic achievement, (h) There will be a relative age effect on aerobic fitness, (j) There will be a relative age effect on gross and fine motor skills, and (k) There will be a relative age effect on academic achievement.

## Delimitations of Study

The first delimitation of this study consisted of the child's background. There is the possibility that some of the participants may have engaged from an earlier age (prior to 6 years of age) in a program that focused on enhancing aerobic fitness and/or improving motor skills (such as playing an instrument or participating in a sports program). In that event, that child would be at an advantage over the rest of the sample in aerobic fitness and/or motor skill development. The second delimitation of this study was the participant's engagement in an afterschool math and/or English tutoring program. If a participant was engaged in afterschool tutoring, they may have had an academic advantage compared to the rest of the sample that may only have been receiving instruction time during normal school hours. Finally, the accuracy of the demographic questionnaire was dependent on the information provided by the children's legal guardians. Therefore, there exists the possibility that the questionnaire may not have been completed properly. An incomplete questionnaire could have had a direct impact on the inclusion and exclusion criteria affecting the results of the study.

## Terminology

- Academic achievement- "increased grades in core academic classes, or increasing tests scores on standardized tests" (Podulka, Pivarnik, Womack, Reeves, & Malina, 2006, p.1).
- Academic redshirting- "the act of keeping a child out of school for an additional year before kindergarten" (Dougan & Pijanowski, 2011).
- Aerobic fitness: "the capacity of the cardiorespiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs" (Kowatch, 2012, p.1)
- Attention Deficit Disorder (ADD)- "a syndrome of disordered learning and disruptive behavior that is not caused by any serious underlying physical or mental disorder and that has several subtypes characterized primarily by symptoms of inattentiveness or primarily by symptoms of hyperactivity and impulsive behavior or by the significant expression of all three" (http://www.merriam-webster.com/dictionary/attention%20deficit%20disorder, 2015).
- Attention Deficit Hyperactive Disorder (ADHD)- "a persistent pattern of inattention and/or hyperactivity and impulsivity that is more frequently displayed and more severe than is typically observed in individuals at a comparable level of development" (DSM-lV, 2013, p.1).
- Bruininks- Osteretsky test of motor proficiency (BOT-2) - "an individually administered measure of fine and gross motor skills of children and youth, four through 21 years of age. It is intended for use by practitioners and researchers as a

discriminative and evaluative measure to characterize motor performance, specifically in the areas of fine manual control, manual coordination, body coordination, and strength and agility" (Deitz, Kartin, & Kopp, 2007, p. 87).

- Choice reaction time- "requiring the subject to make the appropriate response to one of a number of stimuli" (Deary, Liewald, & Nissan, 2015, p. 1).
- Cognition- "mental actions or processes of acquiring knowledge and understanding through thoughts, experience, and the senses" (Davis, Pitchford, & Limback, 2011, p. 569).
- Cognitive development- "cognitive development was a progressive reorganization of mental processes as a result of biological maturation and environmental experience" (McLeod, 2015, para.11).
- Cognitive flexibility- "The ability to shift from one topic to another; and the execution of learned behaviors (Chaddock et al., 2010, p. 2).
- Cognitive functioning- "an intellectual process by which one becomes aware of, perceives, or comprehends ideas. It involves all aspects of perception, thinking, reasoning, and remembering" (http://medical-dictionary.thefreedictionary.com/cog nitive+function, 2009).
- Developmental coordination disorder- "motor coordination difficulties which impedes functional performance and interferes with their academic achievement, physical- and psychological development as well as activities of daily living" (Milander, Coetzee & Venter, 2014, p. 1075)
- Fine motor skill- "a motor skill that requires control of small muscles to achieve the goal of the skill; typically involves eye-hand coordination and requires a high

degree of precision of hand and finger movement" (Magill & Anderson, 2014, p. 11).

- Gross motor skill- "a motor skill that requires the use of large musculature to achieve the goal of the skill (Magill, 2014, p. 11).
- Handedness- "the natural or biological preference for using one hand more than the other in performing special tasks depending on which hemisphere is dominant for the task" (Ghayas & Adil, 2007, p. 85)
- Interlimb coordination- "Sequential and simultaneous use of both sides of the body with a high degree of "rhythmicity" (Bobbio, Gabbard & Cacola, 2009, p. 1).
- Motor development- "human development from infancy to old age with specific interest in issues related to either motor learning or motor control" (Magill & Anderson, 2014, p. 5).
- Motor proficiency- "the development of complex movement patterns and motor control which enables complex motor skills using gross and fine motor skills" (Piennar, Barhorst, & Twisk, 2013, p.2).
- Motor skills- "an activity or task that has a specific purpose or goal to achieve" (Magill & Anderson, 2014, p. 5).
- Reaction time- "how quickly someone can respond to a stimulus" (Geersten, et al., 2016, p. 7).
- Relative age effect-"the selection and performance differentials between children and youth who are categorized in annual-age groups" (Romann & Cobley, 2015, p.1).

- Reverse relative age effect- “where low weight and height is an advantage, an overrepresentation of athletes born at the end of the competition year” (Romann & Fuchslocher, 2014, p. 651).
- Rhythm- “a regular, repeated pattern of sounds and movements” (http://www.merriam-webster.com/dictionary/rhythm, 2015).
- Self- regulation- “the processes by which the self- alters its own responses, including thoughts, emotions, and behaviors” (Baumeister, 1997, p. 146).
- Simple reaction time- “involves making a response as quickly as possible in response to a single stimulus” (Deary, Liewald, & Nissan, 2015, p1).
- Spatial abilities- “the ability to mentally represent spatial abilities and to anticipate the course and outcomes of transformations applied to those relations” (Reio, Czarnowlewski, & Eliot, 2004, p. 341).
- Stanford achievement test 10th edition (SAT-10) – “a set of standardized achievement tests used by school districts in the United States and in American schools abroad for assessing children from kindergarten through high school” (Stanford Achievement Test Series, Tenth Edition, 2014, p.1).
- Title 1- “provides financial assistance to local educational agencies (LEAs) and schools with high numbers or high percentages of children from low-income families to help ensure that all children meet challenging state academic standards.” (Department of Education, 2015).
- Urban school-“having a higher concentration of low-income or students in poverty, higher concentrations of special education students, higher percentage of

discipline issues; with many limited financial or physical resources to properly accommodate and/or educate the students" (Holman, 2011, p. 13).

- Working memory- "as short-term memory applied to cognitive tasks" (Cowan, 2008, p. 323).

### Chapter Summary

Chapter 1 introduced the reader to the relationship that may exist between aerobic fitness, gross and fine motor skills and academic achievement. The conceptual framework explained the role that the cerebellum, prefrontal cortex, hippocampus and basal ganglia had in aerobic fitness, motor development, cognition, and academic achievement

# CHAPTER 2

## LITERATURE REVIEW

This chapter will begin by introducing aerobic fitness. The chapter will then review the literature on motor skills, cognition, and then academic achievement. An in depth analysis of the role that the cerebellum and prefrontal cortex play in motor skills and cognitive development will follow.

## Aerobic Fitness

Aerobic fitness is “the capacity of the cardiorespiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs” (Kowatch, 2012, p.1). Aerobic fitness can be performed in a variety of ways including walking, running, and cycling. Recently, there has been a decline in physical activity, specifically aerobic exercises. This decline has been observed in the United States’ school system. This decline in activities may be detrimental because aerobic fitness can have both short term and long-term health benefits, including a decreased risk of being overweight or obese and cardiovascular disease (Beets & Pitetti, 2003). In addition, to the health benefits offered, the implementation of an effective aerobic fitness program may have positive effects on cognition (Hamilton, Erikson, & Kramer, 2008). However, despite these benefits, there has been a worldwide decline in aerobic fitness (Tomkinson & Olds, 2007). Children, in particular, are “becoming increasingly sedentary and unfit” (Haapala, 2013, p. 56). Programs in the United States, such as physical education, that were traditionally seen as designated times through which aerobic fitness could be carried out, are presently being “cut back” or “eliminated” due to the pressure to increase academic test scores (Grissom, 2005, p. 12).

## Motor skills

Motor skills are defined as “an activity or task that has a specific purpose or goal to achieve” (Magill and Anderson, 2014, p. 5). There are many types of motor skills such as visuospatial, perceptual, gross motor, its subsection of interlimb coordination, and fine motor skills. Of the many types of motor skills that exist, gross motor, interlimb coordination, and fine motor skills have been considered to have an effect on academic achievement (Bobbio, Gabbard & Cacola, 2009; Dinehart & Manfra, 2013).

**Gross Motor Skills**

Gross motor skills are defined as “a motor skill that requires the use of large musculature to achieve the goal of the skill” (Magill, 2014, p. 11). When gross motor skills are implemented, the individual relies on utilizing large body parts such as the arms and legs. Certain activities that require the use of the arms and legs to carry out a gross motor movement are running, walking, jumping, and crawling. As these gross motor skills are repeatedly executed, they are being developed (Thelen, 1994). During early childhood development, particularly between the ages of 3 months to 6 six years the child refines his or her gross motor skills (Thelen, 1994). Furthermore, between the ages of 5 and 10 there is an “accelerated development” of these skills (Westendorp et al., 2011, p. 2773).

The development of gross motor skills are refined as a child matures. The repetition of gross motor skills, such as crawling, walking, and running may contribute to the child’s ability to master these gross motor movements. Therefore, gross motor movements at an early age are an important component to the child’s motor development (Bobbio et al., 2009). As a child develops and masters gross motor skills, this may impact cognition and ultimately academic achievement from an early age.

## Fine Motor Skills

Unlike gross motor skills, and its subsection of interlimb coordination, fine motor skills require smaller muscles (Magill & Anderson, 2014). Fine motor skills "typically involve eye-hand coordination and requires a high degree of precision of hand and finger movement" (Magill & Anderson, 2014, p. 11). Fine motor skills are used when a child uses a pen or pencil to write, holds small items, or buttons a shirt. Although the foundation for fine motor skill development occurs during the first 6 years of a child's life, it is first seen as early as 3 months of age (http://www.parents.com/toddlers-preschoolers/development/physical/child-developing-motor-skills/, 2015).

Depending on the level of frequency and exposure to fine motor skills, a child will effectively develop his or her proficiency in carrying out the fine motor task (http:// www.fingergym.info/downloads/Finemotordevpp1-4.pdf, 2015). In order for a child to carry out these tasks successfully, he or she is first required to have their gross motor skills well developed.

## Gender and Motor Skills

There may be a significant difference in motor skill acquisition among boys and girls. Within the ages of 4 and 10, boys and girls refine their level of motor skill development (Gabbard, 2008; Westendorp et al., 2011). Under the age of 6, there is no significant difference between boys and girls in motor skill development (Chan & Chow, 2011; Bonvin et al., 2012). Despite identifying a range in age of motor skill development, "most researchers believe that children mostly gain advanced levels of these skills in preschool aged years or at the age of six" (Pahlevanian & Ahmadizadeh, 2014, p.1). Approximately after the age of six, girls develop an affinity for fine motor skills, whereas, boys develop an affinity to gross motor skills (Junaid & Fellowes, 2009). This may be related to the notion that males and females show different patterns of lateralized cortical and subcortical brain activation across the period of development from childhood through early adulthood (Bruckner et al., 2011).

The motor skills that have been noted to demonstrate a gender difference in young boys and girls are throwing and catching a ball, grasping a pencil, and handwriting legibility (Butterfield & Loovis, 1993). In a cross-sectional study that included a random sample size of 60 boys and 39 girls, motor skill differences were noted (Junaid & Fellowes, 2009). After testing the boys and girls in gross and fine motor skills, there was a difference between the two genders. Boys, for example, demonstrated dominance in ball skills, specifically throwing and catching; while girls demonstrated dominance in pencil grasping, a key component in writing legibly (Junaid & Fellowes, 2009).

In another cross-sectional study on gender differences in gross and fine motor skills, similar results to the study previously mentioned, indicated that girls are more skilled in fine motor activities whereas boys are more skilled in gross motor activities (Pahlevanian & Ahmadizadeh, 2014). After testing 51 girls and 40 boys in fine and gross motor skill level, girls showed a higher performance level compared to boys in actions such as "hand skills, including moving fingers, opening and closing hands alternatively," (p.3) whereas boys showed a higher performance level, compared to girls in “throwing and catching” (p. 3) a ball (Pahlevanian & Ahmadizadeh, 2014).

## Cognition

Cognition is defined as the process where “mental actions of acquiring knowledge and understanding through thoughts, experience, and the senses” occurs (Davis, Pitchford, & Limback, 2011, p. 569). This process plays a pivotal role in cognitive development (Diamond, 2000). Between the ages of 5 and 10 “aspects of cognitive performance related to abstraction, behavioral planning, and executive functioning develop” (Wassenberg et al., 2005, p. 1093). There are several components of cognition such as reaction time, memory, and attention (Geersten et al., 2016). As a child develops a new cognitive skill from the environment, the learning process occurs. This cognitive learning process may take place when learning a skill, such as tying your shoes or solving a mathematical equation. As the learning process is enhanced, cognitive development is enriched, which may ultimately impact academic achievement.

## Academic Achievement

Academic achievement plays an essential role in a student’s educational career. In the United States academic achievement is measured mainly through grade point average, standardized test scores, or both. It forms the basis through which students advance from one grade to the next and may ultimately determine what higher education institution a student will attend. Academic achievement can be defined as “increased grades in core academic classes, or increasing tests scores on standardized tests” (Coe, et al., 2006, p.1). Academic achievement can also be defined as “performance outcomes that indicate the extent to which a person has accomplished specific goals that were the focus of activities in instructional environments” (Steinmayer, 2015, p. 1).

The majority of educational systems regard the first grade as a critical period for overall development, including academic development (Entwisle & Alexander, 1998). This is a time where children begin to be exposed to class like, seated directions and assignments given by teachers. During this period, educators take the time to understand the “factors that shape early achievement” (Bossaert, Doumen, Buyse, & Verschueren, 2011, p. 47). Throughout this stage of early development both gross and fine motor skills continue to be developed; as well as important components in academic achievement, such as higher order thinking, attention, working memory, understanding and cognition. The motor and cognitive co-development that is occurring is very important in early childhood development and could affect academic achievement. Academic achievement should be enhanced using all possible methods, even considering the possibility of allocating the necessary time in curriculums for the development of motor skills such as gross and fine motor skills.

The implementation of gross and fine motor skills in school curriculums can be challenging because of restrictions placed on subjects that require motor skills. For example, since the inception of No Child Left Behind in 2001, 44% of school administrators reported reducing time in classes that require either gross motor skills or fine motor skills such as physical education classes, recess, and the arts in order to allocate more time to reading and mathematics with the intention of improving levels of academic achievement (Kohl & Cook, 2013). However, No Child Left Behind has produced a sense of panic that over emphasizes reading and math test scores but leaves little room for the arts, handwriting, recess, and physical education. Subjects like physical education are areas within school hours that allow children to develop the critical motor skills that correlate to academic achievement (Bobbio, Gabbard, & Caçola, 2009).

## Aerobic Fitness and Cognition

Aerobic fitness is an important component of physical fitness and can be defined as "the capacity of the cardiorespiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs" (Kowatch, 2012, p.1). Schools are an important and "unique venue" for children to meet the daily physical activity requirements, because they serve approximately 56 million students (Center for Disease Control, 2015). However, a number of schools throughout the United States are not offering physical education (Shape of the Nation, 2012). The absence of a quality physical education program may decrease a child's participation in daily aerobic exercise. The absence of a quality program could not only adversely affect a child's health, but it may also affect areas of cognition because of its effect on the brain (Tomporowski, Davis, Miller, & Naglieri, 2009). Prior to puberty, "the early adolescent brain goes through a growth spurt" where "heavily used connections between parts of the brain are strengthened," specifically within the prefrontal cortex (Salyers & McKee, 2009, p.1). This period of time is also a sensitive phase during which aerobic fitness can be improved (Armstrong & Welsman, 1994).

A structured and efficient cardiorespiratory program has been proposed to affect various aspects of cognitive development such as reaction time, memory, and attention (Tomporowski, Davis, Miller & Naglieri, 2009). These aspects of cognitive development may play an important role in academic achievement. Aerobic fitness has been associated with academic achievement (Wittberg, Northrup, & Cottrell, 2012). A longitudinal, correlational analysis on 1725 children obtained baseline aerobic fitness and academic scores and two years later examined the same children on their levels of aerobic fitness (using the PACER exam) and academic achievement. The results indicated that there was a correlation between aerobic fitness and academic performance both at baseline, and two years later (Wittber, Northrup, & Cottrell, 2012).

**Aerobic Fitness and Reaction Time**

Aerobically fit children have demonstrated faster reaction times than their unfit peers (Moore et al., 2013). There are two components of reaction time that will be addressed in this study, simple and choice. Simple reaction time "involves making a response as quickly as possible in response to a single stimulus" (Deary, Liewald, & Nissan, 2015, p1). Choice reaction time is "requiring the subject to make the appropriate response to one of a number of stimuli" (Deary, Liewald, & Nissan, 2015, p. 1). Both simple and choice reaction time are important components of cognition (Deary, Liewald, & Nissan, 2015).

An analysis of aerobic fitness and reaction time in elementary school aged children concluded that there was a positive correlation between the two factors (Scudder et al., 2014). The researchers noted that "greater aerobic fitness was significantly related to shorter reaction time and superior accuracy during the flanker task" (Scudder et al., 2014, p. 1). The correlational study examined children's aerobic fitness using the Progressive Aerobic Cardiovascular Endurance Run (PACER) and then tested for reaction time using the Eriksen flanker test (Scudder et al., 2014). The Eriksen flanker test has been used in a number of studies that have compared aerobic fitness to cognition (Davranche, Hall, & McNorris, 2009; Kamijo, Nishihira, Higashirua, & Kuroiwa, 2007).

A more recent longitudinal analysis of aerobic fitness and reaction time within elementary school aged children supported the results of the above mentioned study (Scudder et al., 2016). This longitudinal analysis also used the PACER exam to measure aerobic fitness and examined the children at baseline, and after continuing to demonstrate aerobic fitness three years later. After three years, the aerobically fit children were asked to perform the Eriksen flanker test of reaction time and the results of this reaction test correlated with the results of the PACER exam, thereby indicating that aerobic fitness may be correlated to reaction. The researchers further recommend that "such evidence is vital for implementing future health recommendations intended to foster improved cognitive performance in children" (Scudder et al., 2016, p. 967).

**Aerobic Fitness and Memory**

Another cognitive function that has been noted to differ among aerobically fit and unfit individuals is memory. Children who have demonstrated a higher level of aerobic fitness have demonstrated differences in hippocampal volume and "superior memory performance compared to lower fit children" (Chaddock-

Heyman at al., 2014, p. 36). Evidence from a meta-analysis on aerobic activity and memory in children indicated that there may be a significant difference between those children involved in cardiovascular activity and those that are not involved in the activity (Chaddock-Heyman et al., 2014). The meta analysis reviewed the literature that focuses on children that are 7-10 years of age and the effects that aerobic fitness has on "brain structure, brain function, cognition, and school achievement" (Chaddock- Heyman et al., 2014, p. 25). In particular, the meta- analysis concluded that the hippocampus, a portion of the brain responsible for working memory has "been found to relate to aerobic fitness in children" (Chaddock-Heyman et al., 2014, p. 36). A longitudinal study supported these results by observing working memory in children after implementing a nine-month aerobic fitness program (Monti et al., 2012). In the results, the researchers concluded that the children within the intervention group, that were exposed to aerobic activity, demonstrated a more efficient level of hippocampal activity when presented with a memory task (Monti et al., 2012).

