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Middle School Girls' Science Motivation and Performance: Cognitive Effects of an Out-of-School Time Program with Nutrition and Fitness Components

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Abstract of the Dissertation

Middle School Girls' Science Motivation and Performance: Cognitive Effects of an Out-of-School Time Program with Nutrition and Fitness Components

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Middle school is a critical period in the cognitive and academic development of young women, and a time when their performance and interest in science may decline. After school programs play a key role in engaging youth in learning by providing opportunities to increase health and wellness, set goals, and strategize problem solving. Skills associated with the capacity to perform well in science are highly dependent upon abilities that fall under executive function. *Executive function* is an umbrella term for higher order cognitive processes including working memory, inhibitory control, cognitive flexibility, and the ability to plan, monitor and carry out goal directed actions. These processes complement the self-regulation of learning required for constructing scientific understandings. Self-regulation serves as a measure of control over behavior and environmental contexts play a pivotal role in the causal structure of *social cognitive theory,* which asserts that cognitive processes exert a determinative influence on goal-directed pursuits. This model was applied to an out-of-school-time (OST) program with measurement of its impact on students' cognition, motivation and science achievement. This study was conducted to address the overarching research question: What is the effect of an OST program for female middle school science students on goal-directed behavior, self-efficacy, attitudes, and achievement?

A 20-week informal science and triathlon training program served as the intervention for $n = 29$ at-risk female middle school students. The comparison group of females was randomly drawn from middle school students of a similar demographic ($n = 30$). The program combined empowerment lessons, nutrition and health science education twice per week from mid-March through June, and after school activities such as triathlon specific training and group fitness classes three times per week through July, with a culminating youth sprint triathlon (300-yard swim, 7-mile bike ride and 1.5-mile run). A mixed methods design was used in a three-part study to assess program outcomes measured by science achievement tests and motivation questionnaires, cognition assessments, fitness measurements, and semi-structured focus group interviews.

The first study employed mean comparisons, analysis of covariance and Roy-Bargmann stepdown analysis to determine the outcomes of a physical activity intervention for at-risk girls on the executive functioning involved in science learning. Data revealed the intervention contributed to a statistically significant improvement in cognition and science achievement. Multiple comparisons showed that the intervention group of adolescent middle school girls demonstrated statistically higher science achievement, with a moderate to strong effect. Inhibitory self-control, metacognition, and cognitive regulation were significantly improved compared to the control; data revealed medium effect sizes for inhibitory control and cognitive regulation, and a large effect size for metacognition.

The second study examined associations between physical activity, executive functions, and science performance with multiple regression analysis. Moderation analysis assessed the interaction of cognition variables and physical activity dose with science achievement. The intervention suggested improved cognition and science achievement in previously sedentary middle school girls. Higher physical activity and faster processing speeds were associated with increased science performance.

In the third study, an explanatory sequential mixed methods design was employed with quantitative pre-/post-measurement of fitness, motivation and achievement, followed by focus group interviews to provide insights into quantitative findings. Wilcoxon signed rank tests revealed significant improvements in cardiovascular fitness, science achievement, and aspects of motivation. Qualitative analysis revealed that confidence, interest, and determination motivational constructs positively influenced goal setting, strategies, improved health outcomes, motivation and academic achievement.

Intervention participants learned to self-regulate their learning and set goals that promoted fitness, academic achievement, better attitudes and resilience. After school community and family inclusive programs with a structured fitness component may increase confidence, self-determination and science performance. These results suggest that an OST program with a nutrition education and fitness component may produce improvement in the cognitive processes and motivations involved in science learning.

Dedication Page

This is affectionately dedicated to my husband, David, and my son, Van, who provided continual support, love, patience, and a sense of humor through the late nights and weekends while I researched, wrote, and prepared papers for publication.

To my mother, a source of strength, and my father, who encouraged every adventure as my "number one fan." To my siblings, Gregory, Wendy, Gary, and Amy, for your encouragement and understanding of the sacrifices that were necessary for me to achieve this goal. For my nieces, Julie, Kate, Skyler, and Natalie, find your niche and stay strong and resilient.

To my "twin" Sinead Fitzgibbon, through the bonds of friendship we have shared similar career paths in allied health, coaching, teaching, and the pursuit of PhDs. I am grateful for your friendship and for all the shared experience that has brought us to graduation at the same time.

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Introduction

1.1   Statement of the Problem

During the middle school years, students go through dramatic physical, emotional, behavioral and cognitive changes that can greatly affect their futures. If developmental changes are not negotiated successfully during this crucial time period, the results are often school failure and inadequate skills to navigate post-secondary education or the work force (Osborne, Simon, & Collins, 2010). The middle school years are a time when gender differences in achievement and attitudes towards science and mathematics widen (Jones, Howe, & Rua, 2000). The purpose of this study is to explore connections among cognitive processes, science motivation, and achievement with aerobic fitness as the mediator. This study was conducted in three parts to address the following overarching research questions:

Exploring program impact through 3 models

Paper 1	Paper 2	Paper 3
Effects of Aerobic Fitness on Executive Function and Science Achievement	Dose Response Effect of Physical Activity on Executive Function and Science Achievement	An After-School Program's Impact on Motivation and Science Achievement
Research Question: What is the effect of an out-of-school time aerobic fitness program on the executive function and science achievement of at-risk middle school girls?	**Research Questions:** 1. How does improved physical fitness affect cognition and science achievement for at-risk middle school girls? 2. How does physical activity dosage moderate the effect of cognition on science achievement?	**Research Question:** How do environmental factors that include triathlon training, peer mentoring, nutrition and health based science instruction in an OST program affect students' motivation, health outcomes, and achievement in science?

Figure 1. Exploring program impact through three models.

This chapter explains the rationale for the overarching research question, along with the theoretical organization of the three studies that explored different aspects of the treatment and its impacts. This is followed by discussion of cognitive control and its relationship to learning, social cognitive theory and triadic reciprocality causation, and positive outcomes associated with out-of-school time (OST) programs.

1.2   Rationale for the Study

Powerful experiences cause the human brain to perform multiple operations simultaneously when stimulated by environmental change (Bandura, 2006). The executive functions network delivers this information subconsciously and the neural networks of the brain coordinate to plan, motivate, and regulate goal directed behavior (Anderson, 1983; Bandura, 2001). Active learning is a dynamic emergent process requiring motivation, organization, interpretation, and synthesis of new information into an existing neural network. An integrative approach of social cognitive theory (Bandura, 1986) and biological mechanisms of informational processing provide a framework for increased motivation and transfer of knowledge between situations that may be different but are similar in context (Anderson, 1997; Anderson, Greeno, Reder, & Simon, 2000). Bandura (2006) contended that cognitive processes are generally studied apart from goal directed pursuits and the ability to be reflective. Research is warranted to examine the relationship among standardized measures of fitness, cognition, self-efficacy, attitudes, and academic achievement in science.

The target sample of the experimental group for this study was girls in grades 6-8 during the spring semester of 2014. The participants for the study were drawn from three small school districts in close proximity for a community based *Transformation Through Triathlon* (TTP) OST program. The program was founded in 2010 as a pilot program for at-risk adolescent girls.

Program and school personnel defined at-risk as girls as experiencing low self-esteem, a sedentary lifestyle, and classification as overweight. The participants met with the program facilitators and certified trainers twice per week for 20 weeks for informal health and nutrition education and aerobic fitness training with a culminating sprint triathlon (300-yard swim, 7-mile bike and 1.5-mile run).

The comparison group was drawn from an additional school district with a similar demographic. A random sample of 6th through 8th grade female students ($n = 30$) matched for pre-test science scores was selected. The comparison group received the same instruments with the exception of the OST triathlon training intervention. Quantitative data collection occurred over two days, pre- and post- over a 12-week time period in the early spring to match the experimental group intervention time period. The timing ensured that the control and treatment students were at a similar level of learning, curricular topics, and development within the same grade levels. All districts had similar science curricula for each grade according to the NYS Intermediate Science Curriculum for grades 5-8 (New York State Education Department [NYSED], 2014). Table 1 shows a breakdown of measures received by the intervention and comparison groups as well as a brief description of the treatment that the intervention received.

Table 1

Summary of Measures and Description of the Treatment the Intervention Received

Intervention Group	Comparison Group
MEASURES	
Project 2061 based science assessment	Project 2061 based science assessment
Trail Making Test Parts A & B	Trail Making Test Parts A & B
Science Motivational Questionnaire - II	Science Motivational Questionnaire - II
Behavior Rating Inventory of Executive Function – Parent form	Behavior Rating Inventory of Executive Function – Parent form
Physical Activity Questionnaire - Children	Physical Activity Questionnaire - Children
TREATMENT	
Informal science lessons in health, wellness, and nutrition. Character building and empowerment lessons after school twice per week from mid-March through June.	
Triathlon specific swim/bike/run training and group fitness classes three times per week from mid-March through the program conclusion in early July. 1.5 mile run times and 100 yard swim times were measured pre- and post-intervention.	
Completed a youth triathlon, 300 yard open water swim, 7 mile bike ride, and 1.5 mile run in early July.	

1.3 Exploring Program Impacts through Three Studies

In the three papers to follow, self-efficacy, STEM and the at-risk student, and the relationship these factors have to cognitive self-regulation were addressed. Bandura's perspective on social cognitive theory provides the theoretical framework for this research study (Bandura, 1986, 1999, 2001, 2006). Bandura suggested that individuals prefer tasks and activities in which they feel competent, confident and capable. Bandura (2001, 2006) defined self-efficacy as judgment of capability, and referred to self-efficacy as human agency that extends to a collective power. Within social groups, shared beliefs in collective efficacy come from shared intentions, knowledge, and skills, as well as the interactive and dynamic interactions among them. As a result, beliefs of collective efficacy function in a similar way to self-efficacy and operate through similar processes.

The first paper addresses the skills associated with science performance that fall under executive function (Latzman, Elkovitch, Young, & Clark, 2010). Executive function is described as behaviors that include attention, problem solving, verbal reasoning, multi-tasking, planning, scheduling, control of inhibition, and working memory (Colcombe & Kramer, 2003; Etnier & Chang, 2009; Hillman, Castelli & Buck, 2005). As such, executive function is a higher order cognitive ability that controls basic cognitive functions for purposeful, goal-oriented behavior, which is associated with frontal lobe activity in the brain. Functioning of the frontal lobe is critical for the performance of complex cognitive functions (Etnier & Chang, 2009; Miyake et al., 2000; Serrian, Ivry, & Swinnen, 2007). Increased functioning of the frontal lobe processes as a result of an informal science OST program with a fitness component may provide the link between thought and action in improved science achievement. Research is warranted to examine the relationship among physical activity, executive functions, and academic achievement in science.

The second paper discusses physical exercise as an environmental factor that affects cognitive processes concerned with processing speed in the brains of adolescents. The executive function hypothesis predicts that the largest improvements in cognition due to exercise will be on executive brain functions (Davis et al., 2007). There is evidence that executive function develops with increasing age in children throughout adolescence suggesting that physical activity might be particularly beneficial for this age group. It is plausible that the executive function hypothesis can be extended to predict exercise related changes in children's brain function greater than those observed in adults (Hillman et al., 2005). Assessing how exercise influences children's neurocognitive development may prove to be a simple but important mediator towards

understanding the role an active lifestyle plays in science learning (Tomporowski, Davis, Miller, & Naglieri, 2008).

The third paper examines the attitudes, motivations, and changes in goal directed behavior prompting changes in self-regulated learning for the intervention group. Self-esteem, school achievement, attitudes, and motivations, particularly in science and mathematics, often decline in the middle school years for girls and underrepresented minorities (Miller, 2003). If OST programs provide a positive, supportive alternate learning environment, they may make a difference in improved student engagement, self-efficacy, attitudes, and science achievement. The use of inquiry-based learning in these programs promotes student learning and engagement and can particularly support the learning of disadvantaged students, minorities and female students (Brotman & Moore, 2007; McClure & Rodriguez, 2007).

Planning for goal accomplishment, evaluation of alternatives, and revision of hypotheses so they are consistent with new information are skills practiced in quality OST programs that parallel scientific reasoning and habits of mind. The subjects in this study found meaning in what they learned in school, developed confidence in STEM, built competence, and enjoyed relationships with peers and adults. They engaged in learning and improved attitudes towards school and science. Reflection, planning, teamwork, decision-making, fitness, communication, and problem solving with peers positively influenced their development through cognitive processes, executive function, and ultimately interest in science.

In summary, understanding of cognitive processes can inform science education research by examining interactions between students engaging in informal science in an OST program and the effect of these experiences on a developing brain. Informal, active learning environments in a non-traditional setting may promote meaningful connections that are an important aspect of

science process skills. Since each individual has different life experiences, new concepts may be learned in a multitude of ways and science educators must differentiate instruction. An understanding of cognitive processes, the role of increased physical activity, and self-efficacy improvement based on collective efficacy of a group will help focus science education research in regards to alternatives for underrepresented female students to improve attitudes towards science in traditional settings.

Improved cognition and science learning. Cognitive processes and experiences that have contributed to the improvement of executive function are discussed to explore connections between improved cognition and science learning. In regards to the interplay of social factors on human development, adaptation and change, Bandura (2006) suggested that a comprehensive theory was necessary to merge the study of cognitive processes and goal directed pursuits within a unified causal structure. It was proposed that integration of personal and social influences operates through cognitive processes to produce behavioral effects. In this model, personal factors in the form of cognitive processes, behavioral patterns, and environmental influences are mutually influential. Behavior is not just influenced by environmental factors. Regulation of motivation and activities is dependent on social and physical environments. Cognitive processes are therefore emergent brain activities that exert a determinative influence on behavior (Bandura, 2006).

Science educators need to be aware of a student's strengths and weaknesses to foster development of academic skills. Strategies that include specific processes can be adapted to learning tasks including goal setting, monitoring, time management, and self-reflection. Each cognitive process mirrors executive function and scientific inquiry. Students can learn to apply self-regulation and cognitive control of automatic responses and therefore improve their problem

solving ability with directed study of self-regulatory activities, self-reflection, and monitoring; however, these skills must be modeled, taught and practiced. Informal science learning and experimentation offer a positive avenue for development of these skills and can bridge the gap between research in the cognitive sciences, science education and teaching practices. It is important to examine the types of situated learning and environmental influences that have a dynamic interplay with self-regulation. The rationale for the influence of aerobic exercise will be introduced next to explain correlational gains in cognitive processes.

Dose response of physical activity, processing speed, and science achievement. In the second paper, the association between physical activity, processing speed, and science achievement was examined to determine the dose response effect of physical activity. The cardiovascular fitness hypothesis suggests that aerobic exercise is a physiological mediator that explains various mental benefits correlating to gains in cognitive performance achieved through participation in aerobic exercise (Aberg et al., 2009; Etnier, Nowell, Landers, & Sibley, 2006; Hillman, Erikson, & Kramer, 2008). Aerobic fitness may be the first mediator in a cascading series of physiological events that ultimately impact cognitive performance (Etnier, et al., 2006). Increased cardiovascular fitness may improve informational processing by stimulating stronger network connections within and between motor and sensory components of the brain for accessing pieces of knowledge more efficiently (Anderson, 1997). If this is the case, changes in cardiovascular fitness may be necessary for changes in cognitive performance to occur. Research is warranted to understand the complex physical and psychosocial relationships reflected by the association of aerobic fitness training, informal science learning, and academic performance in science.

OST programs, motivation, and academic achievement. Finally, environmental factors affecting attitudes of girls towards science are reviewed with a link proposed between support and long-term competence. Examining self-efficacy and its relationship with cognitive self-regulation is important in understanding how people learn through creativity, self-discipline, and facilitation of organizational process skills that are highly valued in science. In science, students' self-efficacy beliefs about their abilities in different science tasks, courses and activities affect the effort they expend on those activities, the perseverance after encountering difficulties, and the ultimate success they experience in science (Britner & Pajares, 2006). Self-regulation, the monitoring of a student's pattern of behavior and the environmental conditions under which it occurs, gives rise to actions. Goal setting lends direction and motivation to personal pursuit and this type of self-regulating behavior sustains the attention demands required to achieve goals. Goals must be challenging in order to provide a good incentive for behavior change and achievement may be dependent upon how far in the future they are projected. In line with this aspect of goal incentivized action, the metacognitive capability for self-reflection is where students address motivational conflicts, judging and predicting their chosen plans of action.

In summary, the contribution of an OST program to improve STEM learning and persistence, particularly for at-risk female students, was examined to determine the role this program played in improving self-esteem, self-efficacy, and providing an environment where students might cultivate their skills and competence.

