CASTELLANO, MICHAEL A., M.S. Effects of an Acute Bout of Resistance Exercise on Cognitive Performance in Preadolescents. (2014)
Directed by Dr. Jennifer L. Etnier. 57 pp.

Over the past two decades a positive effect on cognitive performance has consistently been identified following an acute bout of aerobic exercise. (Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997). A limited number of studies have identified a similar positive effect following acute aerobic exercise in preadolescent samples (Ellemberg & St-Louise-Deschenes, 2010; Hillman, Pontifex, Raine, Castelli, Hall, & Kramer, 2009; Pesce, Crova, Cereatti, Casella, & Belluci, 2009; Tomporowski, 2003). Resistance exercise within adult samples has also been associated with increases in cognitive performance (Chang & Etnier, 2008, 2009; Chang, Ku, Tomporowski, Chen, & Huang, 2012). There is currently no existing research examining the effects an acute bout of resistance exercise has on the cognitive performance of a preadolescent sample. A possible reason for this lack of research is the misconception that resistance exercise can have detrimental effects on the developing bodies of preadolescents. These safety concerns have been deemed unnecessary as recent statements from both the American Academy of Pediatrics (AAP) and the American College of Sports Medicine (ACSM) have determined resistance exercise in preadolescence is safe and even beneficial to the bones, joints, and muscles of developing bodies. The purpose of this research was to examine the effects an acute bout of resistance exercise has on cognitive performance by a preadolescent sample.

Participants were randomly assigned to one of two different treatment conditions (exercise or control) and completed two sessions measuring cognitive performance (pre-test and post-test). Participants in each condition completed a number of cognitive tasks testing executive function and completed a 20 minute bout of resistance exercise. Those in the exercise condition completed the cognitive tasks immediately after the resistance exercise. Those in the control condition completed the cognitive tasks immediately before the resistance exercise.

Analyses revealed that for errors within the Stroop W condition, a measure of processing speed and inhibition, there was a significant difference between groups such that the exercise group had fewer errors at the post-test than the control group. There were no significant differences for task switching, problem solving, working memory, and visual attention between groups. The results for this sample thus suggest that resistance exercise may have a clinically meaningful effect on aspects of processing speed and inhibition.

EFFECTS OF AN ACUTE BOUT OF RESISTANCE EXERCISE ON COGNITIVE PERFORMANCE IN PREADOLESCENTS

by

Michael A. Castellano

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Greensboro
2014

Approved by

____
Committee Chair

To…

My Parents

and

Caroline

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair ___________________________________

Committee Members ___________________________________

____

____
Date of Acceptance by Committee

____
Date of Final Oral Examination

ACKNOWLEDGMENTS

I would like to thank my mentor, Dr. Jennifer Etnier, for her faith in this study from the beginning and her unbelievable patience over the past two years.

I would also like to thank the members of my committee, Dr. William Karper, and Dr. Louisa Raisbeck for their support and assistance in the development of this study.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Over the past two decades, a positive effect of exercise on cognitive performance has been established. Etnier, Salazar, Landers, Petruzzello, Han, and Nowell (1997) summarized the results of 134 studies in order to better understand how exercise can affect cognition throughout the life span. It was determined that exercise has a positive effect on cognitive performance across all age ranges. An effect size of ES = 0.16 was identified for studies testing the effects of acute exercise on cognitive performance. Lambourne and Tomporowski (2010) reviewed 40 studies that used a within-subjects design to focus on acute exercise and cognition and their results indicated that the overall mean effect was 0.20 for cognitive tasks following exercise. It was determined that a significant positive effect is seen for cognitive tasks shortly following an acute bout of exercise, particularly in the domains of executive function. Chang, Labban, Gapin, and Etnier (2012) statistically analyzed the results of 79 studies dealing specifically with acute exercise and cognition and identified an overall positive effect size of ES=0.097.Similar to the results identified by Lambourne and Tomporowski (2010), it was determined that the largest effects are observed when exercise intensity is moderate to high and when the exercise sessions lasts for at least 20 minutes. Tasks testing executive function were also shown to result in the highest effect size. These studies show that following exercise a positive effect does exist on cognitive performance, though it should be noted that this research has been conducted primarily with adult samples and with aerobic exercise.