**Aerobic Fitness and Attention**

In addition, to the effects of aerobic activity may have on reaction time and memory, some of the recent literature on aerobic fitness is indicating a minimal correlation between aerobic fitness and attention (Drollette et al., 2013; Mathilde, Moore, & Ellemberg, 2015). In the first correlational study, the participants underwent moderate intensity, treadmill walking and were examined on cognitive performance. The results indicated that physical activity may "facilitate maintenance of attention over time in cognitively demanding settings, which has public health implications for the educational environment and the context of learning" (Drollette et al., 2013, p. 1). In the second correlational study, twelve, nine to eleven year old boys pedaled for thirty minutes on a bike and electrophysiological, or brain scans were obtained prior to the aerobic exercise, and at the tenth, twenty and thirty minute of pedaling. The results indicated "alterations in brain activity" (Mathilde, Moore, & Ellemberg, 2015, p. 4). These alterations indicated a change in neuronal rhythm, specifically in neuronal activity related to attention. Overall, due to the low level of participants in both of the previous studies mentioned, and the limited research that exists, it is not clear as to whether aerobic activity affects attention.

**Cognition and Motor Skills**

Motor and cognitive development may be interrelated (Diamond, 2000). Contrary to past beliefs that cognitive and motor processes are not intertwined, recently, there has been a reemergence in this field of inquiry (Diamond, 2000; Churchland, 2002) Specifically, there exists the notion that "cognitive and motor processes cannot be seen as separate entities because cognitive development relies totally on motor functioning" (Wassenberg et al., 2005, p. 1093). Motor skill development typically precedes cognitive development. For example, a child will learn to coordinate his limbs prior to learning to speak.

The intricacies of the development of motor and cognitive skills begin as the brain develops and matures. In the past, it was believed that the prefrontal cortex was mainly responsible for complex cognitive skills, and that the cerebellum played a significant role in motor development. However, after the introduction of functional brain imaging techniques, it has been identified that the cerebellum is a key player in cognition (Berman et al., 1995; Raichle, 1994; Scholosser et al., 1998). Along with the prefrontal cortex, both contribute in unison, to the successful execution of motor and cognitive skills.

A longitudinal study that began by investigating children between the ages of 5 and 6 in cognitive performance, particularly in reading and mathematics, were then followed throughout the course of a two-year period (Roebers et al., 2013). A significant correlation between motor skills and cognitive performance was identified (Roebers et al., 2013).  More specifically, after the two-year period, it was found that motor skills were linked to later academic achievement. These findings are in accordance with another correlational study that indicated a strong correlation between motor and cognitive skills among 5 to 6 year olds (Wassenberg et al., 2005). After testing 378 children, it was identified that low performance on cognitive assessments, reflected low performance scores in the motor skill assessment. Moreover, it has also been identified, that the unison between motor and cognitive skills are more evident in pre-pubertal children as opposed to pubertal age (Katic & Bala, 2011; Van Der Fels, 2015).

**Aerobic Fitness and Academic Achievement**

The effect aerobic activity has on certain aspects of cognitive development may play an important role in academic achievement (Lees & Hopkins, 2013). Cognition is an important component to succeeding in an academic setting and aerobic activity may be a “a simple yet important method of enhancing those aspects of mental functioning central to cognitive development” (Tomporowski, Davis, Miller, & Naglieri, p.4). A recent meta-analysis of research on aerobic activity and academic achievement documented a positive correlation between the two factors (Lees & Hopkins, 2013). The meta-analysis reviewed existing articles on aerobic activity and academic achievement using MEDLINE, Cochrane, PsycINFO, SPORTdiscus, and EMBASE while focusing on studies that included anyone under the age of nineteen. In addition to noting the correlation between aerobic activity and academics, the researchers concluded that within the school setting "curricular time need not to be a trade-off between aerobic physical activity and academic performance, and that educators and policy makers can be reassured that spending time in aerobic physical activity does not detract from academic achievement" (Lees & Hopkins, 2013, p. 3).

Another meta-analysis of research conducted within the same year, observed that in comparison to students who are not fit, aerobically fit students up to thirteen years of age demonstrated "higher scores in standardized achievement tests" (Haapala, 2013, p. 61). A correlational study published within the same year supported these findings. In this supporting research study, the investigators assessed student's academics using the Stanford Achievement Test (SAT-10) and assessed students in aerobic fitness using the Progressive Aerobic Capacity Endurance Run (PACER)(Bass, Brown, Laurson, & Coleman, 2013). After analyzing the data, the results indicated aerobic activity had a positive impact on academic achievement, in fact students who have been categorized as aerobically fit "were two to four times more likely to pass their reading and math standardized tests than students who were not" (Bass, Brown, Laurson & Coleman, p.1).

Not only is aerobic fitness affecting standard test scores at a specific moment in time, but a longitudinal study has indicated that "this advantage appears to be maintained over time" (Wittberg, Northrup, & Cottrell, 2012, p.2304). In this longitudinal study, 1725 students received a baseline aerobic exam using the Progressive Aerobic Capacity Endurance Run (PACER), an academic assessment and a two-year follow up examination of both exams. The researchers observed that during the baseline exam, those students that were within the healthy aerobic zone had higher academic scores, specifically in reading and math, while those students that needed to improve their aerobic fitness level scored lower in the academic assessment portion (Wittberg, Northrup, & Cottrell, 2012). Moreover, when the researchers examined the students two years later, they identified that once again the children within the healthy aerobic zone had higher academic scores than those children that needed improvement (Wittberg, Northrup, & Cottrell, 2012).

The positive correlation observed between aerobic fitness levels and academic achievement has been observed in an array of schools (Murray et al., 2007). Regardless of whether the school is considered to be exemplifying a high or low level of academic achievement or a school where the majority of the students are at, below or under the poverty level, some studies have indicated that aerobic activity seems to be a factor that relates to academic achievement (Geersten et al., 2016; Murray et al., 2007).

The previously mentioned studies did not control for the time the participants spent studying. The average time children spend studying per week is approximately 150 minutes (Pressman et al., 2015). This is significant because children that are studying for longer periods of time may attain higher levels of academic achievement, not because they are aerobically exercising, but because they a1re spending a significantly higher number of time studying, compared to another individual who may not be studying as much (Pressman et al., 2015). This study aims to control the participant's study time by excluding participants that spend more than the average amount of time studying per week, 150 minutes (Pressman et al., 2015).

**Gross Motor Skills and Academic Achievement**

Gross motor skills are defined as "a motor skill that requires the use of large musculature to achieve the goal of the skill (Magill, 2014, p. 11). Gross motor movements may include, crawling, walking, and hopping. These skills begin to develop between the ages of 3 months to 6 six years (Thelen, 1994). Furthermore, between the ages of 5 and 10 there is an "accelerated development "of these skills (Westendorp et al., 2011, p. 2773). Within a similar timeframe cognitive development begins as well. Cognitive development is defined as "a progressive reorganization of mental processes as a result of biological maturation and environmental experience" (McLeod, 2015, para.11).

Gross motor skills may play an important role in the development of cognition and cognitive functioning (Westendorp et al., 2014). Cognitive functioning is "an intellectual process by which one becomes aware of, perceives, or comprehends ideas. It involves all aspects of perception, thinking, reasoning, and remembering" (http://medical-dictionary.thefreedictionary.com/cog nitive+function, 2009). Children who display developed gross motor skills may be apt to comprehending subject matter taught in class, quicker and more effectively, which may lead to improved cognitive performance and ultimately, academic achievement (Bobbio & Cacola, 2009; Westendorp et al., 2013).

A correlational study that focused on gross motor skill development in children only several months old speculated that gross motor skill development may a play a role in cognitive development at school age (Piek, Dawson, Smith, & Gasson, 2008). By testing children at four months of age and every year after until four years of age, a positive correlation between motor skills and cognitive development was observed (Piek, Dawson, Smith, and Gasson, 2008).

This correlational study supported the hypothesis that gross motor development from four months to four years of age could predict school age cognitive skills and motor development (Piek, Dawson, Smith, & Gasson, 2008). The researchers concluded that when early gross motor development was "tested in relation to the four different IQ indices, both working memory and processing speed was found to be predicted by the early gross motor trajectory information" (Piek, Dawson, Smith, & Gasson, 2008, p. 679).

In addition to assessing a child's gross motor skills at the infancy stage and attempting to demonstrate that there is a positive correlation between those gross motor skills and the child's academic achievement later, during school age; it is also important to assess a child's level of motor skill development and its relation to academic achievement through cognition in the first grade. Assessing motor skills during early childhood "is associated with later school achievement and can be used as one of the indicators of future school achievement of young children" (Son & Meisels, 2006, p. 774). A gross motor skill study that analyzed 402 Brazilian first graders identified a relation between gross motor skills and cognitive development after specifically assessing the child's math, reading, and writing skills (Bobbio et al., 2009). By testing the children's gross motor skill proficiency and evaluating their math, reading, and writing efficiency, the "findings support the contention that there is a close interrelation of motor development and cognitive development and early movement experiences may be an essential agent for developmental change" (Bobbio et al., 2009, p. 2).

These results support other studies that also analyzed the data between gross motor skills and cognitive skills in children by conducting a gross motor skills test at 5 years of age and then a cognitive examination in the first grade (Son & Meisles, 2006; Murray et al., 2006). The results of their studies demonstrated a significant correlation between gross motor skills in kindergarten and cognitive skills in reading and mathematics at the end of first grade (Son & Meisels, 2006; Murray et al., 2006).

Another correlational study that investigated gross motor skills, the relevance of early detection of difficulties in performing gross motor skills and the correlation between gross motor skills and academic achievement was conducted recently (Magistro et al., 2015). A sample of 63 children that were approximately 8 years of age were assessed on motor skills and level of academic achievement (Magistro et al., 2015). The goal of the study included the verification that children's gross motor skills have a positive impact on academic achievement. To assess the children's motor skills, the Test of Gross Motor Development instrument was implemented. To assess achievement levels, teachers were required to complete a Self-Report Questionnaire regarding the children's academic abilities (Magistro et al., 2015). After implementing and evaluating the results of the Test of Gross Motor Development and the teacher's Self Report Questionnaire, it was found that there is indeed a correlation between gross motor skills and academic achievement. As a child develops his or her gross motor skills, he or she will also enhance their cognitive functioning. Furthermore, it is imperative that gross motor skills are assessed and screened at an early age, to identify difficulties. If there is a difficulty, it may have a negative effect on a child's academic achievement (Magistro et al., 2015).

It is important that children between the ages of four and 7 undergo an evaluation of their state of motor development so that if there is a potential motor function problem, it can be identified at an early stage, with the ultimate goal of improving the motor function problem, which in turn may improve academic performance (Bobbio et al., 2009). This system of motor development should not only be developed within physical education classes, but can have "practical applications within preschool, home, or medical intervention planning" (Bobbio et al., 2009).

**Fine Motor Skills and Academic Achievement**

Fine motor skills are defined as “a motor skill that requires control of small muscles to achieve the goal of the skill; these are skills that typically involve eye-hand coordination and requires a high degree of precision of hand and finger movement” (Magill & Anderson, 2014, p. 11). Examples of fine motor skills include using a pencil to write. Fine motor skills are less complex compared to gross motor skills. This is significant because unlike gross motor skills, an analysis of the recent research on fine motor skills has provided conflicting evidence as to whether or not there is indeed a positive correlation between fine motor skills and academic achievement and if there is a relationship, whether that correlation is stronger than that of the positive relationship between gross motor skills and academic achievement (Dinehart & Manfra, 2013; Pacheco et al., 2014).

A correlational study on fine motor skills and academic performance identified a correlation between the two factors (Dinehart & Manfra, 2013). Three thousand two hundred and thirty-four children, approximately five years old participated in the study. The results indicated that “fine motor skills in preschool are important predictors of later academic achievement, particularly fine motor skills that involve the use of a writing utensil” (Dinehart & Manfra, 2013, p. 154).

The authors of the study believe the correlation between fine motor skills and later academic achievement exists because of the participant’s level of self-regulation, or “the processes by which the self- alters its own responses, including thoughts, emotions, and behaviors” (Baumeister, 1997, p. 146). When children are asked to perform a fine motor skill such as copying letters and symbols, they are exercising the cognitive element of self-regulation in the classroom (McClelland & Cameron, 2011). At the cortical level, much like gross motor skills, "fine motor activity is said to stimulate the prefrontal cortex, an area of the brain critical to self-regulation and other elements of executive functioning"(Diamond, 2000, p. 45). This connection may suggest that a neurological link could exist between fine motor skills and cognitive development.

Another fine motor study that analyzed the correlation between the skill and its effect on academic achievement agrees with previous research that supports the positive correlation between the skill and academic achievement (Cameron et al., 2012; Dinehart and Manfra, 2013). After testing both fine motor skills and gross motor skills, and then comparing the results to an academic achievement test the results demonstrated that fine motor skills were positively correlated to the children's present state of academic achievement in kindergarten and predicted future academic achievement in the months that followed (Cameron et al., 2012). It is important to note that the subjects in the study were 3 to 4 years of age and not first graders. However, this study is still of significance because it supports the notion that fine motor skills may play an important role in academic performance from an early age.

Fine motor skills have also been proposed to identify achievement in reading and mathematics not just at an early age but up until middle school. After assessing fine motor skills in kindergarten and executive function throughout 6 different stages in a child's academic career, fine motor skills measured in kindergarten positively correlated with reading and math scores within all 6 points of testing (Carlson, 2013). It is important to note that that students who began their academic careers with high executive function levels advanced in their academic skills at a much higher rate throughout elementary and into middle school than those students who did not begin with a high level of executive function (Carlson, 2013).

In contrast to correlational studies on fine motor skills and academic achievement (Dinehart & Manfra 2013; Carlson, 2013) that identified a positive correlation between the two factors, there exists literature that suggests fine motor skills do not correlate to academic achievement (Piek, Dawson, Smith, & Gasson, 2008; Westendorp et al. 2011; Lopes et al. 2013; & Pacheco, Gabbard, Ries, & Bobbio, 2015). Some correlational research that has tested fine and gross motor skills and then compared these motor skills results to academic achievement, identified that fine motor accounted for the lowest correlation to academic achievement, and that gross motor skills accounted for the highest correlation to academic achievement (Westendorp et al. 2011; & Lopes et al. 2013; Pacheco, Gabbard, Ries, & Bobbio, 2015).

For example, after obtaining results from both fine and gross motor skill levels and then comparing those results to the cognitive development of children several years later, the results from a fine motor correlational study demonstrated that "although there was no evidence that fine motor trajectory information predicted cognitive performance, gross motor trajectory information was a significant predictor of cognitive performance" (Piek, Dawson, Smith & Gasson, 2008, p. 679). This is an important finding because it may not only signify that gross motor skills are correlated to cognitive performance but that contrary to some of the previous studies conducted, there is the possibility that fine motor skills may not be correlated to academic achievement (Pacheco, Gabbard, Ries, & Bobbio, 2015; Westendorp et al. 2011; & Lopes et al. 2013).

## Handedness and Cognition

Handedness may play a role in a child's early, cognitive development (Johnston, Nicholls, Shah, & Shields, 2009). Handedness is defined as "the natural or biological preference for using one hand more than the other in performing special tasks depending on which hemisphere is dominant for the task" (Ghayas & Adil, 2007, p. 85). When referring to handedness, children are typically categorized as right, left, or mixed handed. As a child physically develops, he or she begins to demonstrate preference in using the right hand, the left hand, or both hands to carry out specific actions such as writing, drawing, and throwing.

A child's hand preference has been speculated to be determined by a number of factors. In general, handedness can be "genetically determined," (Bruckner et al., 2011, p. 264) or influenced by culture or environmental factors (Bryden & Steenhuis, 1991; Reiss & Reiss, 2000). As a child is exposed to situations that require the use of right or left hand, that child will initially show signs of dominance with a specific hand, a lack of dominance with either the right or left hand. There is a high prevalence of children being right handed, with only

10% of the world's population being categorized as left handed (Bruckner et al., 2011).

Left handedness has often been a subject of interest as it is "more common among musicians, mathematicians, professional baseball and cricket players, architects, and artists," while being right handed has been thought to be important in spatial abilities (Ghayas & Adil, 2007, p. 86). In addition, being ambidextrous has been of particular concern because of its possible correlation to development at the cognitive level (Bruckner et al., 2011).

Cognition plays an important role when considering a child's success in school through academic achievement (Kaufman et al., 2011) and can be defined as the "mental actions or processes of acquiring knowledge and understanding through thoughts, experience, and the senses" (Davis, Pitchford, & Limback, 2011, p. 569). Cognition has been of particular interest when analyzing handedness. A review of the literature indicates conflictive results regarding handedness with cognition and intelligence. For example, in a correlational study analyzing 5,000 children, 4 and 5 years of age, left handedness and ambidextrous children were positively correlated to a low level of cognitive abilities (Johnston et al., 2009). However, another correlational study that observed 89 schools and a total of 1671 children, concluded that among the left and right handed children they tested, with cognition, only left handed boys demonstrated a positive correlation to cognitive skills, while left handed girls showed a negative correlation to cognitive skills (Faurie, 2006). A more recent cognition and handedness study found "small differences in cognitive abilities between right and left handed individuals" (Al-Hashel et al., 2016, p. 1). The results stated above contrast with earlier research that found a cognitive advantage for left handers (Ehrman & Perelle, 1983; Hicks & Dusek, 1980). Overall, there does not seem to be a clear trend that establishes a significant relationship between right, left handedness and cognition (Faurie, 2006).

The published literature on handedness and cognition that does seem to be consistent is that children who do not have a hand preference, or mixed handers, show a low level of cognitive ability (Tan, 1985; Crow, Crow, Done, & Leask, 1998; Corballis, Hattie, & Fletcher, 2008). In the previously mentioned, large sample size study consisting of 5,000 children, although left handers scored poorly on the cognitive test, mixed handers that were 4 and 5 year olds scored even lower (Johnston et al., 2009). In fact, "the degree of disadvantage for mixed-handers was roughly double the disadvantage of left-handers relative to right handers (Johnston et al., 2009, p. 296). Mixed handedness can be seen at a young age and may be a result of brain immaturity, which may then reflect cognitive immaturity (Bruckner et al., 2011). A child that is mixed handed should be identified as early as possible and further examinations should occur after to observe whether a specific hand has been selected.

## Handedness and Motor Skills

Handedness is "the natural or biological preference for using one hand more than the other in performing special tasks depending on which hemisphere is dominant for the task" (Ghayas & Adil, 2007, p. 85). Children typically fall under the category of right, left, or mix handed. Handedness can be observed as early as two years of age but the age at which an established and stable use of handedness is observed, may vary (Michel et al., 2006). In addition to handedness, gross and fine motor skills begin to develop between the ages of 4 and 10 (Gabbard, 2008). As previously noted, this is a period of time where girls typically demonstrate proficiency in fine motor skills, whereas boys demonstrate proficiency in gross motor skills (Junaid & Fellowes, 2009).