1.4   Cognitive Control and its Relationship to Science Learning

In the late 1950's, the field of cognitive science emerged out of multidisciplinary studies that included philosophy, developmental psychology, cognitive psychology, and neuroscience (Anderson, 1997; Zirbel, 2004). Over the past 25 years, studies conducted by cognitive scientists

and educators yielded new information about the nature of teaching and learning. Advances in neuroscience have confirmed theoretical positions of developmental psychologists converging these scientific fields and expanding knowledge of human learning (Anderson, 1997; Bransford, Brown, & Cocking, 2000). This evolution in the study of the mind over the past six decades has important implications for science teaching and learning.

Research from cognitive and developmental psychology has increased understanding of the nature of learning, including problem solving and the organization of knowledge. Neuroscience has provided evidence for many principles of learning and how learning changes the physical structure of the brain and its functional organization. The cognitive sciences have provided insight into students' abilities to become active learners with the capability of understanding complex concepts and transferring that knowledge to new situations (Bransford et al., 2000).

A major function of education is to produce lifelong learning skills. Self-regulation is a process by which learners transform their mental abilities into academic skills by self-generated thoughts, feelings and behaviors that are oriented towards attaining goals (Bandura, 2006). Self-regulation and cognitive control are executive processes that contribute to science performance (Glaser, 2000; Latzman et al., 2010; Miyake et al., 2000; Zaitchick, Igbal, & Carey, 2014). Informal science learning and experimentation offer a positive avenue for development of these skills and can bridge the gap between research in the cognitive sciences, science education and teaching practices.

1.5   Social Cognitive Career Theory and Triadic Reciprocality Causation

Within the framework of social cognitive theory, Bandura (2006) contended that actions were rooted in performance comparisons with personal goals that were challenging, meaningful,

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and purposeful. However, the actual mechanisms explaining this dynamic interplay were unclear. Bandura stated,

> Human functioning is analyzed as socially interdependent, richly contextualized, and conditionally orchestrated within the dynamics of various societal subsystems and their complex interplay. The mechanisms linking sociostructural factors to action in this macroanyalytic approach are left largely unexplained (2001, p.5).

Self-efficacy as a measure of control over behavior and environmental contexts play a pivotal role in the causal structure of social cognitive theory. Unless people believe they have control over desired results and can inhibit detrimental actions, they have little motivation to persevere in the face of obstacles and difficulties. Conversely, those that have a high degree of self-efficacy have the ability to cope in stressful situations, reducing vulnerability and helplessness in difficult tasks, ultimately strengthening resilience (Bandura, 2006). Within the framework of social cognitive theory of human learning, students understand, monitor, and control their motivation and behavior when learning is self-regulated. Motivated science students achieve by using strategies to engage in positive behaviors such as participation, completing assignments, asking questions, studying, and attending class regularly (Schunk & Pajares, 2001; Zimmerman, Bandura, & Martinez-Pons, 1992).

According to Bandura (2001), the collective performance of a social system involves a dynamic interplay of perceived collective efficacy as an emergent property of the social group. In a sense, people share belief in their collective power to produce a desired outcome. People act jointly on shared beliefs and this phenomenon was termed *Triadic Reciprocal Causation* by Bandura (2001). Triadic Reciprocal Causation factors include personal factors of biological events (e.g. cognitive processes) and environmental factors (e.g. social and institutional practices), and they operate through psychological mechanisms of self-efficacy to produce

behavioral effects. Environmental pressures can alter biological processes and these factors stimulate human adaptation and change, starting with behavior (Bandura 1986, 1999, 2001).

Cognitive processes are mediated by networks of interneurons with a dynamic interplay among perception, organization, and a reconstruction of situated knowledge into existing frameworks (Anderson, 1997). Cell signaling pathways and feedback mechanisms mediate self-regulation via the executive functions of monitoring, inhibition, organization, and planning to stimulate adaptation and maximizing of knowledge acquisition (Cleary, Callan, & Zimmerman, 2012). Efficacy beliefs play a pivotal role in the self-regulation of motivation through goal setting and outcome expectations (Schunk & Pajares, 2005). In science learning, self-efficacy has been found to predict student achievement (Britner & Pajeres, 2006; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011).

Figure 2 illustrates the dynamic relationships among the OST intervention, increased aerobic fitness, improved self-efficacy, improved cognitive processes of executive function and behavior change that potentially contributes to improved science motivation and science achievement.
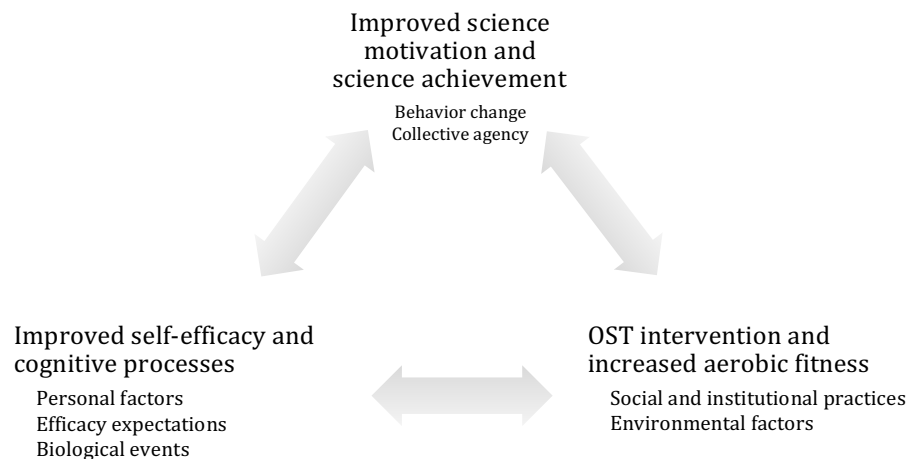
Figure 2. Triadic reciprocality in social cognitive theory: A causal model of student self-motivation in science (adapted from Bandura, 2001, 2006).

Socioeconomic status and family structure affect behavior by impacting aspirations, self-efficacy and personal standards, which for youth are largely modeled by parental and family influences (Bandura, 2001). In general, people will choose what challenges to undertake, how much effort to expend, and how long to persevere in the face of adversity and failures depending on their beliefs about whether or not they can produce those outcomes. Good self-regulators with positive social influences expand their knowledge and cognitive competencies while those with poor self-regulation fall behind. Biological processes that include self-regulatory skills involve constructing and evaluating alternative courses of action, goal setting, and inhibition of an immediate response while problem solving (Bandura, 2006).

1.6   OST Program Impacts

Informal OST programs have helped increase students' sense of self-efficacy by providing environments in which students have cultivated skills, increased feelings of competence, and experienced success (Dierking, 2007; McClure & Rodriguez, 2007). Participation in extra-curricular activities has been highly correlated with school success, including increased attendance, academic achievement, college aspirations and participation in athletics linked to an increase in girls' self-esteem, body image, competence and confidence (Hanson & Kraus, 1998; Miller, 2003; Women's Sports Foundation, 1998; Zill, Nord, & Loomis, 1995).

After school programs have played a key role in engaging youth in the learning process by providing opportunities to explore interests, increase health and wellness, gain competency in real world skills, set goals, solve problems, develop a group identity with similarly engaged peers, connecting with adult role models, and becoming involved in community improvement (Miller, 2003). As a result, OST programs have made a difference in building the pre-requisites for learning, supporting not only science achievement but long term competence and success.

1.7   Research with Human Subjects

The Office of Research Compliance at Stony Brook University approved this study [#517450, CORIHS #2014-2476]. Parental permission and minor assent were obtained in accordance with 45 CFR 46 408.

Chapter 2

Effects of Aerobic Fitness on Executive Function and Science Achievement

2.1 Introduction

Recent reports have called for improved science engagement and performance for middle school children to expand the science, technology, engineering, and mathematics (STEM) pipeline (National Academy of Sciences, 2007; NRC, 2007). During these years, students go through dramatic physical, emotional, behavioral and cognitive changes, and gender differences in achievement and attitudes towards science widen (Jones et al., 2000). There has been a recent focus on synthesizing findings from cognitive psychology and science education research to develop innovative treatments and assessments to diminish the gap in science learning (NRC, 2007). This study explored how middle school girls' participation in an innovative physical fitness program impacted their science achievement and related cognitive performance.

Skills associated with the capacity to perform well in science are highly dependent upon abilities that fall under executive function (Latzman et al., 2010). *Executive function* is an umbrella term for higher order cognitive processes including working memory, inhibitory control, cognitive flexibility, and the ability to plan, monitor and carry out goal directed actions (Skogan et al., 2016). Executive function also includes behavioral action and multi-tasking (Etnier & Chang, 2009; Hillman et al., 2005). Science process skills associated with executive function involve the ability to understand and perform particular ways of observing, thinking, experimenting, problem solving, evaluating plausible explanations, validating conclusions, and storing newly acquired knowledge in long-term memory (American Association for the Advancement of Science [AAAS], 1993; Anderson, 1983). These processes complement the

self-evaluation of learning required for constructing scientific understandings (Schraw, Crippen & Hartley, 2006). Purposeful behavior initiated to reach a goal parallels the scientific discovery process and informed skepticism.

This study explores the impact of an afterschool fitness program on science learning and executive function for middle school, at-risk girls. At-risk was defined by this treatment program as having issues with low self-esteem, experiencing a sedentary lifestyle, and being overweight. Quality out-of-school time programs can make a difference in building the requisite skills needed for engagement in learning, self-efficacy, goals, actions, and persistence by providing environments in which students can increase competency while developing a positive sense of self (Dierking, 2007; Lauer et al., 2006; NRC, 2015). Participation in these programs has provided opportunities for girls to develop generalized skills and personal resources that transfer to other realms of success (Brotman & Moore, 2007).

The purpose of this study is to explore connections among physical activity, science achievement and cognitive processes. This study addresses the following overarching research question: What is the effect of an out-of-school time aerobic fitness program on the executive function and science achievement of at-risk middle school girls? In exploring this research question, the relationship of physical activity to cognitive mechanisms that influence science achievement may be identified.

2.2   Theoretical Framework

The theoretical framework of this study incorporates aspects of executive function associated with self-regulation, strategizing, and science learning. Anderson (2002) proposed a model of executive function that stems from interdependent cognitive control processes that influence goal setting and information processing. Goal setting involves organizing actions to approach tasks

efficiently, while information processing refers to response speed related to the ability to cope with multidimensional switching tasks (Anderson, 2002). Mature cognitive control involves self-regulation or resisting inappropriate or automatic responses or behaviors, as well as adapting behavior to environmental changes (Davidson, Amso, Anderson & Diamond, 2006). Executive functions that fall within these self-regulatory behaviors include working memory and cognitive flexibility. Other researchers have identified behavioral regulation and cognitive control as executive processes that contribute to academic achievement and reasoning (Diamond & Lee, 2011).

Anderson (2002) further defined his model by identifying attentional control as the capacity to redirect automatic responses selectively and focus attention for long periods. Shift and inhibition are considered subdomains of attentional control; shift is the ability to navigate between tasks, and inhibition is the ability to suppress an automatic response in order to complete tasks (Friedman & Miyake, 2004; Miyake et al., 2000). Problem solving, planning, and goal directed actions represent complex executive functions that appear between the ages of seven and nine and continue to develop throughout adolescence (Thomas, Reeve, Frederickson & Maruff, 2011). These are aspects of critical thinking skills necessary for science learning, often occurring through inquiry and collaboration (Schraw et al., 2006).

Previous factor analyses suggested that executive function consists of three separate yet interrelated domains related to these cognitive processes and their contribution to science achievement (Latzman et al., 2010; Miyake et al., 2000). These domains – inhibition, monitoring, and cognitive control – are summarized in Figure 3. Latzman et al. (2010) were among the first to examine the direct relationship between executive functioning and academic achievement that included science with male adolescents. Science knowledge and skills were

assessed by measuring topics within life, Earth and physical sciences with emphasis on the process of science. Results indicated that cognitive flexibility was related to science with process skills requiring shift and flexibility with new information. Inhibition skills also predicted performance in mathematics and science. Monitoring, defined as "evaluating information in working memory" (Latzman et al., 2010, p. 456), predicted achievement in reading and social studies. Monitoring parallels *metacognition*, or knowledge about one's cognition and learning process (Flavell, 1979; Georghiades, 2004). Latzman et al. (2010) encouraged future research to explore the relationship between inhibition and science, postulating that inhibiting one's conclusions until all steps of structured problem solving have been conducted improves science learning and habits of mind. This study builds upon their work to explore the impacts of a physical activity treatment on a broader array of executive functions related to science achievement in female adolescents. Understanding the relationship between executive functioning and science achievement in diverse populations is an important step in designing innovative interventions to improve fitness, cognition, and science achievement for all.
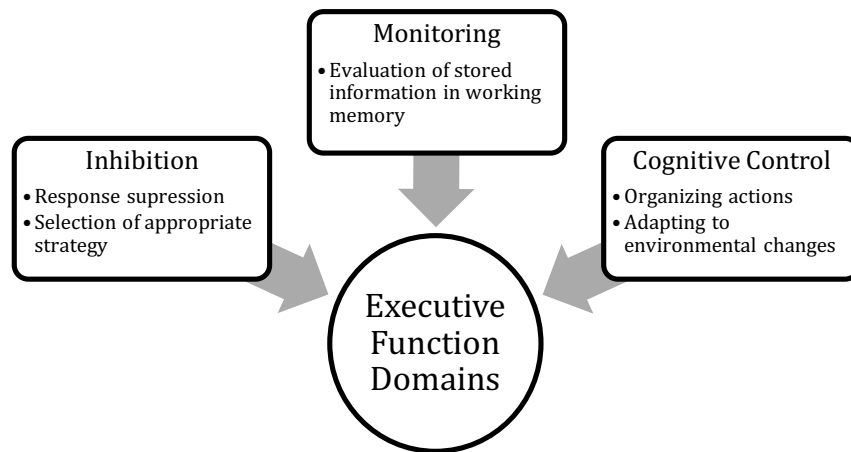
Figure 3. Proposed model of executive function components that impact science achievement.

2.3   Executive Function Hypothesis

The *executive function hypothesis* predicts that the largest improvements in cognition due to exercise will be on executive brain functions (Davis et al., 2007). There is evidence that executive function develops throughout adolescence suggesting that physical activity might be particularly beneficial for this age group. Davis et al. (2007) reported that adolescents who participated in a 15-week physical activity program experienced significant improvements in executive function. Other research has shown that higher levels of aerobic fitness have been associated with increased attention span, concentration, and improved memory (Gallotta et al., 2012; Serrian et al., 2007; Smith et al., 2010). Studies done with fit children reported enhanced cognitive performance, including higher working speed, increased attention span and concentration with vigorous aerobic activity (Brisswalter, Collardeau, & Rene, 2002; Budde, Voelcker-Rehage & PietraByk-Kendziorra, 2008; Chomitz et al., 2009), in contrast with a few studies targeted at lower, less intense levels of physical exertion that did not show significant improvement (Coe, Pivarnik, Womack, Reeves & Malina, 2006; Etnier et al., 2006).

Detecting the effects of exercise on cognition may depend on the particular cognitive function being assessed through selected outcome measures. One limitation of previous literature was that few studies assessed physical fitness as a predictor of cognitive performance and science achievement (Aberg et al., 2009; Davis et al., 2007; Gearin & Fien, 2016). Also, the majority of previous research focused on the effects of acute bouts of aerobic exercise on cognitive processes in adolescents (Best, 2010; Ellemberg & St-Louis-Deschenes, 2010; Hillman et al., 2009; Vazou & Smiley-Oyen, 2014). Research examining chronic physical activity on attention tasks in pre-adolescent children has suggested improved cognitive performance and warrants further study (Hillman et al., 2009; Hillman et al., 2014).

2.4   Cognition in Science Learning

Assessing how exercise influences children's neurocognitive development may prove to be an important mediator towards understanding the role an active lifestyle plays in science learning (Tomporowski et al., 2008). In science, students' beliefs about their abilities in different science tasks, courses and activities affect the effort they expend on those activities, the perseverance they show after encountering difficulties, and the ultimate success they experience in science (Britner & Pajares, 2006). Self-regulation, the monitoring of a student's pattern of behavior and the environmental conditions under which it occurs, gives rise to actions. Goal setting lends direction to personal pursuit and this type of self-regulating behavior and sustains the attention demands required to achieve objectives. Goals must be challenging in order to provide a good incentive for behavior change and achievement may be dependent on how far in the future they are projected.

Networks of interneurons mediate cognitive processes with a dynamic interplay between perception, organization, and a reconstruction of situated knowledge into existing frameworks (Anderson, 1997). Feedback mechanisms enable self-regulation via the executive functions of monitoring, inhibition, and conceptual flexibility (Latzman et al., 2010). Research has established that physical activity improves these aspects of cognition, but more work is needed to relate cognition to academic achievement in specific domains (Gearin & Fien, 2016). It was hypothesized that this intervention with an aerobic fitness component would improve cognitive processes and science achievement in middle school girls. Evaluation of executive function with appropriate age-based cognitive tests may provide understanding of how chronic aerobic exercise intervention influence brain development and processing, and, consequently, science performance.