A limited number of studies exist focusing on the effects exercise has on the cognitive performance of a preadolescent population. Recently researchers have begun examining the effects of acute exercise on cognitive performance in children. Tomporowski (2003) conducted a narrative review of this literature. Based upon findings from four studies, it was determined that acute exercise has a positive effect on cognitive performance in normal functioning children. Since this narrative review, additional empirical studies continue to support a beneficial effect of acute aerobic exercise for the cognitive performance of children. Hillman, Pontifex, Raine, Castelli, Hall, and Kramer (2009) conducted a study identifying the effects an acute bout of aerobic exercise has on a preadolescent sample. Twenty participants (*M*=9.5 years) walked on a treadmill for 20 minutes at 60% of their previously determined maximal heart rate. It was determined that following a moderate bout of aerobic exercise, participants performed significantly better on cognitive tasks testing cognitive control and reading. Pesce, Crova, Cereatti, Casella, and Belluci (2009) conducted a study with the goal of identifying the effect both team training and individual aerobic exercise can have on memory within a preadolescent sample. Sixty participants between 11 and 12 years old completed a free recall memory task to assess immediate and delayed recall following a team aerobic training session or an individual aerobic exercise session. A positive effect on immediate recall performance was seen following the aerobic team activity while delayed recall performance improved in just the recency portion of the memory task for both the team training and aerobic exercise. Ellemberg and St-Louise-Deschenes (2010) conducted a study testing the effect acute aerobic activity has on cognitive performance of 7-year old and 10-year old age groups. It was determined that following a 35-minute bout of aerobic exercise both age groups saw a decrease in reaction time compared to the control session (watching television). It should be noted that a stronger effect was identified for acute aerobic exercise on reaction time in the 10-year old participants compared to the 7-year old participants.

Though there are a few studies focusing on resistance exercise with adults, research focusing on resistance exercise in preadolescence is nonexistent due possibly to health concerns. However, over the past few years it has been determined that the previous cautionary views on resistance training are unnecessary as recent evidence supports that resistance training is actually beneficial to children (Gomez, Johnson, Martin, Rowland, & Small, 2001). The American Academy of Pediatrics and the American College of Sports Medicine have both acknowledged the benefits resistance training has for children (Gomez et al., 2001; Luke, 2009). Benefits such as increased bone density, joint laxity, muscular strength, and a reduction in injury have been seen following proper resistance training programs in children and preadolescents. Behm, Faigenbaum, Falk, and Klentrou (2008) conducted a review of literature pertaining to safety concerns with resistance exercise and preadolescence determining that, "Traditional fears associated with youth RT [resistance training] have been replaced with more recent findings that indicate that regular participation in weight bearing physical activities is essential for normal bone growth and development" (p. 556). While the physical benefits of resistance training in children have been identified, further research is needed to determine the extent to which cognitive benefits result from an acute bout of resistance exercise.

Resistance exercise within adult populations has shown that this mode of exercise is also associated with improvements in cognitive performance. Three studies have been conducted to determine the affect an acute bout of resistant exercise has on the cognitive performance of adult samples. Chang and Etnier (2008) conducted a study testing the effect an acute bout of strength training has on an adult population. Following a 45-minute bout of resistance training at moderate intensity an increase in processing speed was identified, suggesting a positive effect of acute resistance training on cognitive function. Chang, Ku, Tomporowski, Chen, and Huang (2012) conducted a study to identify the effect resistance training has on goal planning (an executive function) in older adults. It was determined that following a 20-minute bout of resistance training at moderate intensity, efficiency of goal planning saw a significant improvement compared to the control condition. Chang and Etnier (2009) identified a dose response relationship between acute resistance training and cognitive function in an adult population. It was determined that a positive effect does exist between acute resistance exercise and cognitive performance in the domains of information processing and attention. A linear effect of exercise intensity was identified on information processing suggesting that a higher intensity of exercise results in the highest effect size. An inverted-u was identified in regards to the effects of exercise intensity on attention resulting in the greatest effect size when exercise intensity is moderate.

In summary, exercise has been shown to result in a positive effect when conducted prior to measuring cognitive performance. Studies looking at the effect resistance exercise has on cognitive performance have generally resulted in a positive effect within young adult, adult, and older adult samples. Perhaps because safety concerns in regards to resistance exercise for preadolescent samples have only recently changed, no research exists examining the effect an acute bout of resistance exercise has on the cognitive performance of a preadolescent sample.

Purpose

In order to further the knowledge of resistance exercise and the effects it has on a preadolescent population within the field of exercise psychology additional research is needed. Evidence supports that a single session of aerobic exercise can benefit cognitive performance by children. This study examines the impact a single session of resistance exercise has on cognitive performance in 3rd grade children.

Hypothesis

It is hypothesized that a single session of resistance exercise will have a positive effect on the cognitive performance in this preadolescent sample. The domains of cognitive performance in which a positive effect are expected are task switching, problem solving, inhibition, processing speed, working memory, and visual attention.

CHAPTER II

EXTENDED LITERATURE REVIEW

While the benefits *resistance* exercise can have on the cognitive performance of a preadolescent population have not been extensively researched, a great deal of information does exist in the field of exercise and cognition in terms of the benefits *aerobic* exercise has for children. This review of literature will highlight the effects various modes, durations, and intensities of exercise can have on cognition in several different age groups, with a focus on acute exercise in preadolescent populations.