Motor skills and certain forms of handedness may correlate with one another (Giagazoglou, 2001). For example, a correlational study found that left handed, dominant individuals may be more proficient in the performance of motor skills (Kilshaw & Annett, 1983). An exploratory study was conducted to understand the relationship between motor skills and handedness/footedness by examining spatial abilities (Reio, Czarnowlewski, & Eliot, 2004). Spatial abilities are defined as “the ability to mentally represent spatial abilities and to anticipate the course and outcomes of transformations applied to those relations” (Reio, Czarnowlewski, & Eliot, 2004, p. 341). There may be a positive correlation between motor skills and spatial abilities with relation to hemispheric brain dominance (Frick & Mohring, 2015). The left hemisphere of the brain is mainly associated with verbal skills, and this hemisphere is associated with right hand dominance. The right hemisphere is associated with spatial abilities, and this hemisphere is associated with left hand dominance (Reio, Czarnowlewski, & Eliot, 2004).This exploratory study found that there is a “slight but significant relation” between left handedness and spatial abilities, which require gross motor skills (Reio, Czarnowlewski, & Eliot, 2004, p.339). In addition, these findings are supported by Annett (2002), which documents “years of empirical evidence” supporting the notion that handedness is directly associated with spatial abilities (Reio, Czarnowlewski, & Eliot, 2004, p. 341).

This supports the above stated exploratory study found that there is a “slight but significant relation” between left handedness and gross motor skills, the literature on right and left handedness and the specific motor skill it may correlate too, is not clear (Annet, 1985; Gurd et al., 2006). For example, after documenting hand preference examining gross and fine motor skills of 512 children, a correlational study indicated that left and mixed handed children performed significantly worse in gross and fine motor skills than right handed children (Tan, 1985). These results are supported by a more recent examination of gross and fine motor skills that determined that left handers performed worse than right handers in both skills (Gabbard, 1995; Giagazoglou et al., 2001). However, the findings of a motor skill and handedness study that was performed several years later, contradicts the notion that left handers perform worse on fine and gross motor skills after observing no significant difference in their examination of handedness and motor skills (Gurd et al., 2006).

Although the literature has failed to reveal consensus on which hand has a positive correlation to motor skills, much of the research is indicating that gross motor skills are correlated to left handedness (Kilshaw & Annett, 1983; Annett, 2002; Reio, Czarnowlewski, & Eliot, 2004; Frick & Mohring, 2015). Overall, what does seem to be consistent is that mix handedness is not only negatively correlated to cognition as previously mentioned, but to motor skills as well (Tan, 1985; Annett, 1985).

## The Relation between Aerobic Fitness and the Basal Ganglia, Hippocampus, and Prefrontal Cortex

Aerobic fitness plays an important role in cognition (Haapala, 2013). Aerobic activity has demonstrated to affect certain parts of the brain that relate to cognition. Specifically, aerobic fitness has affected changes in brain volume within the basal ganglia, hippocampus, and prefrontal cortex (Chaddock et al; 2014 Chaddock et al., 2012; & Davis et al., 2011).

The basal ganglia is a section of the brain responsible for cognition (Chaddock et al., 2012). This portion of the brain is divided into two structures. The first structure, the dorsal striatum plays an important role in "cognitive flexibility" or the ability to shift from one topic to another; and the execution of learned behaviors (Chaddock et al., 2010, p. 2). Cognitive flexibility can be seen when children are attempting to consider different answers to questions and create alternate answers to problems that are presented to them (Johnco, Wuthree, & Rapee, 2013). A reduction in the volume of the dorsal striatum has been observed in children that are not aerobically fit (Chaddock et al., 2010). The second structure, the ventral striatum, is responsible for the fortification of learning skills and the motivational states of a child (Aron et al., 2009; Casey, Getz, & Galvan, 2008).

The second section of the brain that has shown to positively correlate with aerobic fitness activity is the hippocampus (Erickson et al., 2016). The hippocampus is a section of the brain found within the temporal lobe that is an important factor in memory related tasks (Erickson et al., 2016). Memory is a significant component for children in their school setting because it assists a child in a number of different areas in academics, including the ability to focus on a task, remembering instructions and executing steps on a math problem (Klingberg, 2012). Aerobic activity also triggers neurogenesis, or the growth and development of neurons, in the hippocampus (Erickson et al., 2011). This is significant as neurons form the basis through which signals travel within the different structures of the brain, allowing for a swift and effective recall of information within the hippocampus when a child, in this case, is confronted with school work (Erickson et al., 2011).

The third part of the brain that has been shown to positively correlate with aerobic activity is the prefrontal cortex (Chaddock-Heyman et al., 2013; Davis et al., 2011). This is significant because the prefrontal cortex plays an important role in attention related tasks and reaction time to stimuli (Chaddock-Heyman et al., 2013; Davis et al., 2011). Children require a level of attention throughout their academic endeavors in order to effectively work on different assigned tasks in school. A decrease in attention can cause “distracting thoughts or habitual responses which get in the way of performing the task at hand” within different subjects (Stevens & Bavelier, 2012). For example, in mathematics a child must be able to use the material explained by a teacher to solve a problem. While in reading, a student must consistently pay attention to the passage to be able to comprehend the material. Both subjects require that students concentrate when a teacher is lecturing on a new subject, in an effort to obtain all the details and methods needed to excel in the subject matter.

## The Relation between Motor and Cognitive Development with the Cerebellum and Prefrontal Cortex

Cognitive and motor development is much more interrelated than previously considered (Diamond, 2000). It is believed that when the prefrontal cortex and the cerebellum work together, they contribute to motor and cognitive development. The prefrontal cortex and cerebellum are sections of the brain that develop, “participate in similar functions,” (p. 44) and work together to execute a motor or cognitive activity (Diamond, 2000). The prefrontal cortex is a section of the brain that is commonly perceived to be responsible for attention and working memory, which contribute to cognition. Therefore, when a cognitive task is presented, the prefrontal cortex is activated. However, when presented with a motor skill, the cerebellum is known to be activated. There has been a shift in paradigm that supports the notion that the cerebellum also plays a role in cognition (Koziol et al., 2013) by being “heavily recruited” during new and complex activities that require close attention and concentration (Diamond, 2000, p. 46). In addition, when a motor or cognitive task is presented, not only does each section of the brain become activated but together they work in unison to achieve the task at hand (Koziol et al., 2013). The concept that the cerebellum plays an important role in cognitive development is contrary to the common belief that the cerebellum mainly plays a role in motor skills and has little impact on cognitive activities.

Depending on the task at hand, neural activity within the cerebellum will increase. Sixteen experts in the field of neurodevelopment address that the “general consensus no longer concerns whether or not the cerebellum plays a role in cognition, but instead, concerns how the cerebellum contributes to both movement and thought” (Koziol et al., 2013, p. 152). There are neurological pathways that transfer information from the prefrontal cortex (mainly seen as an area of the brain involved in cognition) to the cerebellum (mainly seen as an area of the brain involved in motor skills).

After assessing 596 children in motor coordination and academic achievement, it was found that “in both genders, children with insufficient motor coordination or motor coordination disorder exhibited a higher probability of having low academic achievement, compared with those with normal or good motor coordination” (Lopes et. al, 2013, p. 9). The authors believed the outcomes demonstrated a relationship between motor coordination and academic achievement because coordination exercises, involve the triggering of the cerebellum, which can influence attention (Courchesne et. al, 1994), working memory (Klingber et al., 1996), verbal learning and memory (Andreasen et al., 1995). In addition, gross motor skills and cognitive development have been considered to be linked together by several researchers who suggest this correlation exists because of specific factors that contribute to the execution of the task itself (Pacheco, Gabbard, Ries, & Bobbio, 2015). Factors such as specific cortical activity from the prefrontal cortex and the cerebellum collaborating together, working memory, and attention can play a significant role in any motor or cognitive task.

When addressing which sections of the brain are involved in motor and cognitive activities, it is important to re-acknowledge that the prefrontal cortex and the cerebellum may play an active role in cognitive and motor activities. Both cognitive and motor activities “co-activate” the cerebellum and prefrontal cortex (Diamond, 2000, p. 679).

**Working Memory in Motor and Cognitive Development**

When considering the relationship between motor and cognitive performance it is important to take note of the role working memory has in both aspects. Working memory is defined as “short-term memory applied to cognitive tasks” (Cowan, 2008, p. 323). Whether someone is learning to perform a physical skill such as riding a bike or learning to add or subtract, working memory plays an important role. Both motor and cognitive skills require a degree of working memory to reproduce the same skill once it has been taught. When presented with a complex task, the prefrontal cortex, which as previously stated, is responsible for higher order thinking, attention and understanding, is co-activated with the cerebellum, which is responsible for visual, spatial, and working memory, aiming, catching, coordination, and attention (Diamond, 2000).

After assessing 195 children ages 5-11 in cognitive skills, including working memory, and motor skills at a baseline, and then 18 months later, a positive correlation was found between motor skills and working memory (Rigoli et al., 2013). The results indicated that “intervention in the motor domain may support cognitive development and vice-versa" (Rigoli et al., 2013, p. 1124). With regards to motor skills and working memory, there was a strong correlation between the two. The results demonstrated that working memory may predict motor skill performance (Rigoli et al., 2013).

This conclusion supports a previous correlational study which investigated whether motor coordination could predict working memory (Rigoli, Piek, Kane & Oosterlaan, 2012). Using a different test, the Wechsler Intelligence Scale for Children-1V (WISC-4), children's IQ, verbal comprehension, perceptual reasoning, working memory and processing speed were compared to results on a motor skills test (Wechsler, 2003). The results demonstrated that the motor coordination action of aiming and catching correlated with the executive functions of visuo-spatial and verbal working memory (Rigoli et al., 2012). The researchers in this study attributed their findings to the co-activation of the cerebellum and prefrontal cortex.

**Self-Regulation and Motor and Cognitive Learning**

Self-regulation, or "the process by which the self- alters its own responses, including thoughts, emotions, and behaviors" (Lakes & Hoyt, 2004, p. 146) has also been considered an important aspect necessary to learn both motor and cognitive skills. The ability of students to self-regulate themselves within the classroom is an important portion of any learning process because it may demonstrate how much self-control and focus a student has when an instructor is lecturing on subjects such as reading and mathematics. A student that has less self-regulatory abilities could lose focus and either act out in class or lose interest in a subject. This makes it very difficult for a student to retain information learned either inside or outside the classroom.

Self-regulation requires two components that have been previously discussed in this paper, attention and working memory (McClelland and Cameron, 2011). Attention and working memory are necessary in a learning setting, whether it is a motor skill or cognitive skill, because as information is presented, a student must first be focused to absorb the information and then be able to remember the information presented in order to add on future information and build on the knowledge that has been presented. It is for this reason that McClelland and Cameron (2011) believe that self-regulation is a predictor of not just academic achievement, but the learning of any task at hand.

Whether a child learns how to dribble a basketball outside of the classroom or solve a math problem inside the classroom, that child is still learning. This is important because it indicates that when testing motor skills at a young age, perhaps the student that is not proficient in the motor skill may have a learning disorder that could hinder his ability to learn within the classroom setting. Therefore, by testing for motor skill development at a young age there may be an indicator of self-regulation abilities that can be foreseen and possibly improved at an early age.

An interventional study of 207 children within the early ages of kindergarten to fifth grade (Lakes & Hoyt, 2004, p. 1) demonstrated how the gross motor skill of martial arts improves self-regulation. In the study, 207 children were separated into two groups. The first group attended their standard physical education class, while the second group participated in a 45 minute martial arts class. The students were pre and post tested. Following the pre-test, the intervention group underwent twenty-six, 45- minute sessions of martial arts training throughout the span of 3 months.

The results indicated that the intervention group showed improvements in "areas of cognitive self-regulation, affective self-regulation, affective self-regulation, prosocial behavior, classroom conduct, and performance on a mental math test" (Lakes & Hoyt, 2004, p. 283). The authors make note of the characteristics the motor skill of martial arts contains, which could have contributed to the improvement in self- regulation. Throughout the study, the children were taught techniques that consisted of "blocks, kicks, and punches" along with other "martial art movements and techniques" as well as "board-breaking techniques, complete body-stretching techniques, and deep breathing relaxation techniques" (Lakes & Hoyt, 2004, p. 288). It is important to note that the majority of these techniques are gross motor skills. This study is significant because it indicates that perhaps gross motor skills play a vital role in improving those characteristics needed to learn, like self-regulation, and this study suggests that gross motor skills can play a role in a student's academic career.

## Relative Age Effect

The relative age effect refers to "the selection and performance differentials between children and youth who are categorized in annual-age groups" (Romann & Cobley, 2015, p.1). The relative age effect displays itself when, for example, a child is born January 1st and another child is born December

31st of the same year. This twelve month difference in age could signify substantial physiological and cognitive differences among the two children (Dixon, Horton & Weir, 2011). This age difference could signify that by the time a younger and older student enter kindergarten, the older child could be 20% older than his younger counterpart (Dixon, Horton, & Weir, 2011; Baxter-Jones et al., 1995).

The relative age effect was first analyzed in the 1980s when researchers identified a trend in which older children were repeatedly observed to be in the elite teams, on a consistent basis (Barnsley, Thomspon, & Barnsley, 1985). This pattern of age and elite status is a “trend that emerges early in youth hockey and continues through to the sport’s highest level” (Dixon, Horton, & Weir, 2011, p. 3). Since the 1980s, the results of the hockey study (Barnsley, Thomspon, & Barnsley, 1985) have been repeated in a number of different sports, around the world (Musch & Grondin, 2001). In particular, the relative age effect has been analyzed on aerobic related sports (Muller, Hildebrandt, Schnitzer, & Raschner, 2016; Dougan & Pijanowski, 2011). In contrast, there is limited research that examines the relative age effect in children within their physical education program (Gadzic, Milojevic, Stankovic, & Vuckovic, 2016).   Furthermore, there is scarce literature that evaluates the impact the relative age effect may play on aerobic fitness, academic achievement, and children’s motor skills.

**Relative age Effect and Academic Achievement**

The relative age effect has demonstrated a consistent pattern of higher academic achievement among children who are older but born within the same year (Romann & Cobley, 2015). This pattern of higher levels of academic achievement has been observed in schools across the world, with its effects being seen primarily through the elementary school grade levels (Smith, 2009; Bedard & Dhuey, 2006). A review of the literature has indicated that older children are more likely to have higher test scores until fifth grade (Lin, Freeman & Chu, 2009), particularly in subjects such as reading and mathematics (Oshima & Domaleski, 2006), be enlisted in gifted programs (Cobley, McKenna, Baker & Wattie (2009), and are less likely to be retained (Martin, Foels, Clanton, & Moon, 2004).

Older children may have an advantage by the time they enroll in their first years of school for a number of reasons. For example, an older student may begin school being more emotionally mature, behaving better, being more proficient in fine motor skills, and displaying a higher level of attention span as the teacher explains the reading and mathematics content (Dougan & Pijanowski, 2011). This child may then excel in the material that is covered by the instructor and then be placed in a higher level reading and mathematics group. These children will therefore be “challenged” to a higher degree than those students that are not retaining the same information at the same pace; thereby opening the opportunity for a higher level of self-confidence and probability of being placed in a higher reading and mathematics in the following school years (Dougan & Pijanowski, 2011, p. 5). In contrast, the younger children may feel a lower level of confidence and a sense of having to catch up to the older peers. This could lead to a child’s risk of falling behind academically to their older counterparts after only a couple years in school.

The risk of falling academically behind has led parents to consider the notion of what has been termed as academic redshirting or “the act of keeping a child out of school for an additional year before kindergarten” (Dougan & Pijanowski, 2011, p. 1). A longitudinal study on academic redshirting showed that children who were purposefully retained a year obtained “higher test scores in kindergarten” (Dougan & Pijanowski, 2011, p. 3). Particularly, those children that were of lower socioeconomic status, obtained higher academic results than those children coming from high socioeconomic backgrounds. The conclusions demonstrated that “poor and disabled children and boys benefit significantly more from delaying kindergarten entrance, in terms of test score gains especially in reading” (Datar, 2006, p. 58).

**Relative Age Effect and Aerobic Fitness**

The relative age effect has also been proposed to effect the aerobic fitness levels of both boys and girls (Roberts, Boddy, Fairclough, & Stratton, 2012). Children who are born earlier in the year have performed better on aerobic tests than their older peers who were born within the same year (Roberts, Boddy, Fairclough, & Stratton, 2012). Although there are an array of explanations as to why a difference in age can affect the aerobic fitness levels of children born the same year but on different months, the common factor points to the differences in growth and maturation that both children experience as a consequence of their differences in birthdate (Cobley et al., 2009; Malina, Bouchard, & Bar-Or, 2004).

A correlational analysis that focused on 11,404 children ages nine through ten and 3,911 children ages eleven to twelve observed this difference in cardiorespiratory fitness levels among older children of the same year (Roberts, Boddy, Fairclough, & Stratton, 2012). After performing an aerobic fitness test similar to that of the PACER exam, the 20m multistage shuttle run test (20mSRT), and observing on which month each child was born, the data indicated that the boys and girls who were born earlier in the year performed better on the 20mSRT (Roberts, Boddy, Faiclough, & Stratton, 2012). A similar analysis conducted in the United Kingdom also noted a significant difference in the cardiorespiratory fitness levels of older children within a physical education class after testing with the 20mSRT (Schorer et al., 2009).

Another analysis performed on nine-year old soccer players also examined the cardiorespiratory fitness levels of each player and took note that 36-50% of the children were born the first months of the year, while 4-17% of the children were born within the last three months of the year (Maria Gil et al., 2013). Therefore, the majority of the children were born at the beginning of the year, indicating that a relative age effect existed since these children performed better in the aerobic exam performed, compared to the children that were born later in the same year (Maria Gil et al., 2013).

**Relative Age Effect and Gross and Fine Motor Skills**

The relative age effect has been noted to have a significant impact on levels of educational and athletic performance among young children (Maria Gil et al., 2013; Dougan & Pijanowski, 2011). However, when considering the impact the relative age effect may have on children's development of motor skills, particularly gross and fine motor skills, the literature focuses more on the gross motor skill component that many sports demand (Nolan & Howell, 2010; Muller et al., 2015; & Delorme & Raspaud, 2009).

A gross motor skill is defined as "a motor skill that requires the use of large musculature to achieve the goal of the skill (Magill, 2014, p. 11). Gross motor skills are a fundamental part of a number of competitive sports. For example, gross motor skills are seen in hockey when a child moves his legs to skate and chase the puck and in basketball when a child moves his arms to dribble a ball. A number of correlational studies have observed a relative age effect on sports that require gross motor skills such as ice hockey (Nolan & Howell, 2010), skiing (Muller et al., 2015), and basketball (Delorme & Raspaud, 2009).

This relative age effect advantage in gross motor skills among children that are born earlier in the year as opposed to those who are born later in the year can be attributed to the differences in physical maturation (Muller et al., 2015; Dixon, Horton & Weir, 2011). A child that is born later in the year and displays a higher level of physiological maturity could outperform his younger counterpart in a number of athletic endeavors. A child who is more physically mature than another child may then be more likely to be selected to some sort of organized team in a sport and obtain more opportunities to further develop the gross motor skills needed for their sport (Malina, Bouchard & Bar-Or, 2004). For example, when performing a motor test on 1218 children ages 9 to 10, the older, the more physiologically mature children outperformed the younger children in gross motor tests such as sprinting, jumping, push-ups, sit-ups, and aerobic running (Wattie et al., 2014).