2.5   Research Design

The study employed a quasi-experimental research design with a sample of adolescent girls who elected to participate in the treatment, as well as a control group of adolescent girls with similar backgrounds. The participants ($n = 29$) met with the program facilitators three times per week from March through July. The purposive sampled matched comparison group ($n = 30$) completed the same physical activity, science achievement, and cognition instruments. The early springtime data collection ensured that the students were at a similar level of science learning within the same middle grade levels. All districts involved had standardized curricula for each grade in compliance with the *New York State Intermediate Level Science Core Curriculum* (NYSED, 2014). There were 59 students (age, 12.5 ± 0.9 yr) who completed pre- and post-assessments. A priori analysis indicated that a sample of 53 students would be necessary to detect medium to large effects with 80% power, using linear regression with 95% confidence (Cohen, 1988; Faul, Erdfelder, Buchner & Lang, 2009). Participant demographics and physical characteristics were compiled during the baseline assessment phase (Table 2). The Physical Activity Questionnaire score (PAQ-C) indicated their self-reported fitness levels at the start of the program (Crocker, Eklund, & Kowalski, 2000). Treatment participants reported higher weight than the control group, consistent with the program's intent of targeting girls who would benefit from increased fitness.

Table 2

Participant Characteristics

Characteristic	Control Mean (SE)	Intervention Mean (SE)
Age (yr.)	12.93 (0.17)	12.03 (0.14)
Weight (kg)	52.47 (1.9)	56.92 (2.7)
Height (m)	1.56 (0.14)	1.54 (0.11)
PAQ-C Activity Score	2.58 (0.12)	2.26 (0.11)
Ethnicity	***n* (%)**	***n* (%)**
Caucasian	19 (63)	16 (55)
Black	2 (7)	5 (17)
Hispanic	9 (30)	8 (28)

Context and treatment. The program was founded in 2010 as a pilot for at-risk middle school girls, with at-risk defined as having issues with low self-esteem, sedentary lifestyle, and being overweight or obese. Eligible participants were selected by a combination of program coordinators, social workers, middle school teachers, instructional support teams, and nurses in identifying females struggling socially and/or academically in grades six through eight. The program combined physiology education and physical activities such as triathlon training and yoga three times per week for 20 weeks. The fitness component of the program culminated with a timed sprint triathlon (300-yard swim, 7-mile bike ride and 1.5-mile run). The girls were required to set goals, plan physical activities to meet these goals, and self-regulate to meet the established benchmarks.

Science achievement assessment. Science achievement was measured using a 15-question pre/post multiple-choice assessment developed for middle school students from Project 2061 (AAAS, 2014). These assessment items were expertly reviewed to identify specific knowledge and skills required to complete each task. Test items were not targeted towards informal nutritional science to better compare science achievement between the groups since the control group was not exposed to the informal science lessons. Fifteen questions were selected to

measure middle school students' science conceptual understandings and process skills (Appendix A), which were aligned with the *New York State Intermediate Level Science Curriculum* (NYSED, 2014). Topics were selected from physical, Earth, and life sciences and were consistent with the science curricula learned by both treatment and control groups in their schools. Student scores were based on percentage correct. Bivariate Pearson correlations revealed significant moderate to strong positive relationships between the control, intervention, and normative samples (Table 3). An independent samples *t*-test was conducted to compare science pre-test scores between groups. Scores were normally distributed. There was no significant difference in pre-test science knowledge scores between the control ($M = 55.23$, $SD = 18.52$) and intervention ($M = 56.09$, $SD = 21.86$) groups; $t(57) = -.16$, $p = .87$. Responses demonstrated adequate measured reliability ($\alpha = 0.74$). The Rasch person reliability was 0.72 and item reliability was 0.92, MNSQ = 1.0 ($SD = 0.18$), indicating good person and item fit as measures of science achievement (Bode & Wright, 1999). Questions, corresponding standards, and scores for treatment, control, and national normative sample groups are indicated in Table 4.

Table 3

Correlations Between Control, Intervention and Normative Samples for Science Assessment

Paired Groups	n	r
C-pre and NS	15	.911**
I-pre and NS	15	.697**
C-pre and I-pre	15	.762**
C-post and NS	15	.753**
I-post and NS	15	.827**
C-post and I-post	15	.878**

** $p < .001$

Table 4

Science Assessment Items, Science Standards, and Project 2061: Topic and Normative, Control and Intervention Group Percentage Correct

Question	NYS Standards	Project 2061 Topics	Norm Sample	Control Pre-Test	Control Post-Test	Treatment Pre-Test	Treatment Post-Test
1	Std 4 PS: KI 3,	atoms, molecules,	57	53	67	55	79
2	PI3.1, 3.3a,c,f	states of matter	53	50	40	55	48
3	Std 4 PS: KI 1,	weather, climate	29	30	50	45	45
4	PI 1.1c,e,j,h,i		36	40	47	35	48
5	Std 1, GPS 8	variable control	63	63	67	35	62
6	Std 4 LE: KI 3,	evolution, natural	62	70	80	69	76
7	PI 3.1b, 3.2b	selection	74	80	83	83	93
8	Std 4 PS: K I5, PI 5.1a-d, GPS 16	force, motion	42	30	30	21	45
9	Std 4 LE: KI 6,7 PI 6.1 a-c, 7.2 a LE Process Skill 7	ecosystem interdependence	84	87	90	72	90
10	Std 4 LE: KI 5, PI 5.1d, 5.2 a; KI 6, PI 6.1c; Std 4 PS: KI 4, PI 4.1c	matter and energy of living systems	60	63	67	66	69
11	Std 1, S1.2, S3.2f; T1.3b, T1.5b; Std 4 PS: KI 6, PI 2.1; KI 4, PI 4.1a,c; 4.3a, 4.5a	models	43	37	27	42	52
12	Std 4 LE: KI 6, PI 6.1a	energy forms, transformation	65	63	73	76	90
13	Std 4 PS: KI 2, PI 2.2i	weather, climate basic elements	58	57	43	73	59
14	Std 4 PS: KI 2, PI 2.1 h,i	weather, erosion, deposition	68	53	57	55	62
15	Std 4 PS: KI 3, PI 3.1a, 3.3d	chemical reactions, matter conservation	58	57	43	62	62

Key: KI = Key Idea; PI = Performance Indicator; LE = Living Environment; PS = Physical Science; GPS = General Process Skill

Measurement of cognitive processes: Behavior Rating Inventory of Executive Functioning (BRIEF). Executive functioning (EF) involves both cognitive and behavioral elements. The purpose of the BRIEF Parent related scales questionnaire (Gioia, Isquith, Guy & Kenworthy, 2000) is for parents to assess EF in their children aged 5-18. In responding to 86 items, parents were instructed to rate how often their child had a problem with specific behaviors over the prior six months. Each item was coded as one for never, two for sometimes and three for

often, for a maximum global index score of 219. Higher scores on any of the constructs indicated

an increase in problem behavior with lower scores indicating normal to improved EF, therefore

an inverse relationship between science performance and EF measures was expected. Informant

report was used because research suggested that self-report of cognitive ability is only weakly

related to neuropsychological test performance (Burgess, Alderman, Evans, Emslie, & Wilson,

1998).

Parent rating of EF has been shown to be a good predictor of youth functioning in academic,

social, behavioral and emotional domains (Isquith, Gioia, Guy, & Kenworthy, 2015). Parents

observed their children's behaviors and problem solving skills and offered insights that could not

be observed by an independent investigator. Each pre-/post-questionnaire contained items in

eight overlapping EF scales that were broken into four indices: inhibitory self-control index

(ISCI), metacognition index (MCI), emotional regulation index (ERI) and the cognitive

regulation index (CRI). Isquith et al., (2015) defined the ISCI as the ability to modulate actions,

responses, emotions, and behavior via inhibitory control that is fundamental to metacognition

and problem solving. An example item for inhibitory self-control is: "*Has trouble putting the*

brakes on his/her actions." ISCI was calculated by adding the inhibition and emotional control

scales. ERI measures the ability to regulate emotional responses, shift, and adjust to

environmental changes. ERI was calculated by the sum of shift and emotional control scales.

MCI represents the ability to initiate, plan, implement, and sustain strategies. A sample item is:

"*When given three things to do, only remembers the first or last.*" MCI was calculated by the

sum of working memory and plan/organize scales. CRI reflects the ability to control and manage

cognitive processes and solve problems. CRI was obtained by the sum of the scales of planning,

initiation, working memory, monitoring, and organization. Isquith et al. (2015) related CRI to the

ability to solve problems in a variety of contexts and complete tasks such as schoolwork. A

sample item is: "*Has trouble carrying out the actions needed to reach goals (saving money for a*

special item, studying to get a good grade)." Table 5 highlights each of the eight scales with the

constructs they were intended to measure. Responses demonstrated high measured reliability (α

= 0.97). Rasch analysis of the BRIEF revealed that it performed well as a measure of cognition

with a Rasch person reliability of 0.96 and item reliability of .90, MNSQ = .98 (*SD* = .23).

Table 5

Subcomponents of Executive Function as Measured by the BRIEF

EF Subcomponent	Construct Measured
Inhibition	Inhibitory control and impulsivity.
Shift	The ability to make transitions, tolerate change, problem solve flexibly, switch or alternate attention between tasks and change focus.
Emotional Control	Emotional expression to assess ability to regulate emotional response.
Initiate	Ability to begin a task and to independently generate ideas, responses, or problem solving strategies.
Working Memory	Capacity to hold information in mind for the purpose of completing a task, generating goals, plans, and sequential steps to achieve those goals.
Planning/Organize	Ability to manage current and future oriented tasks or activities, anticipate future events, set goals, develop sequential steps to carry out a task. Organize refers to the ability to order information, recognize key concepts when learning and communicate information.
Organize Materials	Measures orderliness of work, play, and storage spaces such as lockers, backpacks, and bedrooms.
Monitor	Assesses work checking habits and whether performance assessment is occurring on his or her own during or shortly after completing a task to ensure accuracy and goal attainment.

Parent-reported observations of EF related behavior in the BRIEF were log transformed to

normalize the distribution. Variable normality was then confirmed by inspecting histograms and

probability plots. An exploratory factor analysis with Varimax rotation for EF domains was

conducted to identify factor loadings. The principal components analysis revealed three factors,

accounting for 85% of the variance (Table 6). Factor 1 included aspects of ISCI and MCI; factor

2 was closely related to ERI; and factor 3, CRI. The loadings support previous research that

suggested EF is comprised of multiple factors rather than a single unitary factor (Anderson, 2002; Latzman et al., 2010; Miyake et al., 2000).

Table 6

Factor Loadings for the Principle Components Analysis of the BRIEF

	Component		
	1	2	3
Planning/Organization	.875	.255	.224
Inhibition	.872	.250	.106
Monitor	.640	.242	.596
Working Memory	.608	.339	.572
Shift	.323	.893	.060
Emotional Control	.199	.851	.320
Organize Materials	.111	.108	.922
Initiate	.371	.520	.609

Independent samples t-tests were conducted for EF measures to determine statistical significance when comparing the independent groups. Significant differences were observed for inhibitory self-control (ISCI), $t(54) = 2.18$, $p = .03$, 95% CI [0.39,9.58]; metacognition (MCI), $t(54) = 2.86$, $p = .006$, 95% CI [2.26,12.88]; and cognitive regulation (CRI), $t(54) = 2.27$, $p = .03$, 95% CI [1.27,20.53]. The emotional regulation index (ERI) was not significant when comparing groups, $t(54) = -.40$, $p = .69$, 95% CI [-.06,.05], and was eliminated from inclusion in multivariable analysis.

Measurement of physical fitness: Physical Activity Questionnaire for Children (PAQ-C). A measure of physical activity was employed to assess whether the control and treatment groups had differences at the start of the program. The PAQ-C has been used successfully in longitudinal research to measure children's general physical activity levels from childhood through adolescence (Crocker et al., 2000; Sirard & Pate, 2001). The PAQ-C summary score is

derived from nine items, each scored on a five-point scale with "no activity" coded as a one and "seven times or more" coded as a five. In a comparison of means between groups with normally distributed scores, a one way ANOVA revealed a significant difference in PAQ-C between treatment and control groups $F(1,57) = 4.18$, $p < .05$. Homogeneity of variance was tested and was not significant. Means and standard deviations for the groups are reported in Table 2 with the intervention group scoring slightly lower in regular physical activity; this was expected from a group classified as at-risk and established that the treatment girls were less active than the control group before the intervention.

Statistical analyses. Several inferential techniques were employed to measure program outcomes. Independent samples t-tests were performed to compare the post-test scores on the science assessment for the treatment, control, and normative sample groups. Analysis of covariance (ANCOVA) was conducted to determine the effect of the intervention on science achievement, with science pre-test as the covariate and group as the fixed factor. A multivariate analysis of covariance (MANCOVA) was conducted to determine the individual and multivariate effects of the treatment on EF index and science achievement, with science pre-test as the covariate and group as the fixed factor. ANCOVA and MANCOVA were chosen to reject the null hypothesis that there was no significant difference between the intervention and the control groups on science achievement and measures of cognition while controlling for science pre-test.

A Roy-Bargmann stepdown analysis was performed to examine the univariate significance of each dependent variable in the MANCOVA listed in a prioritized order. This procedure was selected to illuminate group differences among response variables in a hierarchical structure, so variables might be evaluated in order of importance. This allows for a more nuanced interpretation of the MANCOVA results. In stepdown analysis, the highest priority dependent

variable (science achievement) was tested through ANOVA and was then used as a covariate for the next dependent variable. Each successive dependent variable was then used as a covariate for the next dependent variable until all variance that contributed to significance was extracted (Tabachnick & Fidell, 2007). Prioritized dependent variables were based on the theoretical framework where the proposed model of EF stems from cognitive processes that contribute to science achievement (Latzman et al., 2010; Anderson, 2002; Miyake et al., 2000). Science achievement was the highest priority dependent variable, followed by cognitive regulation as it contributes to academic achievement and reasoning by way of the third dependent variable, metacognition. The final dependent variable was inhibition. This model was utilized to highlight the individual contributions of the dependent variables to the significance of the treatment.

Limitations. A limitation of this research was that observational fitness data were not used. Self-reported physical activity data were used as a proxy for fitness to test for group differences at the start of the program. Although there were different levels of physical activity at the start, post-treatment fitness measures were not available for both groups. The treatment participants were much more physically active at the conclusion of the program since they shifted their sedentary lifestyles to the new demands of triathlon training. Due to the intensive nature of the fitness measures (i.e., running, biking, swimming), it was difficult to collect these data on the control group. We assumed the control group would not change their physical activity significantly during the 20-week duration. It should also be noted that this study did not include assessment of motivation for science learning or exercise. A separate research analysis will investigate intrinsic and extrinsic motivation and related constructs to understand the potential for improved fitness, cognition, and attitudes towards science. Additionally, the young women who participated self-selected for this program. Randomized trials using chronic aerobic exercise

training in adolescents are needed with larger sample sizes and more specific measures associated with executive function. Our research is a first step in contributing to increased understanding of the effects of physical fitness through the mechanisms of inhibition, metacognition, and cognitive regulation on science performance.

2.6   Results

Demographic and anthropometric variables were similar in the control and intervention group with respect to height, weight, and ethnicity, though the treatment group was slightly younger (Table 2). To test the effects of the intervention as it related to science achievement, two initial steps were taken. First, independent-samples t-tests compared the post-test science scores and revealed significant differences for: 1) the treatment ($M = 65.33$, $SD = 16.85$) and control groups ($M = 57.60$, $SD = 19.46$, $t(14) = 3.14$, $p = .007$, 95% CI [2.4, 12.6], $d = .43$; and 2) the normative sample ($M = 56.80$, $SD = 14.48$) and treatment groups $(M = 65.33$, $SD = 16.85)$, $t(14) = 3.48$, $p = .004$, 95% CI [3.5, 13.8], $d = .54$. These results suggest that the intervention contributed to an increase in post-test percentage correct for each item on the science assessment. Secondly, ANCOVA was conducted with group as the fixed factor, and science achievement as the dependent variable while controlling for the science pre-test. Homogeneity of variance was tested and was not significant. There was a significant effect by group with a medium effect size (Cohen, 1988) accounting for 26% of the variance, $F(1,54) = 7.67$, $p < .01$, adjusted $R^2 = .26$, $\eta_p^2 = .08$.