Exercise and Cognition

Etnier, Salazar, Landers, Petruzzello, Han, and Nowell (1997) conducted a meta-analysis that compared results within 176 studies related to exercise and cognition throughout the lifespan. Of the 176 studies identified for this meta-analysis, 134 contained the necessary information for calculating effect size. It was determined that the effect size for all of the studies was 0.25 (SD = 0.69, ES n = 1,260, $p < .05$), suggesting that exercise significantly increases cognitive functioning. The differences between acute and chronic exercise were discussed in terms of the effects they can have on cognitive performance. Chronic exercise consists of any physical activity, aerobic or anaerobic, that continues beyond one session, regardless of duration. Acute exercise is a single bout of physical activity. It was discovered by Etnier et al. that while chronic exercise yields a greater effect size (ES = 0.33), a small positive effect size does exist for acute exercise as well (ES = 0.16).

Lambourne and Tomporowski (2010) conducted a meta-analysis that compared 21 studies measuring cognitive performance before and during an acute bout of exercise, as well as 29 studies that measured cognitive performance before and after exercise. Analyses were used to identify the amount of time during and after exercise it takes for cognitive tasks to be affected. During the first twenty minutes of exercise, cognitive performance is negatively impacted for perceptual tasks and tasks measuring processing speed. Beyond twenty minutes of exercise, effect sizes for simultaneous cognitive performance increases, specifically in tasks measuring inspection time. Following exercise, cognitive performance was positively affected by acute exercise, specifically in areas of memory, retrieval, and processing speed. Of further interest, the particular type of exercise conducted impacted the nature of the effects. Results showed that cognitive performance is positively affected both during and after cycling. However, when running on a treadmill, cognitive performance is negatively affected, whereas following treadmill exercise cognitive performance is positively affected.

Chang, Labban, Gapin, and Etnier (2012) reviewed the results found within 79 studies focusing on acute exercise and cognitive performance. The influences of moderating variables were taken into account within the analyses. Type of cognitive performance and the level of fitness for each participant were identified as moderating variables during exercise such that both executive function and higher fitness levels resulted in higher effects. When cognitive performance was assessed immediately following the exercise session, that is, moving directly from exercise into cognitive tasks, it was determined that moderate intensity exercise results in the greatest positive effect on cognitive performance. A smaller positive effect between lighter intensity aerobic exercise and cognitive performance was also identified. Thus, it was determined that following exercise at a light or moderate intensity, positive effects were observed. In contrast, no positive effect was seen following exercise conducted at intensities above moderate. It was also determined that cognitive task type significantly moderates the relationship between exercise and cognitive performance with higher effect sizes in cognitive tasks measuring executive function and crystallized intelligence. When cognitive performance was assessed following a delay after completion of the exercise, exercise was seen to have a positive effect significantly greater than zero at all intensity levels except very light.

While a number of studies have determined that an acute bout of exercise does have a positive effect on cognitive performance, specific moderators should be noted that result in the largest effect sizes. When conducting cognitive tests following exercise, the intensity of the exercise should be moderate to high with a 1-15 min delay before testing cognition. The cognitive tasks used should test executive function and be administered in the morning in order to result in a slightly higher effect size. In addition, Lambourne and Tomporowski (2010) identified that subjects also tend to perform better on cognitive tasks shortly following an acute bout of exercise with increased performance in measures of processing speed, memory, and retrieval.

Children vs. Other Populations

The brain of a child develops steadily through preadolescence and into early adulthood. Hedman, van Haren, Schnack, Kahn, and Hulshoff (2011) reviewed 56 magnetic resonance imaging studies. It was determined that starting at the age of nine, 1% annual brain growth is seen in children every year, usually leveling off around the age of thirteen. After the age of thirty-five, volume loss is typically seen at a rate of about .02% every year. Concomitant with the increase in brain volume that occurs in children, increases in various levels of cognitive function take place. Executive function in preadolescence improves along with areas of memory and information processing; areas considered important for academic performance. The annual brain growth described above is an average that Hedman et al. identified across a group of studies. However, there is also evidence from a study conducted by Giedd et al. (2001) in which they looked at children younger than age 9 and reported a steady increase in brain growth beginning at age 4 and continuing to the previously described 13 year old peak. While it has been identified that the human brain experiences its largest increase in growth between early childhood and 13 years of age, ways in which to utilize and foster this brain growth are still being discovered. One avenue of research that has received attention is the exploration of the potential benefits of exercise for the cognitive performance of children.