Contrary to gross motor skills, there is a gap in the literature when observing the effects of the relative age effect on fine motor skills. Fine motor skills are defined as “a motor skill that requires control of small muscles to achieve the goal of the skill; typically involves eye-hand coordination and requires a high degree of precision of hand and finger movement” (Magill & Anderson, 2014, p. 11). The literature that does exist on fine motor skills typically examines the motor skill through the lens of a sports such as taekwondo (Albuquerque et al., 2012), and badminton (Nakata & Sakamoto, 2012), and shooting (Delorme & Raspaud, 2009); sports that are heavily dependent on fine motor skills and where the athletes tend to be “smaller, less strong, and less physically mature (Romann & Fuchslocher, 2014).

In sports that require a high level of fine motor skills such as taekwondo, badminton, and shooting, a relative age effect has not been identified (Romann & Fuchslocher, 2014). In contrast to the relative age effect, a reverse relative age effect has, at times, been observed among children that participate in these sports (Romann & Fuchslocher, 2014). A reverse relative age effect occurs when children that are born later in the actually perform better in their sport than those children that are born earlier in the year (Albuquerque et al., 2012; Nakata & Sakamoto, 2012; & Delorme & Raspaud, 2009). This reverse relative age effect may be occurring because some children change “sports after failing in disciplines in which developed physical attributes are determinant”(DeLorme & Raspaud, 2009, p. 14). The children that are not demonstrating the physical attributes that their peers in the more physical sports are relying on, may then consider participating in sports where technical and fine motor skills are needed, such as badminton, and shooting.

However, the literature is not clear as to whether the more technical and fine motor skill related sports lack a relative age effect (Coutts, Kempton, & Vaeyens, 2014; Gibbs, Jarvis, & Dufur, 2012; & Delorme & Raspaud, 2009). In a correlational examination of relative age effect in French shooting sports, 119, 715 boys and 12, 823 girls were observed and in some groups, a relative age effect was identified, while in other groups a reverse relative age effect was documented (Delorme & Raspaud, 2009). A statistical analysis demonstrated that the girls involved in the shooting sports did not show a relative age effect, however in boys under 11 years of age, a relative age effect was identified, and a statistically significant reverse relative age effect was only seen in the boys and girls that were 15 to 17 years of age (Delorme & Raspaud, 2009).

## Chapter Summary

As stated in this Chapter, a number of studies have reported a correlation between aerobic fitness, gross and fine motor skills, with cognition, which may lead to academic achievement. Aerobic fitness plays an important role in cognition and academic achievement. Aerobic activity has demonstrated to affect certain parts of the brain that relate to cognition. Specifically, aerobic fitness has affected changes in brain volume within the basal ganglia, hippocampus, and prefrontal cortex.

Gross and fine motor development has also demonstrated to be an intricate part of academic achievement, specifically within reading and mathematics. Motor behaviors at a young age can be an important component of psychosocial, psycho-emotional, and academic related. A correlational study that focused on gross motor coordination and academic achievement concluded that both male and female children lacking motor coordination or that display a motor coordination disorder demonstrate a higher probability of scoring poorly academically, as opposed to their typically developing counterparts. Concerning fine motor development and academic achievement, after assessing the fine motor skills of participants at six years of age, and comparing the results to the academic performance of the participants in the second grade some studies have indicated that there is a correlation between fine motor skills and academics. In addition, the aerobic fitness, gross and fine motor skills, and academic achievement variables may be affected by the relative age effect.

In conclusion, it is important to demonstrate the possible link between aerobic fitness, gross and fine motor development with academic achievement and the role the relative age effect may have on these variables. It is vital that schools understand the importance of aerobic fitness and motor development because of the role that they may have with cognitive development. This proposed study aims to investigate the correlation between aerobic fitness, gross and fine motor development with academic achievement in urban schools.

# CHAPTER III

# METHOD

This chapter commences with a reiteration of the purpose of the study and research hypotheses as found in Chapter 1. This chapter also includes the methodology, research design, ethical considerations, and data collection. The chapter then concludes with a summarization of the section.

## Purpose of the Study

The purpose of this study was to examine if there was a positive correlation between aerobic fitness, gross and fine motor skills, a component of cognition, reaction time, and academic achievement; and the impact the relative age effect may have on aerobic fitness, gross and fine motor skills, and academic achievement. This study also identified the effect that sex, handedness and footedness may have on motor skills and academic achievement.

## Research Hypotheses

$H_1$: There is a positive correlation among aerobic fitness and academic achievement.

$H_2$: There is a positive correlation among gross motor skills and academic achievement.

$H_3$: There is a positive correlation between fine motor skills and academic achievement.

$H_4$: There is a positive correlation between aerobic fitness and reaction time.

$H_5$: There is a relative age effect on aerobic fitness.

$H_6$: There is a relative age effect on gross motor skills.

*$H_7$:* There is a relative age effect on academic achievement.

*$H_8$:* There is a significant group mean difference by sex in gross motor skills.

*$H_9$:* There is a significant group mean difference by sex in fine motor skills.

*$H_{10}$:* There is a significant group mean difference by handedness and footedness in gross motor skills.

**Design of the Study**

The design of this study was based on previous studies that have observed the relationship between aerobic fitness, motor development, and academic achievement (Gabbard, 2009; Geersten, et al., 2016; Westendorp et al., 2014). This study utilized a nonexperimental design (Johnson, 2001) that is cross-sectional and retrospective. In this form of research design, participants are assessed and data is collected from the participants within one particular moment in time (Olsen & St. George, 2004). Throughout the 2017-2018 academic year, students were tested one time on their aerobic fitness, motor skills, reaction time, and SAT-10 scores. This study implemented a cross-sectional research design so that participants could undergo an assessment that numerically indicated the proficiency of their aerobic fitness, motor skill development, and reaction time, within one particular moment in time throughout the 2017-2018 academic year.

The math and reading assessment (SAT-10) was administered to the participants of the study on April of 2018 and the results were collected on June of 2018. The data collection phase of this study (BOT-2, Yo-Yo Test, and Diery Liewald Reaction Time Test) occurred from April 2017 through June 2018. A retrospective design was utilized to collect the participant's SAT-10 scores. A retrospective design was implemented because the researcher collected the SAT-10 assessment data that was taken by the participants during the latter part of the academic year of 2018 (Gay, Mills, & Airasian, 2009).

**Population and Setting**

Located in southeast Florida, Miami-Dade County is the fourth largest school district in the country and serves a significant urban population (Greenberg, 2015). In the Miami Dade County Public School System, a total of 357,579 students are registered in the Department of Education database (2016). Of these students, 26,288 are matriculated in the first grade (Department of Education, 2015). Further breakdown by demographics indicate that 49% are female, 51% are male, 7% are Caucasian, 69.1% are Latino, and 21.9% are African American (Department of Education, 2015). Due to the fact that the majority of the students in Miami Dade County Public Schools are Latino, a Spanish version of the parental consent form, cover letter, and demographic questionnaire was created and distributed to the 12 schools that participated in this study. Despite being a primarily Latino student population, after collecting the demographic questionnaire from the parents/guardians, the majority of the forms did not report that the students were enrolled in the ESL or English as a Second Language program. Approximately 79.8% of Miami Dade County Public School students do not fall under the category of English as a Second Language (ESL) (Department of Education, 2015). Therefore, only 20.1% fall under the category of ESL (Department of Education, 2015).

A number of studies that have analyzed the relationship between aerobic fitness, motor development and academic achievement have been conducted outside the United States (Gabbard & Cacola, 2009; Geersten et al., 2016; Lopes, Lopes, Santos, & Perreira, 2011; Westendorp et al., 2001). However, this study was conducted in the United States, specifically Miami Dade County, an area that is multicultural and demographically diverse.

**Sample and Setting**

The researcher recruited a total of 79 first grade elementary students from 12 different Title 1 schools in the Miami Dade County Public School System. The study was conducted in each school's designated physical education area and in a classroom with a computer. The physical education areas provided enough space for the implementation of the Yo-Yo Aerobic Fitness Test. Originally, this study had attempted to implement the PACER aerobic fitness test. However, the PACER was not a valid indicator of aerobic fitness for children that were six to seven years of age. The Bruininks-Osteretsky Second Edition (BOT-2) instrument was used to examine gross and fine motor skills. This exam took some time to accomplish for several reasons. First, it is a lengthy exam. Second, because the exam takes approximately 45 minutes to conduct, some children had difficulty sustaining their focus and attention at the different tasks at hand. The examiner was limited in terms of the amount of time available to execute the BOT-2 exam because the student was only allowed to be examined during an elective subject's class time. In addition, participants were examined on their simple and choice reaction time using the Deary-Liewald Reaction Time Test. The Diery-Liewald

Reaction Time Test was originally intended to be on each school's computers, within the computer lab. However, some of the computers did not work. Therefore, the examiner carried out the Diery-Liewald Reaction Time Test using a private laptop. The Diery-Liewald Reaction Time Test was the final test administered in this study. As a result, many of the students were fatigued when the time came to begin this test.

A power analysis was conducted a priori to determine the sample size for this study (Gay, Mills, & Airasian, 2009). After conducting a power analysis, for a power of .80, with an alpha of .05, a sample size of 74 participants was recommended for an actual correlation of .32. Although collecting data during the school year and during break times tended to be problematic, it was possible still to recruit 79 participants.

**Inclusion criteria.** The inclusion criteria for participants in this study were as follows: First, the participant be a first-grade student currently enrolled in a Title 1 grant recipient school. Second, the participants must have been six to seven-years-of-age and enrolled in the first grade for the first time. First-graders were selected because approximately at the age of six, children refine their motor skills (Pahlevarian & Ahmadizadd, 2014). Furthermore, under the age of 6, research suggests there is no significant difference between boys and girls in motor skill development (Bonvin et al., 2012; Chan & Chow, 2011). First grade is also the period of time when the SAT-10 is first administered.

In addition, children who had not participated in an organized sports or music program for one consecutive year and who were not enrolled in the English for Speakers of Other Languages (ESOL) program were included in the study. All the students that participated in this study met the inclusion criteria.

**Exclusion criteria.** The exclusion criteria for participating in this study were as follows: First, participants who were not currently enrolled in a Title 1 grant recipient school. Second, participants that spent more than 150 minutes a week, outside of regular school hours, studying. Although the intent was to mandate that students be excluded if they spent more than 150 minutes studying, this criterion proved difficult to verify.

Another exclusion criteria, mandated that students who repeated the first grade, were not enrolled in the first grade, or skipped the previous grade and were currently enrolled in the first grade, be excluded from the study. Furthermore, students that had been enrolled in an organized sports or music program for one consecutive year. Lastly, participants that were currently enrolled in the ESOL program, or had any physical injuries that limited their physical activity within the last twelve months and at least 25% of the time, were excluded from the study. The reason for excluding participants that were enrolled in an ESOL program or that had been diagnosed with a physical impairment is because these differences may have biased the results of the Yo-Yo Intermittent Endurance Test Level 1, Diery-Liewald Reaction Time Task, SAT-10 and BOT-2 (Martinez, 2012; Meredith & Welk, 2013). No exceptions to these exclusion criteria were made.

## Instruments

The Yo-Yo Intermittent Endurance Test Level 1 is a multi-stage aerobic fitness exam (Ahler, Bendiksen, Krustrup, & Wedderkopp, 2012). This test has been identified as valid and reliable tool to “measure cardiovascular fitness in children younger than 10 years of age” (Fernandes et al., 2016, p. 159). The test requires approximately 20 minutes to conduct. During the test, as many as 15 children can run back and forth within a 20-meter space to a beep noise. Once the beep sounds, children are expected to run the 20-meter distance before the sound of the next beep noise. The first out of a possible 91 stages of the Yo-Yo Intermittent Endurance test, requires that the participants run the 20-meter distance within approximately 14 seconds. Once the children complete each stage they will have a 9-second active recovery period where they are expected to walk or jog until they hear the next beep noise. The second stage of the Yo-Yo aerobic fitness test, and all the stages that follow, require that the participants run faster in order to advance to the next stage. As the participants advance to the next stage, the time to complete the stage decreases, making the exam more difficult with each stage. In contrast to the first stage, in which participants had 14 seconds to run the 20-meter distance, the second stage requires that participants run the 20-meter distance in 12.5 seconds, the third stage in 11.1 seconds and all the stages that follow continue to decrease the timeframe for completion. While implementing the Yo-Yo aerobic fitness test in this study, a laptop was used to make the beep noise that indicated a change of stage. In this study, one to two students were examined at a time and no student was able to complete the entire 91 stages of the Yo-Yo aerobic fitness test.

The Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) instrument was created in 2005. The BOT-2 is an instrument used to measure fine and gross motor skills in children and youth 4 to 21 years of age. Fine motor skills are examined through tests that include the subject's ability to draw lines through paths. Gross motor skills are examined through tests that include tossing and catching a tennis ball.

The BOT-2 is "intended for use by practitioners (e.g., occupational therapists, physical therapists, and adaptive physical education teachers) and researchers" and is utilized to diagnose motor impairment, to screen a child who could already have a motor impairment, to assist in placement or program adjustment resolutions, and to assess motor interventions (Deitz, Kartin, & Kopp, 2007, p. 89).

Administering the BOT-2 required approximately 5 to 10 minutes of set-up time and approximately 40 to 60 minutes to administer per participant. Scoring the BOT-2 required an average of 30 minutes per participant. Scores for the BOT-2 were identified as total point scores, standard scores or percentile ranks. Scores were reported as "Descriptive Categories ranging from "Well-Below Average to Well-Above Average" (Deitz et. al., 2007, p. 91). The raw scores used, represented the number of correct responses i.e. number of sit-ups completed, or the amount of time an action was performed.

The BOT-2 demonstrated an inter-rater reliability > .90, a test-retest reliability > .80, and an internal consistency > .93 (Deitz et. al., 2007). The BOT-2 also demonstrated a validity score of .74, which according to the authors, "provides support for the construct validity" of this test (Deitz et. al., 2007, p. 97).

The third instrument that was used was the Deary Liewald Reaction Time Task (Deary, Liewald, & Nissan, 2010). The Deary Liewald Reaction Time Task is a computer-based instrument used to examine reaction time. The test has been used in "large epidemiological surveys in the UK, and its parameters' association with age, intelligence and mortality are known and replicated" (Deary et al., 2010, p. 259). The Deary Liewald Reaction Time Task has also been used to examine both simple and choice reaction time in children (Hope et al., 2015).

The Deary Liewald Reaction Time Task has demonstrated a high internal consistency in both the simple reaction time task and choice reaction time portions of the exam (Deary et al., 2010). The simple reaction time task portion of the exam demonstrated an internal consistency of .94 (Deary et al., 2010). The choice reaction time task portion demonstrated an internal consistency of .97 (Deary et al., 2010).

The fourth instrument that was used was the Stanford Achievement Test Tenth Edition (SAT-10) test of achievement. The SAT-10 is a nationally recognized achievement test that is administered throughout the spring in grades K-12. The test is specifically administered in the Miami Dade County School System by the students' teachers and focuses on reading and math. Records of SAT-10 scores were obtained with the permission of both parents of the participants and the elementary school the participant attended.

The SAT-10 measures important aspects of student's reading abilities by examining students on sound and letter recognition, word identification, and vocabulary and comprehension abilities. Math skills were examined using the

SAT-10 through problem solving and reasoning procedures (Pearson Assessments, 2006). The SAT-10 reports a high level of reliability and validity (.88) when compared to other standardized assessment tests (Carney, 2008).

**Procedures**

The procedures of this study commenced with an introduction of this study to all the first-grade teachers of the selected schools. The teachers were verbally informed of the study, its purpose, design, data collection process, and risks and benefits to their students. All first-grade teachers were provided a package that consisted of a cover letter, consent form, parental/guardian contact information and demographic information. The first-grade teachers were then instructed to provide the first-grade students with this package so that it could be delivered to their parents/guardians. A signature from one parent/guardian of the informed consent and completion of the demographic questionnaire represented participation in the study.

Originally, the researcher intended to provide the teachers with the package that contained the cover letter, consent form, and demographic questionnaire, once. However, throughout the academic year, the researcher had to visit the first-grade teachers multiple times to pick up the signed consent forms and completed demographic questionnaires, as well as redistribute a new package to the teachers. After multiple attempts, a total of 79 participants were acquired.

Upon completion of the demographic questionnaire, the researcher adhered to the inclusion and exclusion criteria to determine eligibility in the study. Finally, data collection took place at the elementary school's indoor/outdoor recreational area to determine aerobic fitness level, motor skill development and reaction time. The Stanford Achievement Test (SAT-10) scores were obtained from the elementary school's database.

**Ethical Considerations.** IRB approval was obtained from Florida International University and Miami Dade County Public Schools System. In addition, because the study's sample size consisted of minors (below 18 years of age), parental consent was obtained for each participant. To be able to identify the participants and maintain confidentiality, the researcher randomly assigned a code for each participant. Parents were advised that if their child did not participate in the study, it would not affect their enrollment or grades at the end of the semester. To ensure confidentiality, there was a password-protected database at the home of the researcher, where only the researcher had access to the results. A hard copy of the Yo-Yo Intermittent Endurance Test Level 1, Deary-Liewald Reaction Time Task, BOT-2, and SAT-10 results were kept in the researcher's home, under lock and key. All Yo-Yo Intermittent Endurance Test Level 1, Deary-Liewald Reaction Time Task, BOT-2, and SAT-10 results will be destroyed in an appropriate manner five years post study.

**Dissemination of Informed Consent, Parental/Guardian Contact Information, and Demographic Questionnaire.**

After obtaining IRB approval from Florida International University and the Miami Dade County Public School System, the researcher verbally informed the first-grade teachers of the purpose of the study, the research design, data collection process, and risks and benefits to their students. All first-grade teachers were provided a package that consisted of a cover letter, consent form, parental/guardian contact information and demographic information for each student. The first-grade teachers were instructed to provide the first-grade students with this package so that it could be delivered to their parents/guardians. A signature from one parent/guardian of the informed consent and completion the demographic questionnaire represented participation in the study. Upon completion of the demographic questionnaire, the researcher adhered to the inclusion and exclusion criteria to determine eligibility in the study.

**Eligibility Criteria.** After receiving the parental authorization forms and the completed demographic questionnaires, the researcher determined if the potential participant had met the inclusion criteria, and which participant had not met the inclusion criteria. A total of 330 parental authorization forms and demographic questionnaires were distributed and returned. Upon receiving and reviewing the 330 forms, 250 forms had to be excluded because the potential participant was either not six or seven years of age, had repeated the first grade, was involved in an afterschool music or sports program for one consecutive year, and/or was enrolled an ESOL or English as a Second Language Program. A total of 80 participants met the criteria necessary to participate in the study, and the parents of those participants were then contacted by telephone call or email.

**Data Collection Protocol.** A series of tests were conducted to assess the participant's level of aerobic fitness, gross and fine motor skill level, and reaction time (see table 1.) The Yo-Yo Intermittent Endurance Test Level 1 required approximately 20 minutes to conduct. During the test, as many as 15 children ran back and forth within a 20-meter space to a beep noise. Once the beep sounded, children ran the 20-meter distance before the sound of the next beep noise. The first out of a possible 91 stages of the Yo-Yo Intermittent Endurance test, require that the participants run the 20-meter distance within approximately 14 seconds. Once the children completed each stage, they had a 9-second active recovery period where they were expected to walk or jog until they heard the next beep noise. The second stage of the Yo-Yo aerobic fitness test, and all the stages that followed, required that the participants run faster in order to advance to the next stage. As the participants advanced to the next stage, the time to complete the stage decreased, making the exam more difficult with each stage. In contrast to the first stage, in which participants had 14 seconds to run the 20-meter distance, the second stage required that participants run the 20-meter distance in 12.5 seconds, the third stage in 11.1 seconds and all the stages that follow continue to decrease the timeframe for completion. As time progressed and children advanced within the stages, they scored higher on the aerobic fitness test. The stage and time in which the participant finished was then marked off. Participants that continued to advance in stages within the test were also marked until they could not complete a stage. If the participant failed to run from one 20-meter side to the other within the beep noise, they received a warning. The second time a participant did not complete the 20-meter stage, the test ended for that participant and the final score was determined.