To test the effect of the intervention on index measures of cognition as they relate to science achievement, a MANCOVA was conducted with group as the fixed factor, and science achievement post-test scores, inhibitory self-control (ISCI), metacognition (MCI), and cognitive regulation (CRI) indexes as dependent variables while controlling for the science pre-test. The

assumption of homogeneity of variance was met by Levene's test. There was a significant

multivariate effect by group on cognition measures and science achievement, $F(4,50) = 3.75$, p

$= .01$. The adjusted R^2 for the overall model was 0.24, indicating moderate accounting for the

variance in science performance and executive function. There was a significant main effect by

group on science achievement, $F(1,53) = 4.84$, $p < .05$, $\eta_p^2 = .08$, and a significant effect for

inhibitory self-control, $F(1,53) = 4.59$, $p < .05$, $\eta_p^2 = .08$. Metacognition showed significant

improvement in the intervention group, $F(1,53) = 7.97$, $p < .01$, $\eta_p^2 = .13$. Cognitive regulation

was statistically significant for group, $F(1,53) = 5.01$, $p < .05$, $\eta_p^2 = .09$.

ANCOVA was used after MANCOVA in Roy-Bargmann stepdown analysis to examine the

contributions of dependent variables across groups (Tabachnick & Fidell, 2007). To test the null

hypothesis that there was no effect across groups when the dependent variables were listed in a

specific order, science achievement was given the highest priority, followed by cognitive

regulation (CRI), metacognition (MCI), and inhibition (ISCI) as the final priority; this was based

on the theoretical framework that executive function consists of three separate yet interrelated

domains that contribute to science achievement. Homogeneity of regression was acceptable and

the dependent variables were reliable covariates. Three dependent variables, science

achievement, cognitive regulation and metacognition, made unique contributions to the

composite dependent variable that distinguished between groups (Table 7). After adjusting for

differences in covariates, science achievement had a significant difference by group stepdown

$F(1,54) = 4.62$, $p < .05$. With differences due to science achievement already entered, cognitive

regulation made a significant contribution by treatment group, stepdown $F(1,53) = 4.99$, $p < .05$.

Metacognition, adjusted by science achievement and cognitive regulation also made a unique

contribution to the composite dependent variable, stepdown $F(1,52) = 4.46$, $p < .05$. Univariate

analysis revealed that inhibition did not make a significant contribution, stepdown $F(1,51) = .10$, $p = .75$.

Table 7

Relationships among Executive Function Constructs

EF	1	2	3	4	5	6	7	8
1. Inhibition	1							
2. Shift	.53**	1						
3. Emotional Control	.49**	.76**	1					
4. Initiate	.48**	.60**	.60**	1				
5. Working Memory	.64**	.54**	.54**	.70**	1			
6. Plan/Organize	.77**	.55**	.42**	.61**	.75**	1		
7. Organize Materials	.31*	.20	.36**	.55**	.50**	.31*	1	
8. Monitor	.64**	.48**	.48**	.68**	.76**	.69**	.57**	1

*$p < .05$, **$p < .01$

2.7   Discussion

The present study suggests science achievement and components of executive functioning were significantly improved for at-risk students who participated in the aerobic fitness intervention. Multiple comparisons showed that the intervention group of adolescent middle school girls demonstrated statistically higher science achievement, with a moderate to strong effect. Inhibitory self-control, metacognition, and cognitive regulation were significantly improved compared to the control; data revealed medium effect sizes for inhibitory control and cognitive regulation, and a large effect size for metacognition. MANCOVA revealed that 24% of the variance in cognition and science achievement between the control and experimental groups could be accounted for by the treatment. These data support the use of physical activity interventions to improve aspects of executive function, which may also be related to improvements in science achievement.

Significant lower scores on the post-BRIEF survey suggested improved behavior and executive functioning for the intervention group. They had higher science achievement and

improved cognitive regulation and metacognition, supporting the model whereby mutually dependent executive function domains influence cognitive control and strategizing to meet goals. The results provide evidence that the treatment is a promising innovation for young, at-risk girls to improve science learning along with associated cognitive processes. The relationship between executive function and science proficiency is supported by mutually reinforcing domains, including the self-regulation and problem solving that lead to scientific procedural competence.

While the multivariate analysis revealed a significant finding for inhibition, further analysis is needed to determine the specific contributions of inhibition to science achievement. In the stepdown analysis, the effects of criteria variables were examined. If previous steps extracted all variance that contributed to significance, later steps would show no further differences. Since the ISCI was composed of inhibition and emotional control indices, it may be necessary to examine them separately with additional measures, independent of the moderate to large effects found with cognitive regulation and metacognition. Although Latzman et al. (2010) found inhibition to be related to science achievement, they did not explore its impact in a hierarchical model. Inhibition may be important in formulating scientific conclusions after all evidence is evaluated. However, metacognition and cognitive regulation may supersede inhibition in terms of foundational importance in the scientific method. The emotional regulation index, comprised of shift and emotional control composites from the BRIEF, was not significantly changed. It may be necessary to measure shift with time dependent processing tasks and emotional control in a qualitative manner in order to determine changes in ERI.

A particularly interesting finding was the large effect size for metacognition as it relates to science achievement. The improved MCI demonstrates the long-term effects of physical activity on working memory, contradicting earlier inconclusive findings (Smith et al., 2010). Research

has suggested that the relationship between physical activity and cognitive control is reciprocal (Buckley, Cohen, Kramer, McAuley, & Mullen, 2014). Our findings expand upon this work by providing evidence that chronic physical activity can enhance cognitive control abilities including increased attention span, concentration and improved memory. These improvements enable individuals to maintain the control necessary to inhibit automatic responses, adapt behavior to new and challenging demands, and maintain goal-directed behavior, ultimately leading to self-regulation for improving academic success. These cognitive functions contribute to the critical thinking skills necessary for making scientific inferences about the natural world. Improved self-efficacy in fitness tasks may lead to more confidence in academic domains. Consequently, these impacts have implications for narrowing the achievement gap in science and promoting STEM aspirations early in the lives of at-risk young women.

In the present study, adolescent girls set goals and planned for performance training for a youth triathlon. These efforts required them to hold new information in working memory while changing previously sedentary lifestyles. These findings support a recent study by van der Niet et al. (2015) where boys and girls aged 8-12 in a physical activity intervention demonstrated better performance on inhibition and working memory tasks than children in the control group. The authors suggested that participation in the physical activity intervention required the children to hold information in working memory while inhibiting interference information, which may have led to improvements in working memory and inhibition. Our findings concur with and add to the research knowledge base by examining the effects of a chronic aerobic exercise intervention on science achievement. The results suggest the treatment group participation had significant effects on science performance and cognition and provide evidence for the importance of aerobic

exercise and physical activity in improving specific cognitive processes that support science learning.

2.8   Conclusions and Implications

Afterschool informal aerobic fitness programs can play a key role in engaging youth in science by providing opportunities to explore interests, improve health, set goals, and solve problems. In addition, advances in the understanding of brain development and mechanisms of learning have substantial implications for science education. Since executive function develops with increasing age, physical activity may be particularly beneficial for a student's ability to reason, solve problems, and learn new concepts. This fitness intervention may be easily modified to scale up mechanisms for increasing the amount of physical activity outside of the school day. This might include a recommended minimum threshold for physical fitness training during the academic year, broader opportunities for triathlon training for middle school students, and more fitness activities geared towards holistic wellness to promote lifestyle shifts. Middle school children's executive functions, including planning and carrying out goal directed actions, require self-regulation, inhibition, holding information in memory and increased cognitive control to plan for and carry out goal directed actions. Executive functions may be more sensitive to changes in physical activity supporting the executive function hypothesis with increased aerobic activity contributing towards improved select cognitive processes and science achievement. The stimulation of physical activity holds tremendous promise for improving executive function and achievement in related academic domains such as science.

Self-esteem, school achievement, attitudes, and motivation, particularly for girls, often decline in the middle school years. Advances in the understanding of brain development and mechanisms of learning have substantial implications for academic achievement. Evaluation of

executive function with appropriate age-based cognitive tests may provide a more reliable understanding of how chronic aerobic exercise interventions influence brain development and processing skills related to science achievement. Furthermore, different levels of physical fitness may have varying effects on cognitive and academic outcomes. Future research is needed to explore the impact of dose response as well as causal mechanisms.

The treatment program in the present study promoted student learning and has particular promise for at-risk female students. Planning for goal accomplishment, the evaluation of alternatives, and revision of hypotheses so they are consistent with new information are skills foundational to scientific reasoning and habits of mind. Exposure to out-of-school time programs can help children find meaning in what they learn in school, develop interests in STEM, and build competence. Engaging in reflection, planning, teamwork, decision-making, and communication with peers can positively influence adolescent development by improved cognitive processes, executive function, and ultimately interest in science coursework and careers.

Chapter 3

Dose Response Effect of Physical Activity on Executive Function and Science Achievement

3.1   Introduction

The many health benefits of physical activity (PA) include improved cardiovascular fitness, higher muscular strength, bone density, and lower adiposity, yet less is known about the relationship between PA, brain cognition, and academic achievement (Scudder et al., 2014; Smith et al., 2010; Trost, Rosenkrantz, & Dzewaltowski, 2008). Despite the positive effects of regular PA, only one quarter of U.S. youth ages 6 – 15 meet the *Physical Activity Guidelines for Americans* recommendation of at least 60 minutes of moderate and/or vigorous physical activity (MVPA) per day (Fakhouri et al., 2012; U.S. Department of Health and Human Services, 2008). Less than half of U.S. female youth participate in organized sports and even fewer underrepresented female youth do so (Eaton et al., 2012), with reported activity levels dropping by as much as 50% during adolescence (Kimm et al., 2002). Research has indicated a relationship between MVPA and structure and functioning of the brain (Chaddock, Pontifex, Hillman, & Kramer, 2011; Voelcker-Rehage & Niemann, 2013) but gaps remain in the knowledge base about the varying doses, frequency, timing, and types of physical activity that promote cognitive development and academic performance.

Students' increased physical fitness reflects better overall health, and some studies have shown it contributes to improved cognition, processing speed, and academic achievement (Chomitz et al., 2009). In particular, science educators have examined a wide range of factors that influence science performance, which include cognition-related variables such as behavioral

control and inhibition (Latzman et al., 2010; Pajares, Britner, & Valiante, 2000). Science process skills involve the ability to understand and perform particular ways of observing, thinking, experimenting, problem solving and validating conclusions (AAAS, 1989). Students must exercise behavioral control when applying the scientific method, since they must refrain from making judgments until evaluating all evidence (Pajares et al., 2000). Self-regulation in science learning also involves goal setting, strategy, knowledge integration, and monitoring progress towards goals (Schraw et al., 2006). An active after school program that involves observing peer and adult role models, setting small and large goals to complete a youth triathlon, predicting, making discoveries, communicating ideas, and working as a team to make healthy choices and adhere to exercise, is practicing the process of doing science, albeit informally.

In order to explore the relationship between fitness, cognition, and science learning, the following overarching research questions were addressed: 1) How does improved physical fitness affect cognition and science achievement for at-risk middle school girls?; and 2) How does physical activity dosage moderate the effect of cognition on science achievement? The alternative hypothesis is proposed that faster processing speed and improved behavior regulation and physical activity, influenced by a fitness intervention, significantly predict science achievement in middle school girls. Secondly, it is hypothesized that the level of physical activity moderates the effect of cognition on science achievement.

The majority of research addressing the effects of physical activity on cognition and academic achievement tends to include large scale studies examining physical education programs or physical activity measured via accelerometers (Coe et al., 2006; Grissom, 2005; Hansen, Herrmann, Lambourne, Lee, & Donnelly, 2014) vs. studies that targeted vigorous aerobic exercise interventions on specific cognitive functions in small groups of children (Davis

et al., 2007; van der Niet et al., 2014; Vazou & Smiley-Oyen, 2014). In the limited studies that used self-report methods to measure PA, the dose-response relationship indicated individuals who were more fit also performed better cognitively (Aberg et al., 2009; Etnier et al., 2006). Dose response effect is defined as the volume of physical activity reported by the participants characterized by a pattern of little to no effect for low doses and greater effect at higher doses of physical activity (Lee & Skerrett, 2001). Increased physical activity in youth has been shown to have positive outcomes on improved cognitive processes and exercise-related changes in brain structure (Dishman et al., 2006; Erikson et al., 2011; Thomas et al., 2011).

Exercise related changes in children's brain function with increased physical activity may produce greater changes in children's brain function than those observed in adults (Hillman et al., 2005). Assessing how exercise influences children's neurocognitive development may prove to be a simple but important mediator towards understanding the role an active lifestyle plays in science learning (Tomporowski et al., 2008). The mechanism regarding increased neurogenesis and hippocampal volume is not completely understood but there is evidence that aerobic exercise may be associated with physiological events that impact cognitive performance (Etnier et al., 2006; Hillman et al., 2008; van der Niet et al., 2016; Vazou & Smiley-Oyen, 2014). To address this gap in the literature, evaluation of executive function with appropriate age based cognitive tests may provide a more reliable understanding of how habitual PA influences brain development and processing, and, consequently, science achievement. Given that executive function is an umbrella term for higher order cognitive processes including working memory, shifting attention, initiating goal directed action, and inhibiting pluripotent responses, its measurement can be challenging (Daly & Allan, 2015). Researchers measuring the effect of

fitness on cognition have been encouraged to include multiple measures to focus on specific executive tasks (Etnier & Chang, 2009; Miyake et al., 2000).

An integrative approach of biological mechanisms towards informational processing provides a framework for increased academic performance and transfer of knowledge between different contexts (Anderson, 1997; Anderson et al., 2000). With the majority of previous research focusing on the effects of acute bouts of aerobic exercise on cognitive processes in youth and adolescents (Best, 2010; Ellemberg & St. Louis-Deschenes, 2010; Hillman et al., 2009; Vazou & Smiley-Oyen, 2014), this study is one of the first to examine the effects of a chronic aerobic exercise intervention on science achievement. The extracurricular nature of the treatment program provided flexibility in implementation in a supportive, nurturing environment. Participation in extra-curricular activities has been correlated with school success, including increased academic achievement and participation in athletics linked to an increase in girls' self-esteem, body image, and confidence (Hanson & Krauss, 1998; Miller, 2003; Zill et al., 1995).

3.2   Methods

Participants. Data were collected during the baseline and post-assessment phase of a 20-week after school community based intervention. The fitness treatment program was founded in 2010 as a pilot program for at-risk middle school girls. Program and school personnel defined at-risk as girls as experiencing low self-esteem, a sedentary lifestyle, and classification as overweight. The intervention combined fitness, self-esteem building lessons, and nutrition and health science education twice per week from mid-March through June. After school activities such as triathlon specific training and yoga occurred immediately after the informal science lesson on those two days and one additional day on the weekend through July. The program culminated with a youth sprint triathlon (300 yard swim, 7 mile bike ride and 1.5 mile run).

Intervention participants completed a timed 1.5-mile run as an observed measure of cardiovascular endurance and aerobic power. Observed fitness levels were not measured for the control group due to logistical constraints dictated by the school district. However, the observed fitness data for the treatment group were retained to assess direct physical impacts. A paired samples *t*-test was conducted to determine significant changes in observed aerobic fitness measured by the 1.5-mile run 20 weeks apart for the intervention. Run times significantly improved pre-intervention (*M* = 1013.76, *SD* = 178.98) to post-intervention (*M* = 901.72, *SD* = 145.43), $t(28) = 5.61$, $p < .001$, 95% CI[71.14,152.93], *d* = .69. BMI did not change significantly from the start of the triathlon training program (*M* = 23.77, *SD* = 5.44) and the completion of the program (*M* = 24.33, *SD* = 5.78), $t(28) = -.95$, $p = .35$, 95% CI[-1.78,.66], consistent with female adolescents at the onset of puberty (Watts, Davis, & Green, 2005).

Of the 50 female middle school students in the intervention, 33 consented to participate in research and 29 completed the study. For the comparison group, a sample of 6th through 8th grade female students (*n* = 30) matched for pre-test science scores was selected. The early springtime data collection ensured that the students were at a similar level of learning within the same grades as the intervention group. All districts involved had similar curricula for each grade in compliance with the state mandated *Intermediate Science Curriculum* (NYSED, 2014). Participant demographic characteristics are provided in Table 8. Consistent with the recruitment strategy for the program, the intervention group was less physically active than the control group. This was evidenced by higher average weight and BMI and lower physical activity scores.