While implementing the Yo-Yo aerobic fitness test in this study, a laptop was used to make the beep noise that indicated a change of stage. In this study, one to two students were examined at a time and no student was able to complete the entire 91 stages of the Yo-Yo aerobic fitness test.

The Bruininks-Oseretsky Test of Motor Proficiency Second Edition (BOT-2) was used to assess the participant's gross motor and fine motor skill development. The exam required that the participants perform several fine and gross motor skills. The BOT-2 motor skill examination took approximately 40-60 minutes to administer per participant. Therefore, a maximum of 3 participants were examined in one day. Different tests were conducted on different days, depending on how much time was allocated by the school on that specific day to test the participants and depending on which test the participant needed to complete. Participants completed the YoY o Aerobic Test, BOT-2, and Diery Liewald Reaction Test at different paces. Therefore, participants were often examining at different paces. In total, 12 months were required to administer the motor skill test to all 79 participants. After testing the participants, the researcher scored the student's level of motor skill efficiency, a process that required approximately 30 minutes per participant.

The Deary-Liewald Reaction Time Task was used to assess the participant's level of reaction to a stimulus. Administering the Deary-Liewald Reaction Time Task took approximately 15-20 minutes to administer per participant (Kumar, Rajaram, Rajendran, Ismail, & Subramanian, 2015). The computer-based exam required that participants sit in front of a computer screen and react with their dominant hand, to visual stimuli that were presented on the screen by simply pressing a specific button on the keyboard. For the simple reaction time component, the participants responded to one stimuli (seen within a small box on the computer screen) or pressed one button on the keyboard when they saw a stimuli on the screen. For the choice reaction time, there were four horizontal stimuli (seen within four small boxes on the computer screen) that were presented on the computer screen and the participant had to press the button on the keyboard that corresponded to that stimuli. When a stimulus appeared on the far left box, participants pressed the z –key; when a stimulus was presented in the second to last box from the left, the x-key was pressed. The comma key was pressed for the second box that was second to last on the right side and the full-stop key was pressed when a stimulus appeared on the last box on the right (Kumar et al., 2015).

After scoring the participants in the Deary-Liewald Reaction Time Task, the participant's SAT 10 scores were accessed through the selected school's academic records. Once all the final data from the Yo-Yo Intermittent Endurance Test Level 1, BOT-2, Deary-Liewald Reaction Time Task and SAT-10 examinations were collected, the analysis began. To analyze the data, first, descriptive statistics was used. The descriptive statistics consisted of frequency, mean, standard deviation, and chi-square of homogeneity. All 10 hypotheses used a p level of $p < .05$. The data was entered in the SPSS (version 15.0) database and examined for statistical significance using correlational and regression analyses and group mean comparisons (Hinkle et al., 2006). Table 1 describes the instruments, what they assessed, the time required to implement the instrument, and the requirements for the implementation of the instrument.

Table 1

*Instruments, Assessment of, Required Time, and Requirements for Implementation*

| **Instruments** | **What the Instrument is Assessing** | **Time Required to Implement Instrument** | **Requirements for Implementation of Instruments** |
|---|---|---|---|
| *Yo-Yo Intermittent Endurance Test Level 1* | Aerobic Capacity (how aerobically fit the participant is) | 20 minutes per participant | 20-meter outdoor area for participants to run. 3 participants can be tested at a time. |
| *BOT-2- Bruininks Oseretsky Test of Motor Skills* | Gross and Fine Motor Skills | 40-60 minutes per participant | A simple kit with tools (i.e. tennis balls, thread, beads). Any indoor or outdoor space will suffice. |
| *Deary-Liewald Reaction Time Test* | Reaction Time | 20 minutes per participant | A laptop. Any indoor or outdoor space will suffice. |
| *SAT-10- Stanford Achievement Test Tenth Edition* | Academic Achievement | Already on school records, no need to test participants | Already on school records, no need to test participants. |

**Data Analysis**

To analyze the data, first, descriptive statistics were used. The descriptive statistics consisted of frequency, mean, standard deviation, and chi-square of homogeneity. All 10 hypotheses used a p level of $p < .05$. The data was entered in the SPSS (version 15.0) database and examined for statistical significance using correlational and regression analyses and group mean comparison (Hinkle et al., 2006).

$H_1$: There is a positive correlation among aerobic fitness and academic achievement.

*$H_2$:* There is a positive correlation among gross motor skills and academic achievement.

*$H_3$:* There is a positive correlation between fine motor skills and academic achievement.

*$H_4$:* There is a positive correlation between aerobic fitness and a component of cognition, reaction time.

To test hypothesis 1, 2, 3, and 4, a correlational analysis was implemented to examine if there was a relationship between aerobic fitness and academic achievement, gross motor skills and academic achievement, fine motor skills and academic achievement, and aerobic fitness and a component of cognition, reaction time. A correlational coefficient is a decimal number between -1.0 and 1.0 that indicates the degree to which two variables are related (Gay et al., 2009). This correlational coefficient indicated the strength and direction of the relationship between aerobic fitness and academic achievement, gross motor skills and academic achievement, fine motor skills and academic achievement, and aerobic fitness and a component of cognition, reaction time (Hinkle et al., 2006).

*$H_5$:* There is a relative age effect on aerobic fitness.

*$H_6$*: There is a relative age effect on gross motor skills.

*$H_7$:* There is relative age effect on academic achievement.

To test hypothesis 5, 6, and 7, a regression analysis was implemented to examine if relative age effect had a statistically significant effect on aerobic fitness, gross motor skills, and academic achievement. A regression analysis is used "to construct mathematical models which describe or explain relationships that may exist between variables (independent/dependent) (Seber & Lee, 2003, p. 2).

*$H_8$:* There is a significant group mean difference by sex in gross motor skills.

To test hypothesis 8, a one-way ANOVA was applied.

*$H_9$:* There is a significant group mean difference by sex in fine motor skills.

Similar to $H_8$, a one-way ANOVA examined the group mean scores of boys and girls in fine motor skills and determined if there was a statistically significant group difference (Gay et al., 2009).

*$H_{10}$:* There is a significant group mean difference by handedness and footedness in gross motor skills.

The one-way ANOVA examined the group mean scores in gross motor skills by handedness and footedness and determined if there was a statistically significant group difference (Gay et al., 2009).

## Chapter Summary

Chapter 3 includes details about how the researcher conducted the study. Included in this chapter are: research design methodology, ethical considerations, and data collection. Chapter 4 includes the statistical analyses associated with accepting or not accepting the research hypothesis. Chapter 5 includes the discussion of the results, the limitations, and the relevance of the theoretical framework to the study's findings.

# CHAPTER IV

# RESULTS

This chapter begins with a background of the sample and a description of the demographic variables of the sample. Next, the results of the statistical tests run for each hypothesis will be presented, followed by a statistical table for each hypothesis. The chapter will then conclude with a summary of the results.

## Background of the Sample

Seventy-nine, first grade children from eight Title 1 schools in Miami Dade County. Florida participated in this study. The following sections examine the children's gender and age.

### *Gender*

Of the 79 first grade students, 48.1% were males and 51.9% were females. Table 2A provides a frequency table of one of the demographic variables, gender.

Table 2

*Frequency Table of Demographic Variables*

| **Variable** | ***F*** | **Percent** |
|---|---|---|
| Male | 38 | 48.1 |
| Female | 41 | 51.9 |
| **Total** | **79** | **100** |

*Age*

Age (relative age effect) was operationalized in this study by documenting the total months of age. The analysis revealed a mean score of 82.94 months of age (*SD* = 5.44; 6.92 years of age; *SD* = .52). A relative age effect can be exhibited when, for example, a child is born January 1$^{st}$ and another child is born December 31$^{st}$ of the same year. This twelve-month difference in age could signify substantial physiological and cognitive differences among the two children (Dixon, Horton & Weir, 2011). This age difference could signify that by the time a younger or older student enter kindergarten, the older child could be 20% older than his younger counterpart (Baxter-Jones et al., 1995; Dixon et al., 2011).

## Examination of Hypotheses

### *Correlational Analysis for Testing $H_1$*

$H_1$ stated that there would be a positive correlation among aerobic fitness and academic achievement. To test $H_1$ a correlational analysis was implemented. Aerobic fitness was assessed using the Yo-Yo Test of Aerobic Fitness, and academic achievement was assessed using the SAT-10 scores, which consisted of both mathematics and reading sections. The analysis revealed that there was not a significant correlation between aerobic fitness and reading ($r = .059$ with a $p = 0.606$). However, the analysis did reveal a marginally significant, positive correlation between aerobic fitness and mathematics ($r = 0.218$, $p = .054$). Inasmuch as the analyses did not reveal statistically significant relationships, $H_1$ was not accepted. Table 3 provides correlational statistics regarding aerobic fitness and academic achievement.

Table 3

*Correlational Coefficients for Aerobic Fitness and Academic Achievement*

| **Variables** | **YY** | **RS** | **MS** |
|---|---|---|---|
| YY | -- | | |
| RS | .05 | -- | |
| **MS** | **.21** | **.83**** | -- |

*Note*. $*p < .05$. $** p < .01$. YY is Yo-Yo Aerobic Test. RS is Reading SAT-10 Score. MS is Mathematics SAT-10 Scores. $N = 79$.

### *Correlational Analysis for $H_2$*

$H_2$ stated that there would be a positive correlation among gross motor skills and academic achievement. To test the significance of $H_2$, a correlational statistical analysis was implemented. Gross motor skills encompass the following: manual dexterity, upper limb coordination, manual coordination, bilateral coordination, balance, body coordination, running speed and agility, strength, and strength and agility. The analysis revealed that among the gross motor skills tested and reading SAT-10 scores, only manual dexterity ($r = .301$, $p = .003$) and bilateral coordination ($r = .268$, $p = .008$) were statistically significant with reading SAT-10 scores. In addition, the results also revealed a positive, moderate correlation between the gross motor skill categories of manual dexterity ($r = .399$, $p = .000$) and bilateral coordination ($r = .348$, $p = .001$) with mathematics SAT-10 scores. As a result, $H_2$ was partially accepted. Table 4 provides correlational statistics regarding gross motor skills and academic achievement.

Table 4

*Correlational Coefficients for Gross Motor Skills and Academic Achievement*

| | **RS** | **MS** | **MD** | **UC** | **MC** | **BC** | **BA** | **BN** | **RA** | **ST** | **SA** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RS | -- | | | | | | | | | | |
| MS | .83** | -- | | | | | | | | | |
| MD | .30** | .39** | -- | | | | | | | | |
| UC | .08 | .13 | .35** | -- | | | | | | | |
| MC | .01 | .14 | .44** | .79** | -- | | | | | | |
| BC | .26** | .34** | .53** | .18* | .20* | -- | | | | | |
| BA | -.05** | .00 | .36** | .21* | .04 | .32** | -- | | | | |
| BN | -.02 | .10 | .32 | .17 | .46** | .58** | . 44** | -- | | | |
| RA | .09 | .11 | .34** | .44** | .27** | .20* | .46** | .15 | -- | | |
| ST | .09 | .14 | .47** | .33** | .31** | .47** | .38** | .35** | .25* | -- | |
| **SA** | **.13** | **.21** | **.49**** | **.42**** | **.54**** | **.47**** | **.45**** | **.65**** | **.48**** | **.49**** | **--** |

*Note.* **p* <. 05. ** *p* <. 01. RS is Reading SAT-10 Score. MS is Mathematics SAT-10 Score. MD = Manual Dexterity. UC = Upper limb Coordination. MC = Manual Coordination. BC = Bilateral Coordination. BA = Balance. BN = Body Coordination. RA = Running Speed and Agility. ST = Strength. SA is Strength and Agility. *N*=79

### *Correlational Analysis for $H_3$*

$H_3$ stated that there would be a positive correlation between fine motor skills and academic achievement. To test $H_3$, a correlational analysis was implemented. Fine motor skills encompass Fine Manual Precision, Fine Manual Integration, and Fine Motor Control. Academic achievement was assessed using the SAT-10 scores, which consisted of both reading and mathematics sections. The analysis yielded a moderate positive correlation between Fine Manual Precision and reading (*r* = .301, *p* =. 004); Fine Manual Integration and reading (*r* = .361, *p* = .001); and Fine Motor Control and reading (*r* = 0.266, *p* = .009).

Fine Manual Precision correlated with Mathematics scores (*r* = .354, *p* = .001); Fine Manual Integration correlated with Mathematics scores (*r* = .352, *p* = .001); and Fine Motor Control correlated with Mathematics scores (*r* = .333, *p* = .001). Therefore, based on these results, $H_3$ was accepted. Table 5 provides correlational statistics regarding the moderate, positive relationships among gross and fine motor skills and both types of academic achievement.

Table 5

*Correlational Coefficients for Fine Motor Skills and Academic Achievement*

| | **RS** | **MS** | **FP** | **FI** | **FC** |
|---|---|---|---|---|---|
| RS | -- | | | | |
| MS | .83** | -- | | | |
| FP | .30** | .35** | -- | | |
| FI | .36** | .35** | .59** | -- | |
| **FC** | **.26**** | **.33**** | **.68**** | **.66**** | **--** |

*Note*. $N$ = 79. *$p$ < .05. ** $p$ < .01. RS is Reading SAT-10 Score. MS is Mathematics SAT-10 Score. FP = Manual Precision. FI is Fine Manual Integration. FC is Fine Motor Control.

*Correlational Analysis for $H_4$*

$H_4$ stated that there would be a correlation between aerobic fitness and a component of cognition, that is, reaction time. To test $H_4$, a correlational statistical analysis was implemented. Reaction time encompasses both simple and choice reactions. Simple reaction requires that the participant react to a single stimulus presented in one box as quickly as possible by clicking on a selected box; whereas in choice reaction, the participant is required to react to multiple stimuli as quickly as possible by selecting various boxes. The analysis demonstrated a correlation between simple reaction time and aerobic fitness ($r$ = -.212, $p$ = .030). However, there was not a significant correlation between choice reaction time and aerobic fitness ($r$ = .060, $p$ = .299). Overall, when performing the correlational statistical analysis, simple reaction time ($r$ = -.212) demonstrated a modest correlation with aerobic fitness (Cohen, 1988). As a result, $H_4$

was partially accepted. Table 6 provides correlational statistics regarding aerobic fitness and reaction time.

Table 6

*Correlational Coefficients for Aerobic Fitness and Reaction Time*

| **Variables** | **YY** | **SR** | **CR** |
|---|---|---|---|
| YY | -- | | |
| SR | -.21* | -- | |
| **CR** | **.06** | **.30**** | **--** |

*Note*. *N* = 79. **p* <. 05. ***p* < .01. YY is Yo-Yo Aerobic Test. SR is Simple Reaction Time. CR is Choice Reaction Time.

*Linear Regression for* $H_5$

$H_5$ stated there would be a relative age effect on aerobic fitness. To test this hypothesis, a linear regression was performed. The purpose of regression analysis "is to construct mathematical models which describe or explain relationships that may exist between variables (independent/dependent) (Seber & Lee, 2003, p. 2). For $H_5$, the independent variable was relative age effect and the dependent variable was aerobic fitness. The data revealed that there was not a statistically significant link between relative age effect and aerobic fitness ($\beta = .025$, $p = .195$). Therefore, $H_5$ was not accepted. The results of the regression analysis of relative age effect on aerobic fitness are provided on Table 7.

Table 7

*Regression Analysis of Relative Age Effect on Aerobic Fitness*

| **Variable** | **B** | **Std. Error** | ***T*** | **Sig.** |
|---|---|---|---|---|
| **AF** | **.025** | **.019** | **1.30** | **.195** |

*Note.* $N$ = 79. AF = Aerobic Fitness.

*Linear Regression for $H_6$*

$H_6$ stated that there would be a relative age effect on gross motor skills. Similar to $H_5$, a regression analysis was implemented. Gross motor skills encompass upper limb coordination, manual coordination, bilateral, balance, body coordination, running speed and agility, strength, and strength and agility. For $H_6$, the independent variable was expressed as relative age effect, and the dependent variables are the different gross motor skill subcategories. The results indicated that there was not a statistically significant effect of relative age effect on the gross motor subcategories of body coordination ($\beta$ = -.094, $p$ = .478), running speed and agility ($\beta$ =.119, $p$ = .307), manual coordination ($\beta$ = .032, $p$ = .833), and strength and agility ($\beta$ = -.096, $p$ = .491). However, the analyses indicated that the gross motor subcategories of manual dexterity ($\beta$ = .158, $p$ = .017), upper limb coordination ($\beta$ = .457, $p$ = .013), bilateral coordination ($\beta$ = .180, $p$ = .018), balance ($\beta$ =.129, $p$ = .090), and strength ($\beta$ = .201, $p$ = .040), were positively linked with relative age effect. Therefore, $H_6$ was partially accepted. The results of the regression analysis of relative age effect on body coordination are provided on Table 8A manual dexterity, bilateral coordination on Table 8B, bilateral coordination Table 8C, upper limb coordination Table 8D, running speed and agility Table 8E, strength Table 8F, strength and agility Table 8G, and balance Table 8I.

Table 8A

*Regression Analysis of Relative Age Effect on Manual Dexterity*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **MD** | **.158** | **.065** | **2.448** | **.017** |

*Note.* *N* = 79. MD = Manual Dexterity.

Table 8B

*Regression Analysis of Relative Age Effect on Body Coordination*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **BN** | **-0.94** | **.132** | **-.713** | **.478** |

*Note.* *N* = 79. BN = Body Coordination.

Table 8C

*Regression Analysis of Relative Age Effect on Bilateral Coordination*

| **Variable** | **B** | ***Std. Error*** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **BC** | **.180** | **.075** | **2.40** | **.018** |

*Note.* *N* = 79. BC = Bilateral Coordination.

Table 8D

*Regression Analysis of Relative Age Effect on Upper Limb Coordination*

| **Variable** | B | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **UC** | **.457** | **.179** | **2.54** | **.013** |

*Note.* *N* = 79. UC = Upper Limb Coordination.

Table 8E
*Regression Analysis of Relative Age Effect on Running Speed and Agility*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **RA** | **.119** | **.116** | **1.02** | **.307** |

*Note*. *N* = 79. RA = Running Speed and Agility.

Table 8F
*Regression Analysis of Relative Age Effect on Strength*

| **Variable** | **B** | ***Std. Error*** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **SH** | **.201** | **.096** | **2.08** | **.040** |

*Note*. *N* = 79. SH = Strength.

Table 8G
*Regression Analysis of Relative Age Effect on Strength and Agility*

| **Variable** | **B** | ***Std. Error*** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **SY** | **-.096** | **.139** | **-.692** | **.491** |

*Note*. *N* = 79. SY = Strength and Agility.

Table 8H
*Regression Analysis of Relative Age Effect on Balance*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **BA** | **.129** | **.075** | **1.719** | **.090** |

*Note*. *N* = 79. BA = Balance.

Table 8I
*Regression Analysis of Relative Age Effect on Manual Coordination*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **MC** | **.032** | **.151** | **.211** | **.833** |

*Note*. *N* = 79. MC = Manual Coordination.

*Linear Regression for $H_7$*

$H_7$ stated that there will be a relative age effect on academic achievement. To test $H_7$, a linear regression statistical analysis was implemented. The independent variable examined in $H_7$ was relative age effect, whereas the dependent variable was academic achievement. Academic achievement includes reading and mathematics SAT-10 scores. The results indicated that relative age effect had a significant, positive effect on reading ($\beta = .143$, $p = .004$) and mathematics ($\beta = .169$, $p = .000$). As a result, $H_7$ was accepted. The results of the regression analysis of relative age effect on reading are provided in Table 9A and on math in Table 9B.

Table 9A
*Regression Analysis of Relative Age Effect on Academic Achievement*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **RG** | **.143** | **.048** | **2.97** | **.004** |

*Note*. *N* = 79. RG = Reading.

Table 9B
*Regression Analysis of Relative Age Effect on Academic Achievement*

| **Variable** | **B** | **Std. Error** | ***t*** | **Sig.** |
|---|---|---|---|---|
| **MH** | **.169** | **.046** | **3.66** | **.000** |

*Note*. *N = 79*. MH = Math.

*One-Way ANOVA for $H_8$*

$H_8$ stated that there would be a significant group mean difference by sex in gross motor skill. To test $H_8$, a one-way ANOVA was used. The independent variable for $H_8$ was sex, and the dependent variable for $H_8$ was gross motor skills. The results indicated a statistically significant group mean difference by sex on three of the eight subcategories of gross motor skills (in each of the three cases, males scored significantly higher): upper limb coordination ($p$ = .001), manual coordination ($p$ = .000), and body coordination ($p$ = .044). Strength and agility ($p$ = .053) was marginally significant (males scored higher). As a result, $H_8$ was partially accepted. The results indicating the group mean difference by sex on manual dexterity are provided on Table 10A, upper limb coordination on Table 10B, manual coordination Table 10C, bilateral coordination 10D, balance 10E, body coordination 10F, running speed and agility 10G, strength 10H, and strength and agility 10I.

Table 10A

*One-Way Analysis of Variance of Group Mean Difference by Sex in Manual Dexterity*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | .537 | 1 | .537 | 048 | .828 |
| Within Groups | 868.324 | 77 | 11.277 | | |
| Total | 868.861 | 78 | | | |

Table 10B

*One-Way Analysis of Variance of Group Mean Difference by Sex in Upper Limb Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 857.433 | 1 | 857.433 | 11.246 | .001 |
| Within Groups | 5870.517 | 77 | 76.240 | | |
| Total | 6727.949 | 78 | | | |

Table 10C

*One-Way Analysis of Variance of Group Mean Difference by Sex in Manual Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1300.129 | 1 | 1300.129 | 32.178 | .000 |
| Within Groups | 3111.086 | 77 | 40.404 | | |
| Total | 4411.215 | 78 | | | |

Table 10D

*One-Way Analysis of Variance of Group Mean Difference by Sex in Bilateral Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 19.696 | 1 | 19.545 | 1.350 | .249 |
| Within Groups | 1141.772 | 77 | 14.478 | | |
| Total | 1161.468 | 78 | | | |

Table 10E

*One-Way Analysis of Variance of Group Mean Difference by Sex in Balance*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 19.545 | 1 | 19.545 | 1.350 | .249 |
| Within Groups | 1114.835 | 77 | 14.478 | | |
| Total | 1134.380 | 78 | | | |

Table 10F

*One-Way Analysis of Variance of Group Mean Difference by Sex in Body Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 174.440 | 1 | 174.770 | 4.202 | .044 |
| Within Groups | 3202.698 | 77 | 41.593 | | |
| Total | 3377.468 | 78 | | | |

Table 10G

*One-Way Analysis of Variance of Group Mean Difference by Sex in Running Speed and Agility*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | .545 | 1 | .545 | .016 | .899 |
| Within Groups | 2611.177 | 77 | 33.911 | | |
| Total | 2611.722 | 78 | | | |

Table 10H

*One-Way Analysis of Variance of Group Mean Difference by Strength*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 8.586 | 1 | 8.586 | .350 | .556 |
| Within Groups | 1889.186 | 77 | 24.535 | | |
| Total | 1897.772 | 78 | | | |

Table 10I

*One-Way Analysis of Variance of Group Mean Difference by Sex in Strength and Agility*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 180.009 | 1 | 180.009 | 3.855 | .053 |
| Within Groups | 3595.865 | 77 | 46.700 | | |
| Total | 3775.873 | 78 | | | |

### *One-Way ANOVA for $H_9$*

$H_9$ stated that there would be a significant group mean difference by sex in fine motor skills. To test this hypothesis, a one-way ANOVA was implemented. The fine motor skills examined were Fine Motor Precision, Fine Motor Integration, and Fine Motor Control. These results indicate there was a marginal significance by sex for Fine Motor Integration ($p$ = .057). Further, there was not a statistical significance by sex for either Fine Motor Precision ($p$ = .114) or Fine Motor Control ($p$ = .721). Therefore, $H_9$ was not accepted. Results of the significant group mean difference by sex in fine motor precision can be found on Table 11A, fine motor integration 11B, and fine manual control 11C.

Table 11A

*One-Way Analysis of Variance of Group Mean Difference by Sex in Fine Motor Precision*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 93.590 | 1 | 93.590 | 2.552 | .114 |
| Within Groups | 2824.359 | 77 | 36.680 | | |
| Total | 2917.949 | 78 | | | |

Table 11B

*One-Way Analysis of Variance of Group Mean Difference by Sex in Fine Motor Integration*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 164.598 | 1 | 164.598 | 3.749 | .057 |
| Within Groups | 3380.491 | 77 | 43.902 | | |
| Total | 3545.089 | 78 | | | |

Table 11C

*One-Way Analysis of Variance of Group Mean Difference by Sex in Fine Manual Control*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 10.430 | 1 | 164.598 | 3.749 | .721 |
| Within Groups | 6273.469 | 77 | 43.902 | | |
| Total | 6283.899 | 78 | | | |

### *One Way ANOVA for $H_{10}$*

$H_{10}$ stated that there would be a significant mean difference in handedness and footedness in gross motor skills. To test $H_{10}$, a one-way ANOVA was implemented. The one-way ANOVA examined the group mean scores in gross motor skills by handedness and footedness (i.e., right-handedness, left-handedness; and right-footedness and left-footedness). The gross motor subcategories examined consisted of manual dexterity, upper limb coordination, manual coordination, bilateral coordination, balance, body coordination, running speed and agility, strength and strength and agility. The analysis revealed that within the gross motor skill subcategories, upper limb coordination ($p$ = .001), manual coordination ($p$ = .001), running speed and agility ($p$ = .000), strength ($p$ = .014), and strength and agility ($p$ = .000) were statistically significant (see Tables 13A-13I); that is, right-handers demonstrated significantly higher group mean scores than left-handers in the aforementioned categories.

With regards to footedness, the results indicated that the subcategories of gross motor skills, manual dexterity, upper limb coordination, manual coordination, bilateral coordination, balance, body coordination, running speed and agility, strength and strength and agility did not demonstrate statistical significance by right- or left-footedness. Therefore, $H_{10}$ was partially accepted. Results of the one-way ANOVAs in handedness and gross motor skills can found on Tables 12A-12I. The results of the one-way ANOVAs for footedness and gross motor skills can be found on Tables 13A-13I.

Table 12A

*One-Way Analysis of Variance of Group Mean Differences by Handedness in Manual Dexterity*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 40.865 | 1 | 40.865 | 3.800 | .055 |
| Within Groups | 827.996 | 77 | 10.753 | | |
| Total | 868.861 | 78 | | | |

Table 12B

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Upper Limb Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 909.492 | 1 | 909.492 | 12.036 | .001 |
| Within Groups | 5818.457 | 77 | 75.564 | | |
| Total | 6726.949 | 78 | | | |

Table 12C

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Manual Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 553.497 | 1 | 553.497 | 11.048 | .001 |
| Within Groups | 3857.719 | 77 | 50.100 | | |
| Total | 4411.215 | 78 | | | |

Table 12D

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Bilateral Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7.111 | 1 | 7.111 | .474 | .493 |
| Within Groups | 1154.357 | 77 | 14.992 | | |
| Total | 1161.468 | 78 | | | |

Table 12E

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Balance*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 18.912 | 1 | 18.912 | 1.305 | .257 |
| Within Groups | 1115.468 | 77 | 14.487 | | |
| Total | 1134.380 | 78 | | | |

Table 12F

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Body Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 83.155 | 1 | 83.155 | 1.944 | .167 |
| Within Groups | 3294.313 | 77 | 42.783 | | |
| Total | 3377.468 | 78 | | | |

Table 12G

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Running Speed and Agility*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2132.911 | 1 | 478.811 | 17.285 | .000 |
| Within Groups | 2611.722 | 77 | 27.700 | | |
| Total | 144.405 | 78 | | | |

Table 12H

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Strength*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 144.405 | 1 | 144.405 | 6.342 | .014 |
| Within Groups | 1753.367 | 77 | 22.771 | | |
| Total | 1897.772 | 78 | | | |

*Table 12I*

*One-Way Analysis of Variance of Group Mean Difference by Handedness in Strength and Agility*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 818.532 | 1 | 818.532 | 21.312 | .000 |
| Within Groups | 2957.342 | 77 | 38.407 | | |
| Total | 3775.873 | 78 | | | |

Table 13A

*One-Way Analysis of Variance of Group Mean Differences by Footedness in Manual Dexterity*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7.229 | 1 | 7.229 | .646 | .424 |
| Within Groups | 861.632 | 77 | 11.190 | | |
| Total | 868.861 | 78 | | | |

Table 12B

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Upper Limb Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 63.828 | 1 | 63.828 | .737 | .393 |
| Within Groups | 6664.121 | 77 | 86.547 | | |
| Total | 6727.949 | 78 | | | |

Table 12C

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Manual Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 27.974 | 1 | 27.974 | .491 | .485 |
| Within Groups | 4383.241 | 77 | 56.925 | | |
| Total | 4411.215 | 78 | | | |

Table 12D

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Bilateral Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17.560 | 1 | 17.560 | 1.182 | .280 |
| Within Groups | 1143.908 | 77 | 14.856 | | |
| Total | 1161.468 | 78 | | | |

Table 12E

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Balance*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | .747 | 1 | .747 | .051 | .822 |
| Within Groups | 1133.633 | 77 | 14.723 | | |
| Total | 1134.380 | 78 | | | |

Table 12F

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Body Coordination*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 16.018 | 1 | 16.018 | .367 | .546 |
| Within Groups | 3361.450 | 77 | 43.655 | | |
| Total | 3377.468 | 78 | | | |

Table 12G

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Running Speed and Agility*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 17.400 | 1 | 17.400 | .516 | .457 |
| Within Groups | 2594.322 | 77 | 33.692 | | |
| Total | 2611.722 | 78 | | | |

Table 12H

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Strength*

| | Sum of Squares | *df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 1.091 | 1 | 1.091 | .044 | .834 |
| Within Groups | 1896.681 | 77 | 24.632 | | |
| Total | 1897.772 | 78 | | | |

*Table 12I*

*One-Way Analysis of Variance of Group Mean Difference by Footedness in Strength and Agility*

| | Sum of Squares | *Df* | Mean Square | *F* | Sig. |
|---|---|---|---|---|---|
| Between Groups | 3.748 | 1 | 3.748 | .076 | .783 |
| Within Groups | 3772.126 | 77 | 48.989 | | |
| Total | 3775.873 | 78 | | | |

## Chapter Summary

This chapter begins by examining and illustrating the demographic variables, using descriptive statistics. Next, the ten hypotheses were tested. The results indicated that aerobic fitness and academic achievement were not significantly correlated with reading or mathematics scores. Regarding gross motor skills, manual dexterity and bilateral coordination were statistically significant with both types of academic achievement. On the other hand, all fine motor skills correlated significantly with reading and mathematics achievement scores. When analyzing reaction time and aerobic fitness, only simple reaction time correlated with aerobic fitness.

With regards to the relative age effect and aerobic fitness, no relationship was identified. However, a relative age effect was identified in the gross motor subcategories of manual dexterity, upper limb coordination, bilateral coordination, balance, and strength. Furthermore, there was a relative age effect observed with both types of academic achievement. When taking participant sex into account, males demonstrated a statistically significant higher mean s in several subcategories of gross motor skills (females did not exhibit significantly higher mean scores in any category); specifically, upper limb coordination, manual coordination, and body coordination. When analyzing the fine motor subcategories, there was not a significant group mean difference by sex in any of the categories.

Last, with regards to handedness and footedness, right-handers demonstrated statistically significant higher mean scores in the gross motor skill subcategories of upper limb coordination, manual coordination, running speed and agility, strength, and strength and agility. However, there were not group mean differences by footedness in any of the gross motor skill categories. Chapter 5 discusses the significance and implications of these results.

# CHAPTER V

## DISCUSSION

Chapter 5 will provide a summary of the study, a discussion of the results, the implications for theory research, and practice; and the strengths and limitations of the study.

### *Summary of the Study*

Physical education programs have slowly been disappearing from urban schools. Urban schools are characterized as “having a higher concentration of low-income or students in poverty, higher concentrations of special education students, higher percentage of discipline issues; with limited financial or physical resources to properly accommodate and/or educate the students” (Holma, 2011, p. 13). As of 2008, only 6 states required physical education in grades k-12 as part of their curriculum (Shape of the Nation, 2012). Specifically, physical education has been disappearing from urban schools (Halpern, 2003).

This disappearance of physical education from urban schools may be attributed to the No Child Left Behind Agenda (No Child Left Behind, 2002). The No Child Left Behind Agenda mandates first, that education throughout the United States follow the same standards (i.e. The Common Core State Standards) (Common Core, 2016). These standards require that all children from grades k-12 successfully complete an examination at the end of the school year in order to advance to the next grade level (Common Core, 2016). Secondly, The No Child Left Behind Agenda mandates that urban schools receive federal funding based on the success of the student’s performance in standardized reading and mathematics scores (Klein, 2015). Therefore, urban schools across the United States may be experiencing significant pressure to raise these standardized test scores in subjects such as reading and mathematics, while exerting less emphasis on subjects such as physical education in an attempt to receive adequate federal funding. School systems may feel that time expended in physical education could instead be spent on refining subjects such as Reading and Mathematics (Patterson, 2013). Physical education should not be neglected from curriculums across the United States, but rather, should be emphasized because it can be a time for children to improve their aerobic fitness, reaction time, and gross and fine motor skills; which may subsequently improve academic achievement. Academic achievement represents “increased grades in core academic classes or increasing tests scores on standardized tests” (Podulka, et al., 2006, p. 1).

Aerobic fitness has shown a positive correlation with cognition (Haapala, 2013). Aerobic fitness is “the capacity of the cardiorespiratory system to deliver adequate oxygen during sustained physical activity to support oxidative metabolic needs” (Kowatch, 2012, p. 1). The notion that aerobic fitness can improve cognition has been attributed to the changes that are occurring at the cerebral level, specifically within the basal ganglia and hippocampus (Chaddock et al., 2010). Aerobically fit children often have increases in hippocampal and basal ganglial volume, through a neuronal increase, compared to children that are not aerobically fit (Chaddock et al., 2010). These are areas responsible for components of cognition, such as memory and attention. Which may contribute to enhancing academic achievement. Furthermore, aerobic fitness may also contribute to augmenting a component of cognition, reaction time (Geersten et al., 2016). Reaction time is defined as “how quickly someone can respond to a stimulus” (Geersten, et al., 2016, p. 7). Reaction time plays an important part in how quickly a child learns a particular task in subjects such as reading and mathematics (Gold et al., 2013).

With regards to motor skills and academic achievement, gross and fine motor skills are co-developing in accordance with cognition and within an "equally protracted developmental timetable" (Diamond, 2000, p. 44). A gross motor skill is "a motor skill that requires the use of large musculature to achieve the goal of the skill" (p. 11) and can consist of walking, jumping, hopping, running, skipping, throwing, and catching (Magill & Anderson, 2014; Lerner & Kline, 2006). Additionally, gross motor skills require large and whole-body movements.

A fine motor skill is "a motor skill that requires control of small muscles to achieve the goal of the skill; it typically involves eye-hand coordination and requires a high degree of precision of hand and finger movement" (Magill & Anderson, 2014, p. 11). "These skills include learning to eat with utensils; dressing; and manually using buttons, zippers, pencils and crayons (Lerner & Kline, 2006). Unlike gross motor skills, fine motor skills do not involve gross movements, large muscles, or the whole body to be effectively put to use.

Until recently, motor development in gross and fine motor skills and cognitive development have often been treated and studied as two different entities that have little to do with one another (Diamond, 2000). Motor development is defined as "human development from infancy to old age with specific interest in issues related to either motor learning or motor control" (Magill & Anderson, 2014, p. 5). Both motor and cognitive developments have been "viewed as independent phenomena" (Diamond, 2000, p.1). However, there has been a reemergence of attention in the role motor development may play in the cognitive, social, and emotional development of a child (Piek et. al, 2007). Motor development is currently being considered to be a “control parameter” and “prerequisite” (Bobbio et al., 2009, p.3) for the development of cognition; moreover, both may fundamentally be interrelated (Diamond, 2000). A number of studies demonstrated a positive correlation between motor development in fine and gross motor skills and overall cognition (Piek, Dawson, Leigh & Smith, 2008; Bobbio et al., 2009; Dinehart & Manfra, 2013). Cognition plays an important role when considering a child’s success in school through academic achievement (Kaufman et al., 2011).

Furthermore, aerobic fitness, motor skills and academic achievement may be affected by the relative age effect (Roberts, Boddy, Fairclough, & Stratton, 2012; Muller et al., 2015; Lin, Freeman & Chu, 2009). The relative age effect refers to “the selection and performance differentials between children and youth who are categorized in annual-age groups” (Romann & Cobley, 2015, p.1). The relative age effect displays itself when, for example, a child is born earlier in the year and another child is later, within the same year. This same year age difference could signify substantial physiological and cognitive differences between the two children (Dixon, Horton & Weir, 2011). A physical education program that implements aerobic fitness and motor skill development may be implemented as an intervention to improve the academic achievement scores of those children that are born later in the year.

In addition, fine and gross motor skills may correlate to certain forms of handedness (Giagazoglou, 2001). Handedness is “the natural or biological preference for using one hand more than the other in performing special tasks depending on which hemisphere is dominant for the task” (Ghayas & Adil, 2007, p. 85). Handedness can be observed as early as two years of age; however, the stable use of handedness whether right, left, or mixed handed may vary within the years of early childhood development (Michel et al., 2006). Similarly, during early child development, between the ages of 4 and 10, gross and fine motor skills begin to develop (Gabbard, 2008). Early child development is also a period of time when motor development occurs as girls typically demonstrate proficiency in fine motor skills, whereas boys typically demonstrate proficiency in gross motor skills (Junaid & Fellows, 2009). Motor skills and certain forms of handedness may correlate with one another (Giagazoglou, 2001). For example, a correlational study found that left handed, dominant individuals may be more proficient in the performance of motor skills (Kilshaw & Annett, 1983).