Table 8

Participant Characteristics

Characteristic	Control (*n* = 30) M(SD)	Intervention (*n* = 29) M(SD)
Age (yr.)	12.93 (0.91)	12.03 (0.73)
Weight (kg)	52.47 (10.51)	56.92 (14.66)
Height (m)	1.56 (0.75)	1.54 (0.07)
BMI (kg*m^{-2})	21.58 (3.39)	23.77 (5.44)
PAQ-C Activity Score	2.58 (0.63)	2.26 (0.58)
Science pre-test	55.23(18.52)	56.09(21.86)
Science post-test	57.77(21.45)	68.04(18.46)
TMT-B pre-test (s)	62.79(22.61)	52.77(23.34)
TMT-B post-test (s)	54.71(20.35)	42.11(15.44)
Behavior regulation pre-test	40.83(9.95)	42.83(10.62)
Behavior regulation post-test	40.84(8.18)	39.97(6.93)
Ethnicity	**N (%)**	**N (%)**
Caucasian	19 (63)	16 (55)
Black	2 (7)	5 (17)
Hispanic	9 (30)	8 (28)

Instruments.

Self-reported fitness level. Since observed aerobic data could not be collected for both

treatment and control groups, self-reported fitness data were collected. The Physical Activity

Questionnaire for Children (PAQ-C) (Kowalski, Crocker, & Donen, 2004) was used to assess the

physical activity levels of both the control and intervention groups at the start of the program;

this self-reported measure is typically given as a pre-assessment to assess habitual MVPA in

children older than nine. The first question provided an activity checklist of common sports,

physical activities and games. The next six questions assessed physical activity during physical

education class, lunch, recess, after school, evenings and weekends. Question eight asked

participants to choose one of five statements that best described physical activity for the past

seven days during their free time. The final question asked participants how often they played

sports, games, danced, or any other physical activity for each day of last week rating one as none

and five as very often. The questions were scored on a five-point scale with increased scores

indicating higher levels of physical activity. A summary score was calculated by averaging the scores of all nine questions. Cronbach's alpha (α = .79) for the PAQ-C revealed that it was a reliable measure of habitual MVPA. While this study observed physical activity by supervised training sessions in the intervention, this was not feasible for the control group. Self-reported measures of physical activity are inexpensive and convenient to administer as a means of estimating physical activity.

Science achievement. Science achievement was measured pre- and post-intervention for both groups using a 15-question pre/post multiple-choice assessment adapted for middle school students from the *American Association for the Advancement of Science Project 2061* (AAAS, 2014) (Appendix A). Questions were selected to assess middle school students' science conceptual understanding and process skills. A subset of questions was chosen with adequate reliability (α = 0.74). In congruence with the NRC Assessment Triangle (NRC, 2001), observations from a test based on questions that match ideas in the curriculum to specific learning goals accurately assess knowledge and skill. Assessment items were created by identifying critical knowledge and skills from key ideas of relevant content standards in *Benchmarks for Science Literacy* (AAAS, 1993) and in *National Science Education Standards* (NRC, 1996) appropriate for middle school students. Data were collected at the start and end of the twenty-week exercise intervention to assess growth in students' science content knowledge. A previous analysis with this sample revealed a significant improvement in science achievement for the intervention compared to the control group, using the science pre-test as a covariate (see Chapter 2).

Cognition. The Behavior Rating Inventory of Executive Function (BRIEF) Parent related

scales questionnaire was administered for parents to assess cognitive and behavioral elements of

executive function in their children aged 5-18 (Gioia et al., 2000). Informant report was used to

measure situated behavior since previous research suggested that self-report of cognitive ability

is only weakly related to neuropsychological test performance (Burgess et al., 1998). Each pre-

/post-questionnaire was administered to both groups and contained items measuring behavioral

regulation, which included the sum of the raw scores of inhibition of reflexive cognitive

responses, attentional shift, and emotional control ($\alpha = .97$). Respondents chose one of three

letter codes for each item, N for never, S for sometimes, O for often. Items were coded as a one

for never, two for sometimes, and three for often so that a decrease in scores would indicate

improved behavioral regulation. Sample items for the BRIEF included one item measuring

emotional control: "*Overreacts to small problem*;" one as an indicator for shift: "*Resists or has*

trouble accepting a different way to solve a problem with schoolwork, friends, chores, etc.;" and

one as an indicator for inhibition: "*Has trouble putting the brakes on his/her actions.*"

Trail Making Test. The Trail Making Test (TMT), with part B given to the treatment and

control groups at the start and finish of the program, is a commonly used neuropsychological test

of executive function that measures attentional set shifting and processing speed (Lezak, 1995).

Part B required that participants alternate the pencil lines of a number and letter in sequence

(e.g., 1-A-2-B-3-C...). Results for TMT-B were reported as numbers of seconds required to

complete the task and higher scores revealed increased processing time, an inverse relationship

with the desired outcome (Corrigan & Hinkeldy, 1987). Total time for the incongruent TMT-B

was used as a reliable processing measure ($\alpha = .79$).

3.3   Procedure

The impact of the treatment program was measured by collecting data on observed fitness level for the treatment group only; whereas, additional evidence is provided of self-reported fitness, science achievement, and cognition for both treatment and control groups. Based on data from a pilot study, a-priori power analysis indicated that a total sample of 53 students would be necessary to detect medium to large effects ($d = 0.5 - 0.8$) with 80% power using linear regression ($\alpha = .05$) (Faul et al., 2009). Data were collected pre- and post-intervention over two days at the start and end of the program, with the exception of self-reported fitness, which was only collected at the start of the program to assess habitual physical activity under normal conditions.

3.4   Data Analysis

Demographic and anthropometric variables were similar in the control and intervention group with respect to ethnicity, age, and BMI (Table 8, p. 42). Independent *t*-tests were conducted for questions one through nine of the PAQ-C to examine any potential group differences in reported environments for physical activity (Table 9). Bivariate Pearson correlations were conducted to determine significant variables that may have predicted science achievement. Grade level ($r = -.02$, $p = .89$), age ($r = -.06$, $p = .64$), ethnicity ($r = -.24$, $p = .07$), and BMI ($r = .06$, $p = .68$) were not significantly correlated with science achievement and therefore not used as predictors in the model. However, the PAQ-C was negatively correlated with science achievement, $r = -.40$, $p < .01$; processing speed was negatively correlated with science achievement, $r = -.31$, $p = .02$; and behavior regulation was positively correlated with science achievement, $r = .33$, $p = .01$.

Table 9

Means and Standard Deviations for Self-Reported Habitual Moderate and/or Vigorous Physical Activity (MVPA)

Physical Activity Environment	Control Mean (SD)	Intervention Mean (SD)	Reported Physical Activity Level
Spare time	1.62(.28)	1.22(.15)	1- "No" 2- "1-2 days"
Physical education class	4.13(1.04)	3.55(.83)	3- "Sometimes" 4- "Quite Often"
Recess	1.67(1.09)	1.28(.53)	1- "Sat down (talking, reading, doing schoolwork) 2- "Stood around or walked around"
Lunch	1.23(.50)	1.10(.31)	1- "Sat down (talking, reading, doing schoolwork)
Right after school	3.23(1.28)	2.90(1.32)	2- "1 time last week" 3- "2 or 3 times last week"
Evenings	2.80(1.22)	2.24(1.09)	2- "1 time last week" 3- "2 or 3 times last week"
Weekends	2.70(1.09)	1.52(.69)	1- "None" 2- "1 time" 3- "2-3 times"
Free time	2.77(1.36)	2.59(1.05)	2- "Sometimes, 1-2 times last week" 3- "Often, 3-4 times last week"
How often each day	3.02(1.06)	2.61(.99)	2- "Little bit" 3- "Medium" 4- "Often"

To provide more nuanced analyses of the association between physical activity and cognition, a multiple regression was performed utilizing science achievement as the criterion variable, and self-reported physical activity score and measures of executive function as predictors. Executive function tests and physical activity were logarithmically transformed for normal distribution. There was no collinearity among the predictors and the assumption for homogeneity of variance was met. Finally, to determine whether there was a significant interaction between measures of cognition and physical activity, moderation analyses were conducted using PROCESS Procedure for SPSS Release 2.15 (Hayes, 2013).

3.5   Results

First, independent *t*-tests were performed to compare reported habitual PA in different settings for the control and intervention groups, with means and standard deviations reported in

Table 10. The summary PAQ score composite from all 9 items was statistically significant, $t(57)$ = 3.35, p = .001, 95%CI[.19,.74]. There was a significant difference in scores for question 1, *Physical activity in your spare time, t(57)* = 6.80, p < .001, 95%CI[.28,.52]; question 2, *In the last 7 days, during physical education classes, how often were you very active (playing hard, running, jumping, throwing? t(57)* = 2.37, p = .02, 95%CI[.09,1.07]; and question 7, *On the last weekend, how many times did you do sports, dance, or play games in which you were very active? t(57)* = 4.97, p < .001, 95%CI[.71,1.66]. All other PA settings during recess, lunch, after school, evenings, and free time were not significantly different between groups.

Table 10

Independent t-Test Results for Self-Reported Habitual Physical Activity Settings

Question	t(57)	Lower bound	Upper bound
1. Spare time	6.80**	.28	.52
2. Physical Education	2.37*	.09	1.07
3. Recess	1.74	-.06	.84
4. Lunch	1.19	-.09	.35
5. Right after school	.996	-.34	1.01
6. Evenings	1.86	-.44	1.16
7. Weekends	4.97**	.71	1.66
8. Free time	.569	.45	.82
9. Each day	1.54	-.12	.95
PAQ Summary Score	3.35*	.19	.74

*p < .05, **p < .001

Secondly, a multiple regression was conducted to see if PA, processing speed, and behavior regulation predicted science achievement. Using the enter method, it was found that physical activity, processing speed and behavior regulation explained a significant amount of the variance in science achievement, $F(3,55)$ = 7.25, p < .001, R^2 = .28, adjusted R^2 = .24. Analyses of coefficients revealed that PA significantly predicted science achievement, β = -.32, $t(55)$ = -2.73, p = .008, 95%CI[-.56,-.09]. Processing speed significantly predicted science achievement, β = -

.26, $t(55) = -2.27$, $p = .03$, 95%CI[-.49,-.03]. Behavior regulation also significantly predicted

science achievement. $\beta = .25$, $t(55) = 2.08$, $p = .04$, 95%CI[.01,.49].

Finally, to evaluate how physical activity may influence brain development and processing

and, consequently, science performance, a moderation analysis was run to examine possible

interaction effects of physical activity on cognition. The interaction between physical activity

and processing speed accounted for a significant proportion of the variance in science

achievement, $\triangle R^2 = .07$, $\triangle F(1,54) = 8.12$, $p < .01$, $\beta = -.28$, $t(54) = -2.19$, $p = .03$, 95%CI[-.53,-

.02]. Examination of the interaction plot showed an overall enhancement effect that PA had on

science achievement with faster processing times (Figure 4). The interaction was probed by

testing the conditional effects of processing speed at three levels of physical activity, one

standard deviation below the mean, at the mean, and one standard deviation above the mean. As

shown in Table 11, processing speed was significantly related to science achievement when

physical activity was at the mean and when at one standard deviation above the mean ($p < .01$),

but not when physical activity was one standard deviation below the mean ($p = .70$). The

Johnson-Neyman technique showed that the relationship between processing speed and science

achievement was significant when physical activity was more than .32 standard deviations above

the mean but not significant with lower values of physical activity. However, the interaction

between behavioral regulation and physical activity fell short of statistical significance, $F(1,54) =$

0.57, $p = .45$, $\triangle R^2 = .01$.

Table 11

Conditional Effects of Processing Speed on Science Achievement

Physical Activity	β	SE	t	95% CI	
One *SD* below mean	.04	.11	.39	-.17,	.25
At the mean	-.28	.10	-2.81**	-.48,	-.08
One *SD* above mean	-.60	.18	-3.27**	-.97,	-.23

**$p \leq .01$
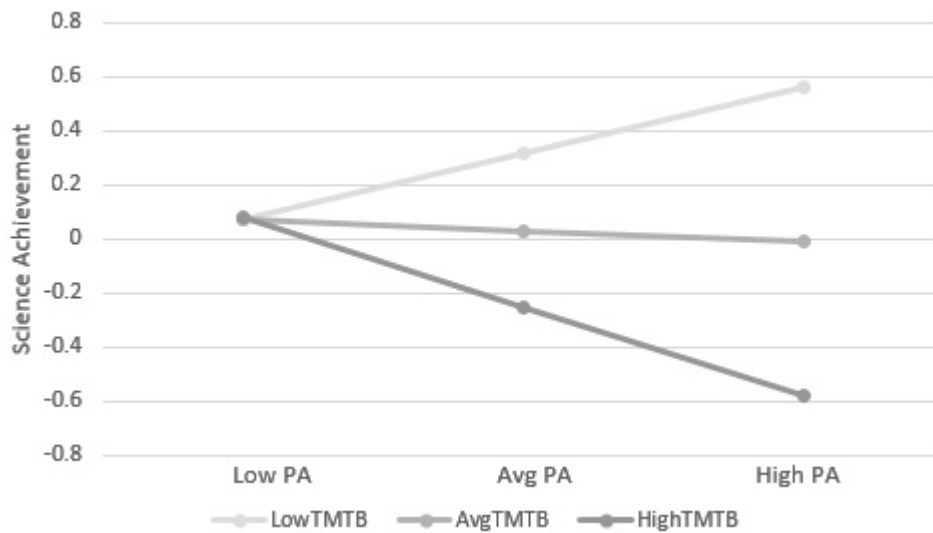
Figure 4. Interaction plot of processing speed, physical activity, and science achievement.

3.6   Discussion

This study explored the relationship among fitness, executive function including behavioral regulation and processing speed, and science achievement for female, at-risk middle school students. The intervention group significantly improved aerobic fitness and science achievement over the course of the 20-week triathlon training intervention. This was a key goal of the program, since improved cardiovascular fitness has numerous positive impacts, particularly for the targeted population.

Examination of differences reported for the PAQ-C highlighted the sedentary nature of the intervention group. The girls in this group reported less physical activity overall, specifically during spare time, physical education classes, and the weekends. This finding highlights the importance of community-based after school programs and in-school activities that offer the opportunity for improved aerobic fitness. Participation in rigorous PA outside of school may translate to more healthy lifestyles that impact in-school behavior in formal physical education.

The predictive power of the PAQ-C is evident in negatively and significantly predicting science achievement in this particular study, highlighting the lower physical activity level of the at-risk intervention group at the start of the program.

As middle school is a critical time period for physical and cognitive changes that impact learning, this study expanded upon previous findings of a positive association between the executive function of inhibition and science achievement (Latzman et al., 2010; Pajares et al., 2000). Processing speed as measured by the TMT-B negatively and significantly predicted science achievement as expected, with lower scores indicating better processing speed for the intervention. Behavioral regulation, a composite of the raw scores of inhibition, shift, and emotional control, significantly predicted science achievement. The ability to self-regulate behavior by inhibiting automatic responses and shifting between tasks, as well as regulating emotions, is an important component of cognitive control that improves academics and adherence to physical activity (Chomitz et al., 2009; Scudder et al., 2014; Smith et al., 2010). These findings support previous research that has demonstrated the beneficial effects of improved aerobic fitness on cognitive processes and a possible reciprocal nature between improved fitness and self-regulation (Daly & Allan, 2015).

While moderation analysis did not reveal a significant interaction between PA and behavioral regulation, the potential association warrants further study, perhaps in a qualitative manner. Regulating behavior through focused effort requires an individual to prioritize and monitor thoughts, emotions and behaviors in order to obtain goals. Future studies should include a qualitative component to determine possible strategies used by adolescents learned through interventions that include MVPA which may positively impact behavior regulation and academics in ways that were not measured here.

Habitual MVPA may be a key determinant of cognitive processes during adolescence. Moderation analyses are of interest to clinical researchers who examine whether the effect of an intervention with individual differences varies over time. This study is one of the first to demonstrate a dose response effect of physical activity on processing speed for improved science achievement in adolescent middle school girls. At low PA, science achievement was similar for students with low, average, or high processing speeds. As processing speed improved and physical activity increased, students' scores on science achievement increased. Those with the fastest processing times and the highest physical activity levels scored the highest on the science assessment. The $\triangle R^2$ explained an additional 7% of the variation for the moderation of processing speed by physical activity suggesting a dose response. Future research is needed to examine a possible bidirectional and causal relationship of physical activity and improved aerobic fitness on cognition. Our research provides evidence that executive function can be improved with fitness related interventions that increase behavior regulation and processing speed and improve science learning. The significant interaction between processing speed and PA demonstrates the effect of individual differences in processing speed on science achievement depending on the level of reported physical activity.