A physical education program, specifically in urban schools, that implements aerobic fitness and motor skill development may be implemented as an intervention to improve the academic achievement scores of those children that are born later in the year. as students develop their aerobic fitness, and gross and fine motor skills in physical education, they may then be developing cognitive skills, such as memory, attention, and reaction time; as well as academic achievement.

The purpose of this study was to examine if there was a positive correlation between aerobic fitness, gross and fine motor skills, a component of cognition, reaction time, and academic achievement; and the impact the relative age effect may have on aerobic fitness, gross and fine motor skills, and academic achievement. This study also identified the effect that gender and handedness had on gross and fine motor skills and academic achievement. Ten research hypotheses were examined to support the purpose of the study:

*$H_1$:* There will be a positive correlation among aerobic fitness and academic achievement.

*$H_2$:* There will be a positive correlation among gross motor skills and academic achievement.

*$H_3$:* There will be a positive correlation between fine motor skills and academic achievement.

*$H_4$:* There will be a positive correlation between aerobic fitness and a component of cognition, reaction time.

*$H_5$:* There will be a relative age effect on aerobic fitness.

*$H_6$*: There will be a relative age effect on gross motor skills.

*$H_7$:* There will be relative age effect on academic achievement.

*$H_8$:* There will be a significant group mean difference by sex in gross motor skills.

*$H_9$:* There will be a significant group mean difference by sex in fine motor skills.

*$H_{10}$:* There is a significant group mean difference in left handedness, footedness and gross motor skills.

The results demonstrated that several hypotheses, were accepted, others were not accepted, while others were partially accepted. The results indicated that aerobic fitness and academic achievement were not correlated. Regarding gross motor skills, and their correlation to academic achievement, only manual dexterity and bilateral coordination were statistically significant with academic achievement. On the other hand, all fine motor skills correlated with academic achievement. When analyzing reaction time and aerobic fitness, only simple reaction time correlated with aerobic fitness.

With regards to the relative age effect and aerobic fitness, no relationship was identified. However, a relative age effect was identified in the gross motor subcategories of upper limb coordination, bilateral coordination, and strength. Furthermore, there was a relative age effect observed with academic achievement. When taking into account males and females, males demonstrated a higher mean difference in several subcategories of gross motor skills, specifically, upper limb coordination, manual coordination, body coordination and strength and agility. In addition, there was no group mean difference between males and females in fine motor skills.

Lastly, with regards to handedness and footedness, right handedness demonstrated a relationship with the gross motor skill subcategories of upper limb coordination, manual coordination, running speed and agility, strength and strength and agility. However, footedness did not reveal a relationship with gross motor skills.

## Discussion of the Results

This section will examine the results of each hypothesis. The results of this study determined that there was statistical significance among some of the hypotheses.

### *Hypothesis 1*

The first hypothesis stated that there would be a correlation among aerobic fitness and academic achievement. After conducting a correlational analysis, the analysis revealed that there was not a significant relationship between aerobic fitness and reading. However, there was a marginally significant, positive correlation between aerobic fitness and mathematics.

In contrast to the findings of this study, much of the literature on aerobic fitness and academic achievement does indicate that there is positive correlation between aerobic fitness and academic achievement. For example, a correlational study found that during a baseline aerobic fitness test, those students that scored higher on an aerobic fitness test, had higher academic scores, specifically in both reading and mathematics, whereas those students that were not aerobically fit, scored lower in the reading and mathematics assessments (Wittberg, Northrup, & Cottrell, 2012). A meta-analysis conducted on aerobic fitness and academic achievement also supports the notion that aerobic fitness and academic achievement are correlated, as the study found a positive correlation between both, aerobic fitness and reading and mathematics scores (Lees & Hopkins, 2013). The positive correlation observed between aerobic fitness levels and academic achievement has been observed in schools considered to be exemplifying a high or low level of academic achievement or schools where the majority of the students are at, or under the poverty level (Geersten et al., 2016; Murray et al., 2007).

Aerobic exercise has been proposed to influence a child's ability to learn (Lambourne et al., 2013). When a child exerts himself physically, more oxygen and nutrients consistently flow to the brain, thereby allowing the brain to function at an optimal level, over a period of time (Meeusen, 2014). In addition, neuronal activity or the communication among brain cells is enhanced, following aerobic exercise (Meeusen, 2014). This overall improvement in how the brain delivers information as a result of aerobic exercise should support the way in which the brain operates when learning. Therefore, it may affect the way in which students perform in reading and mathematics.

The findings of $H_1$ partially contradict previous studies mentioned. The results of this study concluded that there is a marginally significant, positive correlation between aerobic fitness and mathematics test scores, but not aerobic fitness and reading test scores. The latter statement is supported by Lambourne et al., (2013) which found a correlation between aerobic fitness and mathematics but did not find a correlation between aerobic fitness and reading scores. This may be explained by differences in brain activity. Aerobic exercise alters brain activity in the prefrontal cortex. The prefrontal cortex is responsible for executive function, which assists with the “switching and evaluation of new strategies” when dealing with different problems and “maintaining information in working memory” (Bull & Scerif, 2001, p.273). Executive function, is therefore very important in the process of learning mathematics. Reading on the other hand, is not usually associated with executive function unless there is a learning disability (Locascio, Mahone, Eason, & Cutting, 2010).

It should be noted that all of the previous studies mentioned (Murray et al., 2007; Wittberg, Northrup, & Cotnell, 2012; Lees & Hopkins, 2013; & Geersten et al., 2016) conducted their research on children that were eight years or older. This study focused on children that were six or seven years of age and in the first grade. It may be the case that no significant correlation was found between aerobic fitness and reading and mathematics scores because unless a child is involved in a structured, aerobic fitness training regiment, children do not typically demonstrate significant differences in aerobic fitness, amongst each other, until approximately eight years of age (Armstrong, 2006). Therefore, the participants of this study may not have demonstrated a positive correlation between aerobic fitness and reading and mathematics scores because they were slightly younger than the eight years of age necessary to observe differences in aerobic fitness levels.

It is also possible that this study's results contradicted those that have been previously mentioned (Murray et al., 2007; Wittberg, Northrup, & Cotnell, 2012; Lees & Hopkins, 2013; & Geersten et al., 2016) because this study excluded children that had been involved in any afterschool sports program for one consecutive year. As previously mentioned, although there is not a significant difference in aerobic fitness levels of typically developed children under the age of eight, it is possible that children who are consistently involved in a structured, aerobic fitness program could demonstrate an advantage in aerobic fitness activities, over children that are not enrolled in consistent, aerobic activities.

### *Hypothesis 2*

Hypothesis two stated that there would be a positive correlation among gross motor skills and academic achievement. Gross motor skills encompass the following: manual dexterity, upper limb coordination, manual coordination, bilateral coordination, balance, body coordination, running speed and agility, strength, and strength-agility. The analysis revealed that among the gross motor skills tested and mathematics and reading SAT-10 scores, manual dexterity, and bilateral coordination were statistically significant with both reading and mathematics SAT-10 scores. A review of the literature supports the notion that there is correlation between gross motor skills and academic achievement (Murray et al., 2006; Son & Meisles, 2006; Bobbio et al., 2009; Magistro, et al., 2015).

After examining 402 first graders (Bobbio et al., 2009) in gross motor skills and comparing those results with their reading and math standardized test scores, a correlation was found between these variables. Specifically, a correlation was found between the subcategory of bilateral coordination and reading and mathematics scores.

Findings from this study specifically identified a correlation between bilateral coordination and reading and mathematics scores.

This correlation between the specific gross motor skill subcategory of bilateral coordination and reading and mathematics scores may be attributed to the level of cortical activation that coordination exercises require. Bilateral exercises are among the more complex gross motor skills to perform. This is a motor skill that requires the simultaneous use of limbs within both sides of the body (Bobbio et al., 2009). When children perform bilateral exercises, neuronal networks, or the connections between brain cells, are enhanced. As these neuronal networks adjust themselves accordingly to these physical tasks by becoming more efficient at relaying information among one another, the physical movements are carried out more efficiently. This neuronal enhancement occurs in the prefrontal cortex, an area of the brain responsible for cognition, specifically attention. As the brain cells become more proficient at carrying out physical tasks, they may be able to relay cognitive information to each other more effectively. Therefore, bilateral exercises may be an important part of cognition and ultimately reading and mathematics, subjects that require cognition.

With regards to manual dexterity and reading and mathematics scores, a review of the literature supports the finding of this study, however, the correlational coefficients in the literature have been consistently low (Dinehart & Manfra, 2013; Manfra et al., 2017; Cameron et al., 2012; Roeber et al., 2014). The findings of this study indicate a moderate level correlational coefficient.

Although the literature demonstrates a relationship between gross motor skills and academic achievement and explains that it exists because of the co-activation of the cerebellum, an area of the brain responsible for gross motor skills, and the prefrontal cortex, an area of the brain responsible for cognition; it fails to elaborate as to why a direct correlation exists between the specific gross motor subcategory of manual dexterity and reading and mathematics scores (Diamond, 2000). However, research has noted that children who have difficulties with manual dexterity, also experience frustrations in the classroom due to their inability to hold writing utensils and work effectively on their school tasks (McGlashan et al., 2017). Furthermore, children who experience difficulties with manual dexterity often demonstrate a “tendency towards lower achievement in mathematics, lower verbal IQ, and increased attentional difficulties” (McGlashan et al., 2017).

### *Hypothesis 3*

Hypothesis three stated that there would a positive correlation between fine motor skills and academic achievement. Fine motor skills encompass the subcategories of Fine Motor Control, Fine Motor Integration, and Fine Motor Precision. These results of this study revealed a correlation between the three fine motor subcategories previously mentioned and academic achievement.

The results of this study are supported by a fine motor skills study that examined and analyzed fine motor skills and its effect on academic achievement (Cameron et al., 2012). After examining both fine and gross motor skills, and comparing those results to an academic achievement test, the evidence (Cameron et al., 2012) suggested that fine motor skills were positively correlated to academic achievement and predicted future academic achievement in the months that followed. Moreover, another examination of fine motor skills and academic achievement performed on two thousand two hundred and thirty-four children, indicated that “fine motor skills in preschool are important predictors of later academic achievement” (Dineharte & Manfra 2013, p. 154).

The conceptual framework of this study provides a possible explanation for the correlation between fine motor skills and academic achievement. The conceptual framework of this study states that at the cortical level, much like gross motor skills, “fine motor activity is said to stimulate the prefrontal cortex, an area of the brain critical to self-regulation and other elements of executive functioning” (Diamond, 2000, p. 45). This connection may suggest that a neurological link may exist between fine motor skills and cognitive development, and ultimately academic achievement scores.

Another possible explanation for the positive correlation between fine motor skills and academic achievement focuses on the difficulties that arise from not being able to complete school work in the same timeframe as another student who may not have fine motor difficulties. Children that demonstrate poor fine motor skills will have difficulties holding a writing utensil in class. As a result, it becomes very challenging for a child to write, as “poor fine motor control is responsible for incorrect size or placement of letters, and inadequate pencil grip, which may result in slow, jerky writing” (McGlashan et al., 2017, p. 29). This slow process of writing may lead to a child taking more time to complete assigned material, which may then lead to frustration and apathy with the material. A child with poor fine motor skills may also lose attention or be more likely to display behavioral problems because of the lack of engagement with the class and the academic material being covered, which in turn could lead to poor performances in subjects such as reading and mathematics.

*Hypothesis 4*

Hypothesis 4 stated that there would be a positive correlation between aerobic fitness and reaction time. The results revealed that among the two subcategories of reaction time tested (i.e. simple and complex reaction time) only simple reaction time correlated with aerobic fitness. Reaction time is an important component of cognition (Geersten et al., 2016). Cognition is defined as the process where "mental actions of acquiring knowledge and understanding through thoughts, experience, and the senses" occurs (Davis, Pitchford, & Limback, 2011, p. 569). A cognitive learning process may take place when learning a skill, such as tying your shoes or solving a mathematical equation. As the learning process is enhanced, cognitive development is enriched, which may ultimately impact academic achievement.

Aerobically fit children have demonstrated faster reaction times than their unfit peers (Moore et al., 2013). There are two components of reaction time that are addressed in this study, simple and choice. Simple reaction time "involves making a response as quickly as possible in response to a single stimulus" (Deary, Liewald, & Nissan, 2015, p1). Choice reaction time is "requiring the subject to make the appropriate response to one of a number of stimuli" (Deary, Liewald, & Nissan, 2015, p. 1). Both simple and choice reaction time are important components of cognition (Deary, Liewald, & Nissan, 2015).

A longitudinal analysis that focused on the correlation between aerobic fitness and reaction time in elementary school aged children, demonstrated a positive correlation between both factors (Scudder et al., 2014). A more recent longitudinal study supported the previous research, by ascertaining that there is positive correlation between aerobic fitness and reaction time (Scudder et al., 2016).

This study concluded that even though a correlation exists between aerobic fitness and a component of cognition, reaction time; only the subcategory of reaction time, simple reaction time, was statistically significant with aerobic fitness. One of the main differences between this study and the studies previously mentioned, is that this study examined elementary aged children from Title 1 schools. Title 1 “provides financial assistance to local educational agencies (LEAs) and schools with high numbers or high percentages of children from low-income families to help ensure that all children meet challenging state academic standards.” (Department of Education, 2015). The previously mentioned studies (Scudder et al., 2014; Scudder et al., 2016) did not examine children from low income families. It has been noted that socioeconomic stress may be associated with reaction time (Moradi & Esmaeilzadeh, 2017).

The conceptual framework from which this study is based on, states that there may be a relationship between the prefrontal cortex (the area of the brain responsible for cognition) and the cerebellum (the area of the brain responsible for large body movements) (Diamond, 2001). The prefrontal cortex has been noted to experience a decrease in its abilities to function and in chronic cases of stress, such as with socioeconomic stress, an “architectural change in prefrontal dendrites” (Arnsten, 2009, p. 410). Therefore, chronic stress, which in this case appears in the form of socioeconomic status, may be affecting the prefrontal cortex and ultimately, cognition.

*Hypothesis 5*

Hypothesis five stated that there would be a relative age effect on aerobic fitness. The relative age effect has been proposed to affect the aerobic fitness levels of both boys and girls (Roberts, Boddy, Fairclough, & Stratton, 2012). Children who are born earlier in the year have performed better on aerobic tests than their older peers who were born within the same year (Roberts, Boddy, Fairclough, & Stratton, 2012). One of the contributing factors as to why the relative age effect may contribute to significant differences in aerobic fitness, is due to the differences in growth and maturation that children born on the same year but on different months, experience.

After testing 11,404 children in aerobic fitness, and then comparing their birthdates, a segment of the literature found that boys and girls who were born earlier in the year performed better in an aerobic fitness test, then those children that were born later in the year (Roberts, Boddy, Fairclough, & Stratton, 2012). In addition, after examining children of nine years of age on aerobic fitness and taking note of their birth dates, the majority of children born at the beginning of the year, outperformed those children that were born later in the same year, in an aerobic fitness test (Maria Gil et al., 2013).

In contrast to the previously mentioned studies that support the correlation between the relative age effect and aerobic fitness, a more recent examination on relative age effect and aerobic fitness, found that there was not significant difference in aerobic fitness among children born in the same year but on different months (Lovell et al., 2015). In addition, another examination of aerobic fitness and relative age agree with the results of the latter examination (Carling, Gall, Reilly, & Williams, 2009). After testing for aerobic fitness and identifying the month in which a group of children were born on, “no significant difference was observed across any fitness measures” (Carling, Gall, Reilly, & Williams, 2009, p. 1).

In this study, aerobic fitness and the relative age effect were examined and as previously noted, no correlation was found between the two factors. This may be a result of the exclusion criteria, which disqualified participants from being a part of this study if they were involved in any after school program for one consecutive year. By disqualifying children that were involved in an afterschool program, many older children may not have participated. This may have influenced the study by limiting children who might otherwise have been more physically developed, mature, and more likely to perform better on an aerobic fitness test compared to younger children. By excluding children who had participated in some sort of physical activity program for one year, it is also possible that this study may have focused on children that were either unfamiliar or untrained in aerobic fitness, compared to children involved in a year-long afterschool sports program, where a child is likely to be exposed to some sort of aerobic fitness routine (outside of the regular physical education routine), which could improve aerobic fitness.

In addition, it is possible that this study did not observe a positive correlation between the relative age effect and aerobic fitness because typically, boys and girls under the age of eight, do not demonstrate significant difference in aerobic fitness levels amongst each other (Armstrong, 2006). Beginning at approximately eight years of age, boys will typically show annual growth in aerobic fitness levels (Armstrong, 2006). The same can be said about girls, as they too will begin to show differences in aerobic fitness levels at approximately 8 years of age (Armstrong, 2006). Therefore, because this study examined children that were between the ages of six and seven, it is possible that aerobic fitness scores did not correlate to the relative age effect because the children of this study were not old enough to vary significantly in their aerobic fitness levels.

### *Hypothesis 6*

Hypothesis six stated that there would be a relative age effect on gross motor skills. In this study, with the exception of balance and manual coordination, the gross motor skills tested in this study, correlated with the relative age effect. A review of the literature has shown that gross motor skills are a fundamental part of a number of competitive sports. For example, gross motor skills are seen in hockey when a child moves his legs to skate and chase the puck and in basketball when a child moves his arms to dribble a ball. A number of correlational studies have observed a relative age effect on sports that require gross motor skills such as ice hockey (Nolan & Howell, 2010), skiing (Muller et al., 2015), and basketball (Delorme & Raspaud, 2009).

The advantage that the relative age effect presents on gross motor skills is seen when children that were born earlier in the year demonstrate a significant difference in growth and maturation compared to children that were born later in the year (Muller et al., 2015; Dixon, Horton & Weir, 2011). This difference in growth and maturation that may help children excel at a higher level in different gross motor skills of a selection bias that occurs. Older children will likely appear more physically mature than their younger peers and therefore more likely to be selected first, to participate in a sport that can develop their gross motor skills. This could then increase a child's level of self-confidence and motivation to continue to participate in that sport and therefore continue the development of these gross motor skills.

The self confidence that these older children are experiencing outside the classroom, in their sports, may translate into the classroom. As a child engages in gross motor skill development through sports, he or she may improve that skill, which may in turn lead the child to be more likely to feel comfortable with a challenge and understand that he or she can improve by being engaged in the task and dedicating time to the task. As a result, children that excel in their sport, may feel confident in the challenges they face inside the classroom because of the long-term habits that are being formed outside of the classroom.

### *Hypothesis 7*

Hypothesis seven stated that there would be a relative age effect on academic achievement. The relative age effect has consistently shown a positive relationship to academic achievement (Romann & Cobley, 2015). A review of the literature has indicated that older children are more likely to have higher test scores until fifth grade (Lin, Freeman & Chu, 2009), particularly in subjects such as reading and mathematics (Oshima & Domaleski, 2006).

There are a number of reasons as to why older children, born in the same year, may have an academic advantage over their younger counterparts. an older student may begin school being more emotionally mature, behaving better, being more proficient in fine motor skills, and displaying a higher level of attention span as the teacher explains the reading and mathematics content (Dougan & Pijanowski, 2011). This child may then excel in the material that is covered by the instructor and then be placed in a higher-level reading and mathematics group. These children will therefore be "challenged" to a higher degree than those students that are not retaining the same information at the same pace; thereby opening the opportunity for a higher level of self-confidence and probability of being placed in a higher reading and mathematics in the following school years (Dougan & Pijanowski, 2011, p. 5). In contrast, the younger children may feel a lower level of confidence and a sense of having to catch up to the older peers. This could lead to a child's risk of falling behind academically to their older counterparts after only a couple years in school.

Therefore, many parents of children born on specific months, particularly the later months of the year, will often hold back their child from starting school with the hope of possibly having their child commence school at a more mature, and emotionally/cognitively developed period in time (Dougan & Pijanowski, 2011). This study emphasized the relative age effect in low income schools. With regards to the relative age effect and socioeconomic status, evidence suggests that those children that were of lower socioeconomic status, obtained higher academic results than those children coming from high socioeconomic backgrounds. The conclusions demonstrated that "poor and disabled children and boys benefit significantly more from delaying kindergarten entrance, in terms of test score gains especially in reading" (Datar, 2006, p. 58).

### *Hypothesis 8*

Hypothesis eight stated that there would be a significant group mean difference by sex in gross motor skills. Approximately at the age of six, boys develop an affinity for gross motor skills, whereas girls develop an affinity to fine motor skills (Junaid & Fellowes, 2009). After testing boys and girls in gross and fine motor skills, boys demonstrated dominance in gross motor skills such as throwing and catching a ball, while females demonstrated dominance in pencil grasping and writing legibly (Junaid & Fellowes, 2009). These results are supported by a more recent examination of gender and motor skill differences (Pahlevanian & Ahmadizadeh, 2014). This study concluded that girls showed a higher performance level compared to boys in actions such as “hand skills, including moving fingers, opening and closing hands alternatively,” (p. 3) whereas boys showed a higher performance level, compared to girls in “throwing and catching” (p. 3) a ball (Pahlevanian & Ahmadizadeh, 2014).

The results of this study indicated that when comparing boys and girls, a statistical significance was seen among boys in various subcategories of gross motor skills such as, upper limb coordination, manual coordination, body coordination, and strength and agility. This difference in motor skill development may be attributed to “environmental, sociocultural and biological factors” (Kokstejn, Musalek & Tufano, 2017, p. 7). In the United State, from an early age, society steers young boys to dedicate their time and effort into skills that require gross motor development, such as baseball, basketball, and football. Boys that outperform their peers in these gross motor skills, are often encouraged to continue to spend time and focus on the development of that particular gross motor skill. In contrast, within many parts of the United States, boys are not encouraged to develop the other motor skills, such as the fine motor skills, which are often viewed as skills that are reserved only for girls.

*Hypothesis 9*

Hypothesis nine stated that there would be a significant group mean difference by sex in fine motor skills. Similar to hypothesis eight, the research on gender gross and fine motor skills concludes that boys are more proficient in gross motor skills, whereas girls are more proficient in fine motor skills. As previously alluded to, a cross sectional study that included 60 boys and 39 girls, concluded that there was a gender difference in gross and fine motor skills (Junaid & Fellowes, 2009). Specifically, boys scored higher in gross motor activities, while girls scored higher on fine motor skill activities. Another cross-sectional study supported these results by identifying that girls are more skilled in fine motor activities, whereas boys are more skilled in gross motor activities (Pahlevanian & Ahmandizadeh, 2014).

In this study, the results indicated there was a marginal significance by sex for fine motor integration. Girls may be slightly outperforming boys in this particular area of fine motor skill development because of the tendency to emphasize the activities that young girls should participate and should not participate in. From a young age, the majority of girls in the United States are encouraged to participate in less gross motor development and more fine motor development. For example, girls are typically given toys, such as dolls, and told that it is appropriate to accessorize and play with that doll, a simple activity that requires fine motor skills. However, it is not typical for girls to be enrolled in activities that require gross motor skills, such as football, basketball or baseball from a young age. Although a higher number of girls are presently being enrolled in a higher number of sports in general, and more specifically, sports that do require gross motor skills, a significant number of girls are only developing their fine motor skills from a young age and failing to address the full scope of gross motor development they should obtain (NFHS, 2017).

### *Hypothesis 10*

Hypothesis ten stated that there would be a significant group mean difference by handedness and footedness in gross motor skills. In this study, right handedness demonstrated a significant mean difference over left handedness in the gross motor subcategories of upper limb coordination, manual coordination, running speed and agility, strength, and strength and agility.

A review of the literature is not in consensus as to whether left or right handedness correlates with gross motor skills. One correlational study found that left handed, dominant individuals may be more proficient in the performance of motor skills (Kilshaw & Annett, 1983). A more recent study found that there is “a slight but significant relation” between left handedness and spatial abilities, which require gross motor skills” (Reio, Czarnowlewski, and Eliot, 2004, p. 339).

Spatial abilities are defined as “the ability to mentally represent spatial abilities and to anticipate the course and outcomes of transformation applied to those relations” (Reio, Czarnowlewski, & Eliot, 2004, p. 341). There may be a positive correlation between motor skills and spatial abilities with relation to hemispheric brain dominance (Frick & Mohring, 2015). The left hemisphere of the brain is mainly associated with verbal skills, and this hemisphere is associated with right hand dominance. The right hemisphere is associated with spatial abilities, and this hemisphere is associated with left hand dominance (Reio, Czarnowlewski, & Eliot, 2004).

When documenting hand preference and examining gross motor skills in 512 children, a correlational study indicated that left and mixed handed children performed significantly worse in gross motor skill activities than right handed children (Tan, 1985). These results are supported by a more recent examination of gross and fine motor skills that determined that left handers performed worse than right handers in both skills (Gabbard, 1995; Giagazoglou et al., 2001).

As previously noted, this study found a significant group mean difference between right handers and gross motor skills. However, this study examined a total of 79 participants and only seven were left handed. Therefore, it is possible that had more left handers been present in the study, the results may have differed in favor of left handers demonstrating more proficiency in gross motor skill activities. Therefore, despite the lack of consensus in the literature as to whether right or left handed children are more proficient in gross motor skills (Kilshaw & Annett, 1983, Gabbard, 1995; Giagazoglou et al., 2001), future studies should take into account a higher number of left handers, as research (Reio, Czarnowlewski, & Eliot, 2004) has stated that left handers are proficient in spatial abilities, which are an important component to gross motor skills and therefore, may impact the proficiency of gross motor skills.

## Implications for Theory, Research, and Practice

This study provides evidence that there is a relationship between certain categories of motor skills and academic achievement. Certain subcategories of gross motor skills and fine motor skills were linked to academic achievement. In addition, aerobic fitness was linked to math but not reading scores and simple reaction time but not choice reaction time. With regards to the relative age effect, this study found that the relative age effect was not related to gross motor skills or aerobic fitness, but a relationship was found between the relative age effect and academic achievement. Lastly, after examining the effect gender and handedness may have on gross and fine motor skills, only certain forms of gross motor skills were related to boys and right-hand dominance. The subsequent sections elaborate on the implications of this study for theory, research and future practice.

### *Implications for Theory*

Chaddock (2010) provides substantial evidence that explains the foundations of the relationship between aerobic fitness and cognition. After using Magnetic Resonance Imaging (MRI), at the cerebral level, cortical differences are observed between aerobically fit and unfit children (Chaddock, Pontiflex, Hillman, & Kramer, 2011). Low levels of aerobic fitness are "associated with declines in academic achievement, cognitive abilities, brain structure and brain function" (Chaddock, Pontifex, Hillman & Kramer, 2011, p. 1). When associating aerobic fitness and changes in brain structure and function, the parts of the brain that are generally referred to are the Basal Ganglia and Hippocampus.

In accordance with Chaddock (2010), the literature (Aron et al., 2009; Casey, Getz, & Galvan, 2008) describes the basal ganglia as being associated with cortical differences in aerobically fit and unfit individuals. The basal ganglia is also an area of the brain that has been associated with cognition (Chaddock et al., 2012). Therefore, aerobic fitness may be considered a tool with which to enhance brain structure and function in order to improve cognition and positively affect academic achievement (Chaddock, Pontifex, Hillman, & Kramer, 2011).

In addition to cortical differences at the basal ganglia level, the hippocampus is also affected by aerobic fitness (Erickson et al., 2016). The hippocampus is an area of the brain that plays a significant role in memory. Memory is necessary in academic setting, for children because it assists in a number of different areas in academics, including the ability to focus on a task, remember instructions and execute steps in different problems, within different subjects (Klingberg, 2012).

Overall, the basal ganglia and hippocampus work simultaneously in an academic setting to contribute to academic achievement (Chaddock et al., 2011). Aerobic fitness affects the basal ganglia and hippocampus by stimulating neurogenesis, or the growth and development of new neurons and vasogenesis, or the creation of collateral circulation which in turn increases, blood flow and an oxygen supply to the brain (Chaddock et al., 2011). This increase in neurons, and oxygen supply to the brain, may improve cognition and thereby enhance academic achievement (Erickson et al., 2011).

After conducting a correlational analysis, this present study partially supports the conceptual framework in identifying that there is a correlation between aerobic fitness and academic achievement (Chaddock, Pontiflex, Hillman, & Kramer, 2011). However, this study found that aerobic fitness only correlated to mathematic scores not reading scores when testing for academic achievement in children.

In contrast to the previously noted studies, (Chadock et al., 2011) a correlational study (Davis et al. 2011) added to the body of literature on aerobic fitness and test scores, by stating that not only does the basal ganglia and hippocampus play a significant role in academic achievement, but in addition, the prefrontal cortex and its role in executive function is contributing to academic achievement. Executive function is responsible for higher order thinking and “is crucial for adaptive behavior and development” (Lambourne et al., 2013) and “is often related to one’s academic achievement in elementary school” (Lambourne et al., 2013). This is significant because executive function is critical to subjects such as math but not necessarily to subjects such as reading and spelling (Lambourne et al., 2013). Moreover, “reading is typically only associated with executive function in cases where cognitive dysfunction or a learning disability is present” (Lambourne et al., 2013, p. 165).

In addition to the role the prefrontal cortex has been documented to contribute to aerobic fitness and academic achievement, the prefrontal cortex is also responsible for the development of gross and fine motor skills (Diamond, 2000). The cerebellum, an area of the brain responsible for physical coordination (Koziol et al., 2014) is said to co-activate with the prefrontal cortex when exposed to either a motor or cognitive activity (Berman, et al., 1995; Diamond, 2000). In her seminal work, Diamond (2000) explains that there may be an interrelationship between motor and cognitive development. When the cerebellum is exposed to either a motor or cognitive stimuli, the prefrontal cortex is activated as well (Diamond, 2000). As mentioned, the prefrontal cortex is responsible for executive function, which is necessary in cognition and ultimately academic achievement. Therefore, the prefrontal cortex and cerebellum may be working in unison to carry out a cognitive task (Diamond, 2000).

The results of this study, support Diamond’s (2000) conceptual framework. However, more research is needed to support the notion that the cerebellum is working with the prefrontal cortex when presented with either an aerobic fitness activity, certain gross or fine motor activities, and a cognitive task in a classroom setting.

*Implications for Research*

Aerobic fitness and gross and fine motor skills play a role in academic achievement. This study focused on reading and mathematics when assessing academic achievement. Future studies should consider examining other subjects that are frequently under- funded, such as music and art when assessing academic achievement. Music and art require fine motor skills. Fine motor skills, as noted in this study, correlate to academic achievement, specifically when examining children in reading and mathematics.  Fine motor skills may be developed by playing a musical instrument, which in turn may improve writing skills, and examination scores in subjects such as mathematics and science (Mickela, 1990; Rauscher et al., 1994).

This study focused on examining schools in low socio-economic areas of Miami Dade County (Title 1 schools). Future studies should consider examining children in higher income areas of Miami Dade County. Once examined, the results should be reviewed and compared to those results of the children in the low-income areas of Miami Dade County. A comparison should be made as to which motor skills correlated with academic achievement in the high-income areas of Miami Dade County. Moreover, the relative age effect should be examined and compared to aerobic fitness and motor skill development. It has been noted that parents from affluent areas are practicing what has been referred to as academic “redshirting” or the practice of delaying a child’s entry into kindergarten for a year” (Bassok & Reardon, 2013, p. 283). As noted previously in this study, a child who is older, may be cognitively, emotionally, and physically more mature and ready for school than their younger counterparts (Dougan & Pijanowski, 2011). It may be the case that the parents of children born in the latter part of the year in affluent areas, are delaying the entry of their children into elementary school at higher rates than those of children born to parents within a low-income area (Bassok & Reardon, 2013).

A longitudinal study that tracks motor skill development and handedness should also be considered. It has been well documented that motor development occurs between four to ten years of age (Gabbard, 2008; Westendorp et al., 2011). This study examined children that were specifically, six to seven years of age. A longitudinal study will observe differences in motor skill development within children that are older than six or seven years of age and document these motor skill changes from four to ten years of age. It would be interesting to note the rate of improvement among not only the gross and fine motor skills, but their reading and mathematics scores.

In addition, a longitudinal study that observes the cortical changes in prefrontal cortex, basal ganglia, hippocampus, and cerebellum volume before and after the implementation of an aerobic fitness and motor skill program, should be conducted in children. A recent experimental study observed greater blood flow in the hippocampus portion of the brain, within seven to nine year old children after partaking in an aerobic fitness program (Chaddock et al., 2016). However, gross and fine motor skills were not documented in Chaddock et al. (2016) and as noted in this study, gross and fine motor skills may play a role in cognition. The prefrontal cortex and cerebellum are sections of the brain that are responsible for different aspects of cognitive and motor development at an early age (Diamond, 2000).

A qualitative study should also be conducted in order to document the lived experiences that many of the children in these low socioeconomic areas may be facing. The qualitative should specifically focus on documenting the chronic stress that these children may be experiencing, as result of where they happen to reside. This study examined the effects of aerobic fitness on simple and choice reaction time and found that simple reaction time correlated with aerobic fitness. It has been noted, that reaction time may be affected by chronic stress (Moradi & Esmaeilzadeh, 2017). Therefore, chronic stress may have affected the reaction times of the children that participated in this study.

### *Implications for Practice*

The U.S. educational system should reconsider the relevance and importance of a quality physical education program, specifically in urban schools. As it stands, physical education and more importantly, a quality physical education program, may play a role in a child's academic career. Specifically, the gross and fine motor skills, as well as the aerobic components that a quality physical education program is comprised of. The aerobic fitness and motor skill components are relevant because of the relationship to academics that this study has alluded to.

Since the implementation of the No Child Left Behind agenda, physical education classes and their relevance in the U.S. curriculum has slowly been disappearing (Common Core, 2015). This is partially a result of the over emphasis on standardized testing. Standardized testing is over emphasized because it plays a substantial role in school funding. Schools with higher standardized test scores receive more federal funding that those schools with lower standardized test scores (Common Core, 2015).

This study has shown that there is a partial relationship between standardized test scores in reading and mathematics and aerobic fitness, gross and fine motors skills in children within thirteen urban schools in Miami Dade County. Therefore, the education system should focus on the implementation of a quality aerobic fitness, gross and fine motor skill component in the structure of its physical education programs from as early as pre-kindergarten. Although this study did not focus music and the arts, these are subjects that should also be considered by the education department for the development of gross and fine motor skills. This may in turn help promote the early physical as well as cognitive development (cortical development) that a child needs, which may lead to an improvement in academic achievement. Separate from the education system, parents are encouraged to help their child develop their aerobic fitness, gross and fine motor skills from a young age. This can be done by striving for their child to be involved in any form aerobic exercise, as well as activities that require gross and fine motor skills such as music, sports, and the arts.

Furthermore, it is important that the education system and schools themselves, take note of their student's birth month. This relative age effect, as it is known, has demonstrated a consistent pattern of higher academic achievement among children who are older but born within the same year (Romann & Cobley, 2015). This pattern of higher levels of academic achievement has been observed in schools across the world, with its effects have been seen primarily throughout the elementary school grade levels (Smith, 2009; Bedard & Dhuey, 2006). The education system should carefully document and provide the necessary assistance to those children that are born later in the year. This study found a correlation between some fine and gross motor skills and the relative age effect.

Therefore, the education system and parents should emphasize from an early age, the development of gross and fine motor skills either at home or as previously noted, in after school music, sports and art activities. This may help those children that are born later in the year to feel confident in their gross and fine motor skills (Mickela, 1990; Rauscher et al., 1994; Delorme & Raspaud, 2009), which in turn may help with the development of different activities that need these gross and fine motor skills, such as music, sports, the arts and academic achievement. Children that are born later in the year may not be as emotionally, physically and cognitively developed as their older counterparts, as a result their self-esteem may be affected from a young age. By developing the necessary gross and fine motor skills, children born later in the year may feel more confident and apt at performing at par with their older counterparts.

## Strengths of the Study

One of the strengths that was identified in this study is the number of diverse, Title 1 versus non-title 1 schools that Miami Dade County Public School Systems, contains. Title 1 schools "provide financial assistance to local educational agencies (LEAs) and schools with high numbers or high percentages of children from low-income families to help ensure that all children meet challenging state academic standards." (Department of Education, 2015). This study only examined Title 1 schools in the Miami Dade County area. A total of seven, Title 1 schools participated in this study. Focusing on Title 1 schools is a strength because the majority of the literature that exists on motor skills and academic achievement has not focused on children from low socioeconomic areas (Title 1) (Department of Education, 2015).

A second strength of this study were the variables that were tested in each hypothesis. In addition to the relationship between motor skills and academic achievement, this study also focused on the correlation between aerobic fitness, reaction time, and handedness with academic achievement. The literature that exists observes the relationship between the variables that have just been mentioned, however it does so, independently of one another (Bobbio & Cacola, 2009; Dinehart & Manfra, 2013; Westendorp et al., 2014). This study is the first study to examine all the mentioned variables, simultaneously.

## Limitations of the Study

A limitation of this study included the instrumentation. Although the Bruininks Oseretsky (BOT-2) has strong inter-rater reliability, it may not have measured the dependent variable over time. This can occur when a human observer, the principal investigator, commits human errors due to fatigue and a lack of experience in the implementation of the BOT-2 instrument. The results of the participants that were tested early in the study may differ from the results of those participants that were tested later in the study because the principal investigator developed a higher level of experience in the implementation of the BOT-2 on the participants as more and more participants were tested.

A second limitation to this study was that the individual data collection process was prolonged. This was a result of a number of participants had difficulty with concentration, attention, and focus. Some students responded to the various instruments in this study, much quicker than others. This prolonging of testing of those students with poor concentration, attention, and focus lead to fatigue when performing the motor skill, aerobic, and reaction test, based on the length of time it took to complete all the examination of the study.

A final limitation to take note of in this study was the absence of a question within the demographic questionnaire that asked the number of hours each participant spent studying to improve reading and/or mathematic skills. This is relevant because although this study was performed on low income urban schools, there may have been the possibility that some children were enrolled in an afterschool tutoring program outside of the classroom. It may be possible that these children were enrolled in the local YMCA program, which may have emphasized a mandated time for focusing and developing reading and mathematical skills. These programs may have improved the participant's reading and mathematics scores and therefore may have influenced the academic achievement results in this study.

## Chapter Summary

This chapter began by discussing the results of this study. This chapter documented each hypothesis and its significance. The documented hypotheses discussed first, the correlation between aerobic fitness and academic achievement. Second, it addressed gross and fine motor skills, and their correlation to academic achievement. The discussion also covered simple reaction time and its correlation to aerobic fitness, as well as the relationship between handedness with gender, gross and fine motor skills. The relative age effect and its relation to academic achievement was also discussed. Furthermore, based on the discussion, implications for theory, research, and practice, were addressed. Finally, the strengths and limitations of this study were discussed.

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