3.7   Limitations

There were several limitations to this research. First, the small sample size, though adequate for the desired power, inherently limits generalizability. Additional randomized trials with physical activity as a moderator or mediator for improved science learning are needed with larger sample sizes. Secondly, fitness data for the control group were measured indirectly due to logistical constraints. Direct measures of physical activity would triangulate fitness with traditionally timed performance variables. Finally, this study did not directly measure science

attitudes and self-efficacy, which are often related to science achievement. Future research will investigate motivational factors to explore the effect of informal science learning programs with a fitness component.

3.8   Conclusions

Assessing how exercise influences children's neurocognitive development is an important factor in understanding the role an active lifestyle plays in science learning. Students' increased physical fitness and time spent in MVPA contributes to science achievement by improving self-regulation and processing speed. Evaluation of executive function with appropriate age-based cognitive tests may provide a more reliable understanding of how chronic aerobic exercise intervention influences brain development and cognitive skills related to science achievement. It is plausible that exercise related brain changes may moderate cognitive processes and can be extended to predict exercise related changes in children's brain function. Advances in the understanding of brain development and mechanisms of learning have substantial implications for science education. Physical activity, particularly for adolescents in at-risk/low fitness level populations, may produce greater changes in brain function resulting in improved science performance.

3.9   Implications for School Health

The findings from this research have several implications for school health professionals and policy makers. First, there are numerous missed opportunities for adolescents to increase MVPA during the school day. The physical activity of the control and intervention groups indicated few differences in time spent during recess and lunch, with most reporting sitting, reading, or doing schoolwork. This is an important implication to consider for children that may not have as many opportunities after school, in the evenings, or on weekends to participate in physical activity.

While physical education contributes towards the benchmark of 60 minutes of MVPA per day, for the majority of students in the U.S. not meeting that benchmark, physical activity interventions that focus on incorporating time during lunch and recess for play and MVPA would not take away from time needed for academic instruction. This may positively impact academic learning, specifically science learning during a period of maturation where interest in STEM declines for female middle school students. Increasing PA during lunch and recess may contribute to consistent MVPA to meet the 60-minute daily threshold, and could be met by providing optional activities such as yoga or strength training. This is particularly important for underrepresented and/or sedentary students that are not physically active after school or on weekends to develop healthy lifestyles.

Secondly, the self reported PAQ-C indicated significant differences in activity level in physical education classes. This finding is problematic in light of the dose response effect of increasing physical activity on processing speed. This may indicate an opportunity for physical education instructors to monitor MVPA more closely to avoid disparities among students. Although middle school adolescents undergo rapid cognitive and physical changes that may negatively influence their willingness to participate in physical education, they should not miss out on in-school opportunities to maintain fitness and improve executive functions related to learning. Future study is required to match physical education curricula between districts or samples to control for the level of effort during physical education classes.

Finally, the results indicated that improved fitness and cognition predicts science achievement, and this finding may be applicable to other academic domains. A physically active environment stimulates learning and activates the brain. More schools and communities should provide opportunities for goal-based fitness programs to improve health and learning for

traditionally underserved youth. These programs should incorporate holistic lifestyle components such as optimal MVPA, nutrition, and healthy choices. A rigorous goal such as completing a triathlon is an attractive program for young girls to improve fitness, self-esteem, cognitive function, and related academic performance. Since executive function develops with increasing age, physical activity in an enriched learning environment inside or outside of the regular school day may be particularly beneficial for a student's ability to reason, solve problems and learn increasing complex scientific concepts.

Chapter 4

Fitness, Motivation, and Academic Achievement

4.1   Introduction

Adolescence is a period of rapid change in maturity, social relationships, and academic pressure where students go through dramatic physical, emotional, behavioral, and cognitive changes (Blackwell, Trzesniewski, & Dweck, 2007). Early adolescence has been shown to be a critical development period marked by declines in physical activity, self-esteem, academic motivation, and increased obesity rates (Fakhouri et al., 2014). If developmental changes are not negotiated successfully during this crucial time period, the results are often school failure and a negative impact on health status (Dweck & Leggett, 1988).

After school programs (ASPs) have played a key role in engaging youth in the learning process by providing opportunities to explore interests, increase health and wellness, gain competency in real world skills, set goals, solve problems, develop a group identity, and connect with adult role models (Kuperminc, Smith, & Henrich, 2013). ASPs have positively influenced early adolescents' critical thinking skills, study skills, and content knowledge (Dierking, 2007). Quality ASPs can make a difference in building the requisite skills for engagement in learning, self-efficacy, choice goals, actions, and persistence by providing supportive environments in which students can increase competency while developing a positive sense of self (Lauer et al., 2006).

In ASPs that work with nurturing adult mentors, students are viewed more as collaborators rather than passive recipients. Positive relationships with peers and adult mentors have provided

students with a chance to contribute to the learning process (McClure & Rodriguez, 2007). These positive relationships can have a very powerful effect on motivation, self-efficacy, persistence, self-directed behavior, and overall academic achievement (Eccles & Grootman, 2012). ASPs have provided an alternative environment that may be more aligned with middle school aged interests and motivations, benefiting adolescent developmental needs of the whole child (Lauer et al., 2006). Consequently, ASPs can make a difference in building the pre-requisites for learning, as well as long-term competence and success.

Physical activity has been consistently related to higher levels of self-esteem with decreased levels of anxiety and stress, all of which have been correlated with increased academic performance (Budde et al., 2008). With student attention span likely to increase in an active environment, cognitive development may also be enhanced (Zaitchik et al., 2014). The question remains as to whether the level of increased aerobic fitness as part of an ASP can be linked to academic achievement, self-regulated behaviors, attitudes, and motivation. The aim of this study was to evaluate the effectiveness of an ASP towards improvement in academics, confidence, and motivation for female middle school students. The overarching research question was: How do environmental factors that include triathlon training, peer mentoring, nutrition and health based science instruction in an ASP affect students' motivation, health outcomes, and achievement in science?

4.2   Theoretical Framework

Social cognitive theory and motivation. Powerful experiences cause the human brain to perform multiple operations simultaneously when stimulated by environmental change (Bandura, 2006). The executive functions network delivers this information subconsciously and the neural networks of the brain coordinate to plan, motivate, and regulate goal directed behavior

(Anderson, 1983; Bandura, 2001). An integrative approach of social cognitive theory (Bandura, 1986) and biological mechanisms of informational processing provide a framework for increased motivation and transfer of knowledge between situations that may be different but are similar in context (Anderson, 1997). With regard to the interplay of social factors on human development, adaptation and change, Bandura (2006) proposed that integration of personal and social influences operates through self-regulation to produce behavioral effects. In this model, regulation of motivation and activities is dependent on the types of social and physical environments in which people interact (Bandura, 2006).

Social processes may be potential mediators that encourage increased physical activity and reduced risk of obesity with strategies implemented in ASPs (Kuperminc et al., 2013). Acknowledging the role of personal efficacy in health behaviors, Bohnert & Ward (2013) found that girls in a health and wellness intervention reported more physical activity and higher levels of healthy nutrition knowledge than girls in a control group. Efficacy beliefs influence choices in regard to what challenges to take on, how much effort to expend, and how long individuals must persevere through adversity and difficult obstacles (Bandura, 2006). Cognitive and motivational variables have been found to correlate with adolescent health practices (Tyc, Nuyybrock-Allen, Klosky, & Ey, 2004), and appropriate interventions need to be explored to promote physical activity (Taymoori, Berry, & Lubans, 2011).

Bandura (2004) stated that educational efforts to promote health in youth typically produce weak results as most models are only concerned with predicting health habits. Bandura (2004) contended that intensive programs with rigorous implementation and an integrative aspect that includes family and community efforts are more successful than health programs during the school day that lack the time and resources to engage students in lasting change towards

adopting healthier lifestyles. Information imparted in normal school day lessons without teaching the skills to cope with obstacles and setbacks make it difficult to sustain healthy behaviors. ASPs that involve families and community can reach a large number of children to promote healthy nutrition and exercise.

Unless people believe they have control over desired results and can inhibit detrimental actions, they have little motivation to persevere in the face of difficulties. Motivated students achieve by using strategies to engage in positive behaviors such as participation, completing assignments, and studying (Schunk & Pajares, 2001; Zimmerman et al., 1992). For this study, perceived self-efficacy is presented as the confidence that a person believes she possesses in succeeding at task demands. Research is warranted to examine potential motivators and perceived efficacy or confidence as mediators for the effect of increased collective efficacy in sustained positive health outcomes for youth.

Self-determination. Self-determination theory (SDT) of motivation addresses basic issues of needs including identity formation, self-regulation, goals, and the impact of social settings on behavior and well-being (Deci & Ryan, 2008). SDT differentiates motivations with the idea that the type and quality of an individual's motivation are more important than looking at motivation as a unified concept (Deci & Ryan, 2000). Different types of motivations predict important health outcomes, performance, problem solving, and meaningful learning (Deci & Ryan, 2008). Internalizing personal goals increases intrinsic motivation, which improves outcomes for sustained participation in ASPs, compared to extrinsic motivation that has been shown to result in a decline in socioemotional outcomes (Berry & Lavelle, 2013).

Bandura (2001, 2006) reported that self-regulatory strategies developed in one type of activity or powerful experience are serviceable in other domains with resulting covariation in

self-efficacy among them. Participation in social practices is a fundamental form of learning where a social display of cognitive competency through group participation serves as a mechanism for internalizing and practicing knowledge and skills in individuals (Glaser, 2000). Situated learning can provide an interactive social setting for students to adopt the criteria for competence they observe in others and then apply this new information to their own performance, forming collective agency of the group (Bandura, 2001; Glaser, 2000). Bandura (2001) referred to self-efficacy as "human agency" that extends to a collective power. Within social groups, shared beliefs in collective efficacy come from shared intentions, knowledge, and skills as well as the interactive and dynamic interactions between them. Thus, beliefs of collective efficacy function in a similar way to self-efficacy and operate through similar processes.

Beliefs about intelligence. The middle school years are a time when gender differences in achievement and attitudes towards physical activity, science, and mathematics widen (Jones et al., 2000). The *Implicit Theories of Intelligence* model (Dweck, 1999) posits that students may hold one of two different frameworks – fixed or malleable intelligence. A fixed mindset refers to an uncontrollable intelligence that may result in students giving up or withdrawing effort if the perceived outcome appears negative (Blackwell et al., 2007). Students with a malleable or growth mindset hold the view that effort drives ability and that challenging and/or difficult tasks lead towards increased effort to overcome obstacles (Dweck & Leggett, 1988). The two frameworks can have significant consequences for students facing setbacks during challenges that are typical of early adolescence. With a malleable mindset, individuals perceive that ability can be further developed, as opposed to a fixed intelligence that often results in a learned helplessness and withholding of effort (Blackwell et al., 2007; Covington, 2000).

Middle school is a challenging transitional time for adolescents as academic workload increases, social relationships broaden, and learning environments change with students expected to be more independent (Dweck, 2003). During adolescence, ideas about ability have an impact on interest and motivations. Researchers have found achievement motivation and perceived ability to be rooted in youth perceptions of "goodness" and this early meaning system has been shown to extend into adolescence (Heyman & Dweck, 1998). Blackwell et al., (2007) found that those with a malleable view held positive effort beliefs compared to those with a fixed mindset that endorsed negative effort beliefs. Previously, Blackwell et al., (2007) used mathematics as an academic challenge that students found difficult. Science is also considered to be difficult and middle school is a time when interest in science declines, specifically for females, therefore, it can be used to measure motivational patterns and establish how academic attitudes may relate to theories of intelligence.

4.3   Research Design

The present investigation used quantitative and qualitative procedures to assess students' achievement, learning habits, motivations and attitudes towards physical training and academics. Self-regulated learning strategies may include actions directed at acquiring information or skills that involve goal setting and self-efficacy (Zimmerman & Pons, 1986). This study utilized a mixed methods design for collecting and analyzing quantitative and qualitative data in order to answer the research questions comprehensively. The rationale for using a mixed methods approach is that neither quantitative nor qualitative methods are sufficient alone to capture the trends in changing fitness, motivation, and achievement as ASP outcomes.

The initial phase of the explanatory sequential design (Bryman, 2015) consisted of pre- and post-intervention quantitative data collection and analysis of quantitative data. Out of 50 possible

volunteer students for the study, 33 consented and 29 completed all pre- and post-intervention measures. The initial phase was followed by collection and analysis of qualitative data to provide context for the quantitative component. The goal of the quantitative phase was to identify changes in fitness as well as the related changes in science achievement and motivation towards science. The qualitative phase used data from focus groups in a semi-structured interview format immediately post-intervention and again 12 weeks later.

4.4   Methods and Context

Data were collected during the baseline assessment phase of an after-school health education and triathlon training program. The program was founded in 2010 as a pilot program for at-risk middle school girls. Program personnel defined at-risk as having low self-esteem, sedentary lifestyle, and being overweight. The program combined self-esteem building lessons, nutrition and health science education twice per week from mid-March through June, and after school triathlon specific training three times per week through July, with a culminating youth sprint triathlon (300-yard swim, 7-mile bike ride and 1.5-mile run). Early data collection ensured that students were at a similar level of learning and experienced similar curricula in compliance with the NYS Intermediate Science Curriculum (NYSED, 2014). There were 29 students (age, 12.03 $\pm$ 0.73 yr) that completed pre- and post-assessments. Group descriptive statistics are provided in Table 12.

Table 12

Participant Characteristics

Characteristic	Intervention Mean (SD)
Age (yr.)	12.03 (0.73)
Weight (kg)	56.92 (14.66)
Height (m)	1.54 (0.07)
BMI (kg*m^{-2})	23.77 (5.44)
VO$_{2max}$ (mL*kg^{-1}*min^{-1})	38.20 (4.34)
Ethnicity	**N (%)**
Caucasian	16 (55)
Black	5 (17)
Hispanic	8 (28)

Baseline data were collected in the 2014-2015 academic year from sixth through eighth grade students from three separate schools.

The nutrition component consisted of five hands-on participant and family nutrition lessons. Lesson objectives included reading food labels and describing the importance of major nutrients, vitamins and minerals in supporting and promoting growth (aligned with NYSED, 2014). The empowerment curriculum consisted of 14 lessons designed for science in personal and social perspectives (aligned with NRC, 1996). Fundamental concepts and principles included discussion and strategies for thinking critically about risks and benefits of important personal and social decisions. Lessons included the power of positive affirmations and goal setting. The fitness, strength, and triathlon training curriculum focused on the importance and benefits of physical fitness for maintaining a healthy weight, energy levels and strength for routine activities, and improved cardiorespiratory fitness and mental health. The fitness curriculum also used interdisciplinary problem solving to address real life problems, set goals, and make informed decisions to continue a path towards improved physical fitness.

4.5   Measures and Instruments

Health status. In March (pre) and July (post) of 2014, the intervention group completed two standardized fitness assessments with the baseline assessment used to identify training needs and

the post-assessment used to evaluate the success of the program in achieving its stated health objectives. Standardized physical fitness tests included cardiovascular fitness measured by pre-/post-timed 1.5-mile run and 100-yard swim test. Body Mass Index (BMI) was calculated from pre-/post-height to weight ratios. The energy requirements of running were calculated by estimating the oxygen requirements of the amount of exercise being performed, commonly called oxygen consumption (VO_2). VO_2 provides a criterion measure of cardiorespiratory fitness known as VO_{2max}.

Academic motivation. The original *Science Motivation Questionnaire* (SMQ) (Glynn & Koballa, 2006) was developed to examine students' motivation to achieve in science. The SMQ-II (Glynn et al., 2011), an updated version based on social cognitive theory, was given to study participants on the first and last day of data collection to identify positive motivators. The construct of the SMQ-II is a latent variable, but it can be measured by means of items that serve as indicators for how motivation is conceptualized (Glynn et al., 2011). The SMQ-II contains a breakdown of the scales and items for five constructs: 1) intrinsic motivation, 2) self-efficacy, 3) self-determination, 4) grade motivation, and 5) career motivation (Glynn et al., 2011). The five extracted factors explained 71% of the variance. The 25 items had high reliability ($\alpha = .93$).

Science achievement. Science achievement was measured using a 15-question pre-/post-multiple-choice assessment developed for middle school students from Project 2061 (AAAS, 2014). The NYS Intermediate Level Science Core Curriculum indicates that science process skills should be based on a series of inquiry-based discoveries (NYSED, 2014). The focus of the curriculum is on conceptual science understandings consistent with approaches recommended by *Benchmarks for Science Literacy* (AAAS, 1993). The science achievement test had acceptable

reliability (α = .74). The impacts of the health and nutrition curriculum were assessed in focus group interviews.

4.6   Qualitative Methods

Phase II of the explanatory sequential mixed methods design was implemented to provide insights into the results of the SMQ-II survey. Small focus groups of five to eight girls were convened immediately after the completion of the program, and again 12 weeks later. A semi-structured interview protocol was developed with questions regarding individual goals, perceptions of the program structure, the program setting, and the effects of the program on the participants (Appendix B). Focus groups lasted approximately 40 minutes. All names were changed to protect confidentiality.

Qualitative methods of analysis included a hypothesis driven approach derived from grounded theory. This process involved multiple stages of data collection with multiple iterations to identify interrelationships among categories and information (Strauss & Corbin, 1998). The primary characteristics of grounded theory involve the constant comparison of data with emerging categories and theoretical sampling to maximize the similarities and differences of information (Creswell, 2003). The interviews were analyzed with methodologies that included triangulation of quantitative and qualitative data to provide cross validity checks.

Categorical analysis of qualitative data. Phase I categorized the data by coding the interview transcripts and noting emergent theoretical constructs (Strauss & Corbin, 1998). Key words and phrases from the SMQ-II were used to open code the transcripts to explain changes in self-determination and grade motivation. These codes included: changes in attitudes, feelings, skills, behavior, knowledge, and self-regulated learning strategies. The transcriptions of focus

groups were independently coded by two researchers to establish reliability (Mays & Pope, 1995). Intercoder interpretive agreement was evident in 94% of the cases and discrepancies were resolved through discussion (Saldaña, 2013).

In the second part of qualitative data reduction, axial coding was employed to identify connections between categories and subcategories that focused on situations surrounding the actions and/or reactions of the participants and the consequences or results of the behaviors (Strauss & Corbin, 1998). The themes that emerged were peer mentoring, confidence, interests, and strategies. In the final phase of the qualitative interview analysis, data on program processes and participant outcomes were sorted and integrated around social cognitive theory, self-determination theory, and theories of intelligence. Data reduction revealed common threads of social support, effort, and motivation.

4.7   Quantitative Results

To determine changes in health status, cognitive processes, and motivations after the 20-week ASP, Wilcoxon signed rank tests were performed. This was used to measure the median difference between the paired samples of the intervention participants ($n = 29$), and to understand the performance benefits of the 20-week triathlon training and informal nutrition science education program. The differences between pre- and post-measures were symmetrically distributed as assessed by histograms. Of the 29 participants, the intervention elicited an improvement in self-determination ($Mdn = 20.00$) compared to the pre-test ($Mdn = 17.00$), $z = 2.33$, $p = .02$. Grade motivation was significantly improved, $z = 2.08$, $p = .04$; science achievement showed significant improvement post-intervention, $z = 3.20$, $p < .01$; as well as cardiovascular fitness as measured by run times, $z = -3.67$, $p < .01$, swim times, $z = -2.97$, $p < .01$, and VO_{2max}, $z = 4.27$, $p < .01$. Science motivational constructs of self-efficacy, $z = 1.78$, p

= .08; intrinsic motivation z = .15, p = .88, and career motivation, z = 1.25, p = .21 were not

significantly changed between pre- and post-assessments. Means, standard deviations, and

percentiles are presented in Table 13.

Table 13

Descriptive Statistics and Percentiles of the Wilcoxon Signed-Rank Test (n = 29)

	M	SD	25th	Percentiles 50th (Median)	75th	z
Swim pre-test (s)	147.77	39.97	121.25	134.00	128.00	
Swim post-test (s)	132.48	35.78	105.50	128.00	153.00	-2.97**
Run pre-test (s)	999.90	177.68	867.00	972.00	1112.00	
Run post-test (s)	915.59	156.31	791.50	970.00	1016.00	-3.67**
VO_{2max} pre-test ($mL*kg^{-1}*min^{-1}$)	31.84	9.45	23.59	31.93	38.56	
VO_{2max} post-test ($mL*kg^{-1}*min^{-1}$)	36.79	8.03	30.50	35.86	43.65	4.27**
Intrinsic motivation pre-test	15.93	4.12	13.50	16.00	19.50	
Intrinsic motivation post-test	15.90	4.89	12.00	15.00	20.00	.88
Self-determination pre-test	16.90	3.61	14.50	17.00	19.00	
Self-determination post-test	18.38	4.41	15.00	20.00	21.50	2.33*
Self-efficacy pre-test	19.03	3.66	17.00	19.00	21.00	
Self-efficacy post-test	20.17	4.17	17.00	22.00	23.00	1.78
Grade motivation pre-test	20.66	2.86	18.00	21.00	23.00	
Grade motivation post-test	21.59	3.32	20.00	22.00	24.00	2.08*
Science pre-test	56.09	21.86	40.00	60.00	73.33	
Science post-test	68.05	18.46	56.66	73.33	80.00	3.20**

* $p < 0.05$, ** $p < 0.01$

4.8   Qualitative Results

The coding analysis generated three major themes. First, the girls spoke repeatedly about the

value of social support in building confidence. Secondly, their success improved motivation in

achieving goals, largely driven by the value they recognized in hard work. The increase in

motivation was reflected in improved self-regulation and self-determination, which suggested

program participation impacted their sense of agency in both fitness and academic domains.

Finally, the girls improved in self-acceptance. Social support and personal success led to

healthier self-concept, improved motivation, and confidence in executing behaviors required to achieve goals.

Social support. The concept of social support provided by peers, family, and program facilitators was a pervasive theme in focus group discussions. The girls valued support to achieve their program goals, and it contributed to improvements in motivation and self-determination. Social support was clearly related to expressions of confidence.

Many girls expressed improvement in basic confidence and social engagement when asked what they liked about the program. Julie stated that the program gave her "a lot of friends and confidence." She also shared that the program helped her deal with uncomfortable social situations: "Like, if you're being bullied, you have, like, your [program] sisters with you." Kate stated that the program gave her a firm social grounding: "It helped me, like, find my group. And it did help me have confidence to stand up to people." She also shared the value of having family and friends supporting her immediate goals in the program; this inspired her to persevere in completing a difficult task:

> *Kate (grade 7):* I would say that you might think it's gonna be hard work and it's gonna be too much, but there's really nothing so far that I've felt better than crossing the finish line and having your parents and your friends and your family all standing there and cheering for you. So all that work and all that effort that you put in and you think, oh, my God, this is too much, you just have to think of the ending and think of how great it's gonna be and keep going.

Peer support and improvement in basic confidence also led to an increase in self-efficacy for tasks that the girls initially found difficult. Rather than feeling singled out for not knowing something, Amy shared that the program helped her to meet people with common interests and it felt good for her to be able to learn with others:

> *Amy (grade 8):* I really like how I made so many friends. Like, everyone I met, like, you have something in common with. And if I didn't know how to do something, I would be the only one who didn't know how to do it. But in [the program], if I didn't know how to

do something, there would be someone else who didn't know how to do something so I felt really good, like, oh well, we'll learn together and I won't feel bad about not knowing how to do something.

Several girls spoke of previously not liking certain tasks because they did not come easily. That changed for many of them in the treatment program. Mathematics was commonly identified as a subject the girls did not like because it was difficult, but the impact of the program was evident with several girls adopting more of an incremental intelligence mindset. When prompted about what she didn't like about mathematics, Kate (grade 7) stated, "Math doesn't come as quickly to me as English, so sometimes, I get confused and I feel like I'm not good at it, but I'm trying harder." Julie (grade 7) concurred with Kate stating, "Math, it was like, I didn't understand it…I wouldn't get it at first. But then since we learned some stuff that I actually knew, I actually got a lot better in math and I liked it after that."

Perceptions of ability and interest were tied to performance success at first, however, the affirmations learned in the program, and the ability to self-regulate learning in thinking critically about important decisions was evident in changing attitudes and approaches to difficult academic subjects. When asked about how the program changed their perception and achievement in subjects they did not like at first, many girls replied that they were able to think critically before reacting, for example:

> *Amy (grade 8):* It gets you to think about things more deeply, before I used to panic for no reason and I would overreact and now I learned to take things better… math is my least favorite but I want to achieve, I want to get an A.

Lasting impact of the program was observed in the older girls. Mary, when asked about how the program affected her, indicated that each year in the program helped to increase her confidence which carried over to academics:

> *Mary (grade 8):* Confidence to be able to believe that I can do better and to know I can do better. It makes me want to go out and get it and like, show myself that I can do it…It's definitely helped me achieve my goals and become more advanced in my classes

and be more interested in my classes. I wasn't always, like, I didn't do bad, but I was like in the 70's. Before I would get B's and C's, but now I'm A's all across the board.

The participants in this study demonstrated a change in self-efficacy with an increase in confidence in their ability to succeed in both academic and fitness tasks. The girls received positive performance feedback from both program personnel and their peers. Natalie shared this view that she and others had when asked about what she learned from the program about achievement of athletic or academic goals:

> *Natalie (grade 6):* If you don't feel like you can complete a triathlon in the beginning, it would be a really big accomplishment and you would be able to be more confident about more things that you could do…I like seeing the impact in other girls' lives…it could inspire you to work harder in school.

Motivation and self-determination. The participants spoke of the skills and determination they learned in the program and how this related to their commitment and motivation to do well in academics. Kate discovered that her hard work and success in the triathlon training allowed her to direct the same effort to her academic work, particularly science:

> *Kate (grade 7):* The best thing in [the program] is teaching us to be ourselves. And the best thing that relates to science I would say is having determination. When you want to do something, be determined to get it done. Like in [the program], it's finishing our race. And then if you apply that to science, it's like getting the A, it's staying in, like, the Regents course. The determination to do that leads you to study more, get better grades.

Kate was able to transfer feelings of success from fitness to science, a subject that many of the girls categorized as difficult. Mary concurred with her peer by emphasizing her newfound grade motivation after her confidence boost from the fitness program:

> *Mary (grade 8):* It gives me confidence to do everything and anything, basically, that I want to do and achieve anything, like, if I want. It helps me to realize that anything is possible if I just believe and try. So, like, I can do anything. If I want to get a good grade, I can work hard and get a good grade if I want it bad enough, which I do. And, like, it helps you achieve anything, because they teach you, well, you want to cross the finish line.

Mary recognized that the internal drive she had developed as a result of her participation was motivating her in academics. She also showed evidence of her belief in malleable intelligence, stating, "And I feel like if I don't get it, I'm gonna sit there, I'm gonna work through it and I'm gonna try to get it." Her incremental mindset facilitated her persistence in academic tasks. She expressed confidence in her ability to self-determine academic outcomes by applying herself, something she had learned in the program.

Julie shared that she experienced an increase in motivation because of the tangible results of her effort in the triathlon program. She related this to "affirmations," a program strategy where the girls vocalized their belief in themselves:

> *Julie (grade 7):* We do affirmations in [the program], so when you're taking a test it's easy to say that I will do good on this test. I can do it, like [facilitator] teaches us. So the affirmations help a lot. I think that it does help with math and with all the subjects that I need help with tests on.

It is interesting to note that the increases in grade motivation were often articulated by the focus group with younger girls 12 weeks after the program completion. This finding is promising in that it suggests positive program impacts extended well beyond participation. Kate expressed this when asked about whether she was struggling with any classes at the start of her eighth-grade year, "I've been doing pretty good in math actually, this year. Last year it was a bit of a struggle, but I've done a lot better this year." When asked about what made her change her thinking, she said:

> *Kate (grade 8):* All the things we've done, the activities, to show that we are unique and the talks we've had together, we just really aren't afraid to be ourselves and that leads us to do the same things outside of [the program]. In [the program] we learned to, like, keep going, don't give up. So when a subject gets kind of hard, at first you are like, oh man, like, I don't know what to do. I think it's taught me that when you are so close, like with the race, you just have to push on and keep going…like in tests, if they are difficult, I just sit down and study for awhile and I do pretty good. It's helped me a lot.

Goal setting was an important strategy in maintaining motivation. Amy verbalized this notion when asked about the most important outcome for her, relating her positive experiences to an increase in goal setting:

> *Amy (grade 8):* Well, after [the program]… I did start setting more goals… It's an amazing, life changing experience that is vital – that gives vital lessons to girls and makes them become better people and makes them feel a lot better about themselves and makes them sort of achieve anything they want to.

When asked about what they learned about goal setting through the program, Kate indicated how important this strategy was:

> *Kate (grade 7):* We learned that you shouldn't give up on your goals, because it can take you really far. Our triathlon was our biggest goal, if you didn't finish all the sessions and didn't do the race, you would never feel that satisfaction of finishing. [Facilitator] helped us visualize things and told us that achieving our goal, setting and achieving goals is definitely worth it, it's gonna pay off in the end so that worked.

Setting goals was also linked with effort. This is an important finding as growth oriented mindset has been shown to be related to adopting a focus that emphasizes new learning through challenging tasks (Dweck, 2003). Positive effort beliefs inspire strategies to improve performance when challenged (Blackwell et al., 2007). One strategy that was used for increased academic performance was studying more. Wendy stated this when asked about how the program contributed to goal setting in and out of the classroom, "I'm just like, okay, I have to do good on this test, so, like, I study for it and I actually try really hard." Wendy indicated that she adopted strategies for time management: "It helped me to study at different times and so then I'd have a rhythm and then I would actually study and get a good grade." An emergent theme was that grade motivation prompted effort and the strategy that was learned in the program and this was applied to studying:

> *Amy (grade 8):* Well after [the program] after I finished last year and this year, I did start setting more goals. Like something small, like before – I like to read, but I was very lazy about it. And now I say, okay, by the end of this hour I'm gonna be up to this page and I

would at least be close. Or like with school, with science, if it was boring, I wouldn't pay attention but it was important for me to get a good grade so I would study hard. Especially when it's time and the Regents came, I was like, okay, so tonight, I would set a goal. Like tonight I'm gonna read from this page to this page of our review and I'm going to study it well, so I can do well on the [state exam]. I got an 88 on the [state exam] which I was really happy with.

Self-regulation is a process by which learners transform their mental abilities into skills by self-generated thoughts, feelings and behaviors that are oriented towards attaining goals (Bandura, 2006). Theories of intelligence can predict students' goals, personal beliefs about effort, and strategies in dealing with setbacks (Dweck, 2003). When asked about obstacles and what strategies the girls used to overcome them, many reported using lessons learned from the program.

> *Mary (grade 8):* I used one of the lessons from [the program]. If I get thrown an obstacle in my way, I'm gonna do whatever I can to overcome it…like I did in the race. I remember running across the finish line crying hysterically and it was just like, 'cause you never think you are going to be able to do something and then you go out and do it, it's the most amazing feeling in the world.

Self-regulatory strategies were evident in how Mary approached her Spanish final exam:

> *Mary (grade 8):* Like my Spanish test for this year, it's like my final and I was freaking out because we had to sit there and talk Spanish to our teacher. I wasn't like great, best at, like pronunciation but what I ended up doing was I would rewrite my paragraphs out and I'd like, recite it into my memory with the exact pronunciation and everything and that helped. It makes me think that if I make myself sit down and read the work and understand it and go to my teacher if I need help and just work towards it.

Lasting change in their ability to overcome setbacks was further evidenced 12 weeks post-program when participants were asked how they responded to setbacks since completing the program. Mary used the example of a guest speaker the program brought in to help the girls develop skills in overcoming obstacles:

> *Mary (grade 8):* There was this speaker and he referred to [obstacles] as brick walls and basically, like, there's been many brick walls. Like, for biochemistry, getting confused, that was like a brick wall. But the brick walls are there to show you how badly you want

something and if you can get over that brick wall then that means you really want it. If you can get over it, you can achieve your dream.

Confidence and self-acceptance. Program outcomes regarding the overcoming of obstacles and an increase in health status were also evidenced by an increase in self-acceptance. When asked about what they liked best about participating in the program, Wendy shared that "I feel like it really helps you feel better about yourself. It also gets you really fit." This sentiment was also expressed by Amy, "I like how I became much healthier, like, before I didn't really do much exercise and now I am. It's something I look forward to." Participants expressed self-acceptance from what they learned through the health and fitness related curriculum when asked about what their favorite lessons were:

> *Amy (grade 8):* I like the nutrition ones because I always feel like, not like I have a nutrition problem but I was always looking to feel healthier. So I learned many things that, some things I knew, but some things I didn't know. And I tried to put these into practice at home, like, with different nutrients and food and try to eat better at home.

The improvement in health status was linked to confidence in one's ability to complete the program and successfully finish the youth triathlon. Natalie shared that the program gave her improved "health, fitness, and confidence" in the second interview 12 weeks after the completion of the program. Julie concurred and expanded on this finding, "I was really unsure of myself in sixth grade, but now I am positive most of the time." Self-assurance was a theme echoed by most participants as a beneficial aspect of the program:

> *Kate (grade 8):* It's gotten me to be so much more confident, but in myself that the fact that I am who I am and that's what makes me unique and I should be proud of the things that I love. Last year I wouldn't show exactly what I loved, but this year I come in [to school] wearing, like, a DC comics shirt and I'm like, yeah, that's who I am, so you're gonna deal with it if you want to be around me.

The sentiment of self-assurance was also expressed by the older girls that had been through the program for the second or third year suggesting that the empowerment curriculum, affirmations,

goal setting and confidence building were program outcomes that demonstrated lasting change

and influence on adolescent girls' perspectives of their identities:

> *Wendy (grade 8):* If you feel like you're not the way you want to look, [the program] makes you feel better about who you are and makes you learn to appreciate who you were, like, meant to be. But it also at the same time, gets you healthier and if you are still unhappy, you have new ways to find out how to become the way you want to be…I feel like it helps people understand and accept who they are and it really helps people feel better about themselves. [The program] makes you do things that you normally would not do, like you would think, oh, I can't do this, but now I actually can, because I've tried, I try, and when I try I can accomplish anything.

4.9   Discussion

A major function of education is to produce lifelong learning skills. The results of this study

have important implications for health education because self-management strategies developed

in one realm were serviceable in academic domains due to increased self-efficacy. During

adolescence, ideas about ability begin to have an impact on interests and motivations (Dweck,

2003). Self-determination and grade motivation constructs showed significant improvement from

the intervention and this was mirrored in the qualitative analysis with students expressing

increased motivation to exert the requisite effort to achieve their goals of higher grades in more

difficult subjects such as science and mathematics. The girls learned to self-regulate their

learning and set goals that promoted improved fitness and academic achievement, better

attitudes, and resilience.

Self-regulation and cognitive control are executive processes that have been shown by

previous researchers to contribute to academic performance (Glaser, 2000; Lorenz, Stylianou,

Moore, & Hodges Kulinna, 2016; Zaitchick et al., 2014). The self-monitoring of behavior

patterns and the peer and adult support provided by the program provided positive environmental

conditions that gave rise to lasting confidence changes and improved academic attitudes. Goal

setting and motivation drove personal pursuits and sustained the attentional demands required to succeed (Zimmerman, 2000).

Goals must be challenging to provide a good incentive for behavior change and achievement may be dependent on how far in the future they are projected. Prior research has shown that this aspect of goal incentivized action is aligned with the metacognitive capability for self-reflection, where students will address motivational conflicts, devise strategies, and predict their chosen plan of action (Zimmerman et al., 1992). Self-reflection was evident in the focus group interviews where girls gave examples of how they approached problems, difficult tasks, or social situations where they previously had felt like "a pushover" (Natalie), and had low self-esteem and confidence (Julie), and nearly all girls in the focus group interviews indicated that they did not have many friends prior to the start of the program. The collective efficacy formed by participation in the program led to an increase in personal agency and the confidence to learn and try new things. They may have considered the goals to be difficult, but approached them with a malleable mindset, believing that with enough effort they could achieve whatever they attempted.

This study supports previous research by Bohnert & Ward (2013) and assertions by Bandura (2004) that quality ASPs can provide the time and personal attention required to foster skills that affect adherence to healthy habits and academic success in the face of challenges. By involving the family and community in developing requisite skills to self-regulate behaviors, this ASP promoted positive health outcomes and improved motivation and academic achievement – lasting and beneficial changes for the female participants. While the quantitative analysis did not reveal a change in science self-efficacy as measured by the SMQ-II (Glynn et al., 2011), qualitative analysis revealed the increase in personal efficacy expressed as confidence as a

positive outcome of the program. Program outcomes highlight the benefits of developing skills to regulate behavior and to cope with setbacks while adopting a healthy lifestyle.

This study is the first to highlight the transfer of efficacy between difficult fitness-related tasks and academic achievement in more challenging courses such as science and mathematics. As a measure of an academic subject that participants find difficult, the science achievement test showed significant improvement from pre- to post-intervention along with cardiovascular fitness related gains in the form of decreased run and swim times and increased VO_{2max}, with confidence and self-determination as potential mediators. Future study is recommended to examine a possible mediation effect on fitness and academic related gains for female adolescents involved in quality ASPs.

Limitations. Randomized control trials (RCT) are considered to be the gold standard in design to evaluate the effectiveness of an intervention, but this is not always possible for health programs targeted at population level (Bernal, Cummins, & Gasparrini, 2016). RCT was not possible for this study due to the location and availability of trained personnel to volunteer their time, and associated costs of equipment or space needed, such as a pool, in this intensive 20-week long community based intervention. While RCT provides a means for testing the replicability of an intervention, the behaviors and context of a particular community can be difficult to replicate. The strength of this study was that effectiveness was determined under normal conditions in a field setting and evaluation of a complex intervention was demonstrated by quantitative and qualitative evidence.

This study of a complex intervention with an explanatory sequential design to determine behavior related to health and motivational constructs that affect female adolescent development was able to identify values, beliefs, and community related practices of a target group through

mixed methods. Campbell et al. (2000) has posited that RCTs are not appropriate for explanatory research into factors that determine behavior related to health education in identifying cultural context of values and beliefs of a target community based intervention. Future study should examine the relationship of potential mediators of confidence, self-determination and peer support and apply a repeated measures time series experiment for the development, evaluation, and analysis of behavior from community based health interventions.

Conclusions. Cognitive self-regulation refers to students' active engagement in their own learning, including analyzing the demands of school assignments, planning for and mobilizing resources to meet these demands, and monitoring their progress towards the completion of tasks (Covington, 2000). Increasing understanding of self-regulation provides greater insight into how knowledge is organized, how experience shapes understanding, and how people acquire expertise. Students who have a strong belief that they can succeed will be more likely to select tasks and activities that are challenging. Alternatively, students who do not believe that they can be successful will put forth a minimal effort (Zimmerman et al., 1992). Motivated students have a high self-efficacy because they believe success is under their control and that they have the capacity to do the work required to meet higher expectations (Miller, 2003). Students who believe that they can succeed physically and academically set high goals, tend to increase effort and show more resilience and perseverance than their low self-efficacy peers (McClure & Rodriguez, 2007). Quality ASPs like the one evaluated in this study contribute significantly to building the requisite skills needed for engaging in learning, self-belief, persistence, and setting goals to facilitate academic achievement, while developing a positive identity during a time of rapid change in female adolescent development.

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Appendix A: Science Content Knowledge Assessment
(adapted from AAAS, 2014)

1. Imagine that you remove all the atoms from a chair. What remains?
    a. Nothing
    b. A pile of dust
    c. The same chair
    d. A chair that weighs less
2. Which of the following is NOT made up of atoms?
    a. Heat
    b. A gas
    c. A cell
    d. A solid
3. Diagram 1 below shows that the Earth's path around the sun as nearly circular and Diagram 2 shows that the path as strongly elliptical. What is the actual shape of the Earth's path around the Sun?
    a. Nearly circular (slightly elliptical)
    b. Strongly elliptical
    c. The shape of the path changes so that some years it is nearly circular and other years it is strongly elliptical.
    d. Neither. The Earth does not move around the sun; the Sun moves around the Earth.
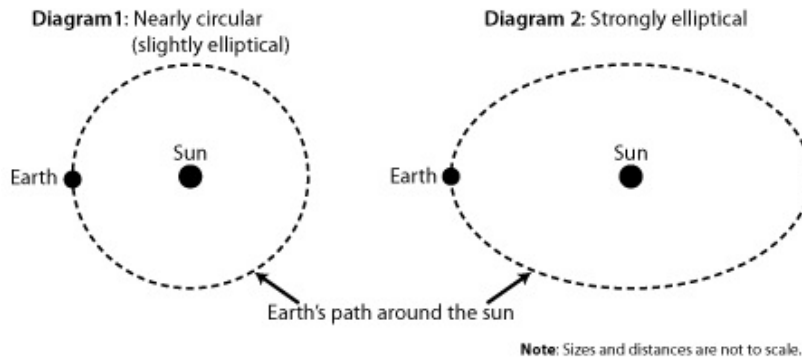

4. The diagram below shows the Earth with its axis of rotation pointed toward the Sun.
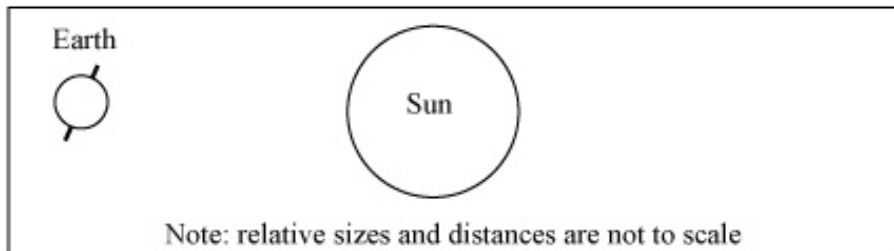
Which of the following diagrams show the earth and sun six months later?

A.   Sun   Earth

B.   Sun   Earth

C.   Sun   Earth

D.   Earth   Sun
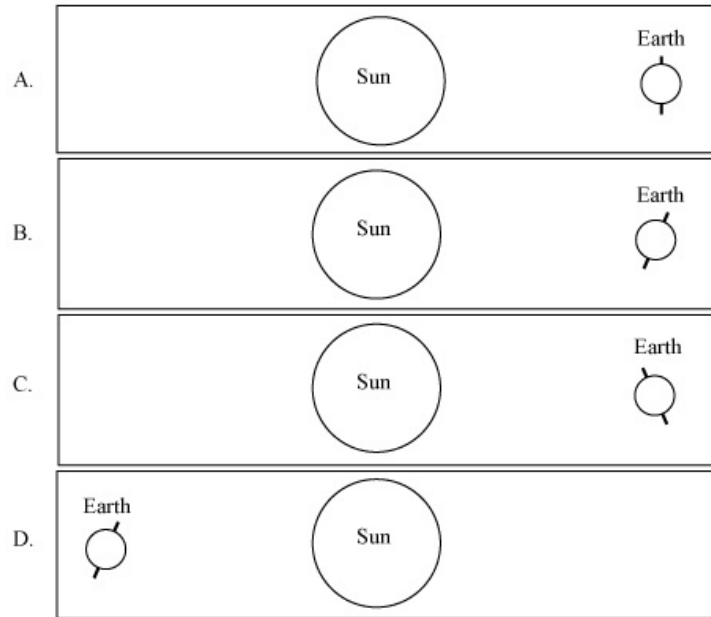
5. A student wants to find out if a particular kind of plant grows better in the sun or in the shade. She has two identical plants. She places one plant in sand and sets the plant in the sunlight. She adds minerals and water to the sand.

Sunlight
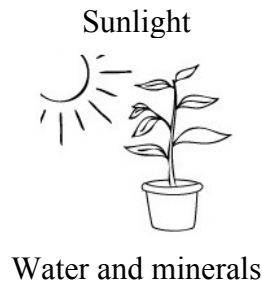
Water and minerals

Which of the following conditions should she use for the second plant to determine the effect of light?

| a. Sunlight	b. Sunlight	c. Shade	d. Shade
Water and minerals	Water	Water and minerals	Water

6. Which of the following is TRUE about how environmental conditions have changed since the time life began on Earth?
    a. Conditions have remained about the same everywhere on Earth, with only minor changes from year to year.
    b. Conditions have remained the same in the oceans but have changed on land.
    c. Conditions have remained the same except for a few sudden changes in certain

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locations due to disasters, such as a meteorite striking the Earth.

    d. Conditions have changed in significant ways everywhere on Earth, with some of these changes happening suddenly and others more gradually.

7. Which of the following have scientists found when they have compared extinct and existing species?

    a. They have found similarities and they have found differences.

    b. They have found similarities, but they have not found differences.

    c. They have found differences, but they have not found similarities.

    d. There is no way to compare extinct and existing species.

8. A person is riding a snowmobile in a snowy field. As the snowmobile reaches a frozen lake, the person turns off the snowmobile's engine and allows the snowmobile to slide across the lake. What will happen to the motion of the snowmobile if friction and air resistance act to slow the snowmobile down?

    a. The snowmobile will move slower and slower the entire time it is sliding across the lake.

    b. The snowmobile will move at a constant speed the entire time it is sliding across the lake.

    c. The snowmobile will move at constant speed for a while and then slow down as it is sliding across the lake.

    d. The snowmobile will slow down for a while and then move at constant speed as it is sliding across the lake.

Friction and air resistance
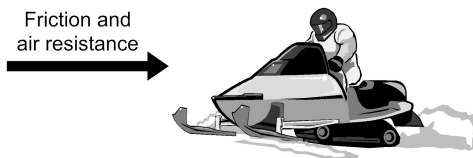
9. The diagram below shows the feeding relationships between populations of organisms in an area. The arrows point from the organisms being eaten to the organisms that eat them. Using only the relationships between the organisms shown in the diagram, if most of the worms are killed, which of the following statements describes what will happen to the number of robins and why?

WORMS → ROBINS → FOXES
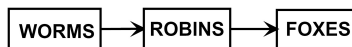
    a. The number of robins will increase because there are fewer worms to eat them.

    b. The number of robins will decrease because there are not enough worms for them to eat.

    c. The number of robins will stay the same because the worms are killed, not the robins.

    d. The number of robins will stay the same because a change in the population of worms will not affect any other population of organisms.

10.   Which of the following statements is TRUE about food for animals and plants?

    a. Animals and plants need food as a source of energy and as a source of material for building body parts such as muscles in animals and leaves in plants.

    b. Animals and plants need food as a source of energy but not as a source of material for building body parts such as muscles in animals and leaves in plants.

    c. Animals and plants need food as a source of material for building body parts such as muscles in animals and leaves in plants but not as a source of energy.

    d. Animals and plants need food to keep them alive, but the food is not a source of

energy or a source of material for building body parts such as muscles in animals and leaves in plants.

11. An engineer wants to know how well an airplane will fly when it is raining. She makes a model of the airplane and finds out that the model is able to fly in the rain. What conclusions can she draw?
   a. She can be absolutely certain that the real airplane will fly well in the rain because the model flew well when it was raining.
   b. She can be absolutely certain that the real airplane will fly well in the rain, but only if her model includes all of the things she thinks might affect how the real airplane flies in the rain.
   c. She cannot be absolutely certain that the real airplane will fly well in the rain unless she actually flies the real airplane in the rain.
   d. She cannot be absolutely certain that the real airplane will fly well in the rain because predictions made using models are never accurate.

12. Consider the following situations: Situation 1: A battery is used to power a cell phone. Situation 2: The Sun shines on a plant. Is energy being transferred in either of these situations?
   a. Energy is transferred in both situations.
   b. Energy is NOT transferred in either situation.
   c. Energy is transferred when a battery is used to power a cellphone, but energy is NOT transferred when the Sun shines on a plant.
   d. Energy is transferred when the Sun shines on a plant, but energy is NOT transferred when a battery is used to power a cell phone.

13. Where can new clouds form?
   a. New clouds form only near factories and cities because clouds need pollution in the air to form.
   b. New clouds form only over lakes or oceans because clouds need a body of water below them to form.
   c. New clouds can form anywhere, even far from bodies of water and cities because water in the air can move from place to place and can form clouds without pollution.
   d. New clouds do not form. Clouds just move from place to place.

14. Which of the following is TRUE about the wearing away of the solid rock of mountains by wind and water over time?
   a. The solid rock of mountains was being worn down by wind and water millions of years ago, and is being worn down today.
   b. The solid rock of mountains was being worn down by wind and water millions of years ago, but is no longer being worn down today.
   c. The solid rock of mountains is currently being worn down by wind and water, but was not being worn down millions of years ago.
   d. The solid rock of mountains was not being worn down by wind and water millions of years ago, and is not being worn down today.

15. Which of the following *always* results from a chemical reaction?
   a. Fire
   b. Bubbles
   c. A new substance that is a solid
   d. A new substance that can be a solid, liquid, or gas

Appendix B: Semi-Structured Interview Protocol

1. What attracted you to joining the girls triathlon training program?
2. What did you like best about participating in the program?
3. Please share how the program has impacted the way you feel about school and science.
4. What are your best subjects in school? Why? What about your weakest subjects?
5. How well do you feel you understand science?
6. (If confidence is lower) What do you think would make science more interesting or exciting?
7. What activities or types of lessons do you enjoy in science?
8. Describe the best teacher you've ever had in science, what made her/him so good? What about the worst teacher?
9. What do you see yourself doing when you grow up?
10. What do you think about women holding top positions in scientific fields?
11. How do you feel about upcoming science courses?
12. What experiences have you had that have best help you prepare for success in science?

Questions were chosen to provide a starting point to apply aspects of *Social Cognitive Theory* in deriving emerging categories that included effects of the OST program on goal directed behavior, self-efficacy, science attitudes, motivation and achievement; environmental factors such as triathlon training, peer mentoring, role models, nutrition and health based instruction that contributed to program outcomes; and the effects of improved fitness on cognitive processes involved in science learning that include constructs and strategies of behavioral regulation and metacognition.

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