Tomporowski, Davis, Miller, and Naglieri (2008) conducted a review on the existing literature focusing on the effects chronic exercise can have on cognitive performance of children. After reviewing sixteen cross-sectional studies, Tomporowski et al. (2008) determined that the more physically fit children are, the better they perform on cognitive tasks. It should also be noted that following a chronic aerobic exercise program, executive function has been shown to increase. Four correlational studies were also reviewed.   Similar to the cross-sectional studies, scores on fitness tests are positively related to academic achievement by children. Three longitudinal studies all showed that children exposed to regular chronic exercise instead of their normal physical education classes performed better on standardized tests and had better overall health than the children within control groups or regular physical education classes. Tomporowski et al. concluded that the evidence supports a positive relationship between academic achievement and chronic exercise. However, one of the primary limitations that they identified was that random assignment was not used for the majority of the studies. Based upon this limitation, they emphasized the importance of using true experimental designs in subsequent research in order to validate research findings and test the causal relationship.

Tomporowski (2003) also conducted a narrative review that focused on acute bouts of exercise and cognitive performance by various preadolescent populations. Tomprowski reviewed 22 studies, 18 of which include children diagnosed with clinical disorders. It was determined that in the studies using a normal functioning sample exposed to acute bouts of exercise, a positive effect on cognitive performance does exist.

It was determined that the ideal length of time for an exercise session is between 30- and 40-min, with significantly higher scores in cognitive tasks following this time frame than following a 20-min bout of exercise. It was also shown that physical activity at a vigorous intensity may result in the greatest positive impact on cognitive performance. In the research focusing on preadolescents diagnosed with clinical disorders such as autism spectrum disorders, attention deficit disorders, mental retardation, and behavioral disorders, the effect of acute exercise on cognitive performance appears to be mixed depending on the clinical disorder being addressed.

Tomporowski et al. (2008) and Tomporowski (2003) have determined that both acute and chronic exercise have a positive effect on cognitive performance in a preadolescent population. A 30- to 40-min bout of acute exercise has been shown to be most effective in increasing performance on cognitive tasks performed following the exercise session. Components of executive function which are present in standardized tests and measures of processing speed and attention have been shown to increase following exercise in preadolescent populations. When comparing children to other populations on the effects exercise has on cognitive performance many of the outcomes are the same. Executive function has been shown to increase following acute and chronic aerobic exercise in children as well as adults. However, much of the available research on acute exercise does continue to focus on adult populations. While few studies exist that identify the effect acute exercise has on cognitive performance in children, the reviews of the available research suggest that this is a promising area of research, and future research is necessary to improve our understanding of how to use exercise to benefit cognitive performance by preadolescents.

Acute Resistance Exercise in Preadolescence

Little is known of the effects an acute bout of resistance exercise has on the cognitive performance of a preadolescent population. Most of the research conducted with preadolescents thus far has focused on chronic training and aerobic exercise. A major reason for this lack of knowledge relative to the effects of resistance exercise in particular is likely because of the possible concern that resistance training can have detrimental effects on the growing body of a preadolescent. It was once thought that resistance exercise could hinder muscle and joint development due to bone plate disturbances and bodily changes occurring throughout childhood and leading into adolescence. However, according to the American Academy of Pediatrics (2013) resistance exercise has been found to be quite beneficial to a preadolescent population. Children, like adults, will see increases in strength, muscle mass, and muscle endurance in addition to reducing risk for injury and enhancing overall fitness levels. The only risks associated with resistance training for children stems from incorrect technique and/or improper programming. The American College of Sports Medicine (ACSM) has also recognized the benefits that children can see following an appropriate resistance program (2009, 2013). According to the ACSM the differences between resistance exercise and weightlifting should be understood prior to beginning a strength-based program with a child. Resistance exercise is a specialized mode of fitness training with the goal of increasing strength, flexibility and endurance within muscles whereas weightlifting is the act of lifting close to maximal amounts of weight for competitive purposes. When determining the amount of weight a child will be using for resistance exercise, a one to five repetition maximal effort lift is not recommended. According to the ACSM, children should be working in the range of 6-15 repetitions for 2-3 sets on 2-3 non-consecutive days per week. While it seems that the views of professional organizations on resistance exercise are beginning to make a shift towards acceptance, it is likely that society will require additional research-based evidence before resistance exercise becomes an acceptable mode of exercise for children. In order to validate the importance of resistance exercise for children it becomes increasingly important to understand the effects anaerobic exercise may have on the brain. A positive effect between resistance exercise and cognitive performance has been identified within older populations and discovering similar results within children could result in powerful implications.

Sibley and Etnier (2003) reviewed 44 studies dealing with exercise, children and cognitive/academic performance. Out of the 44 studies included in this meta-analysis only 16, 9 published and 7 non-published, were considered to be acceptable true experimental designs. Thirteen of these 16 studies used a chronic exercise program while the remaining 3 used an acute design for exercise sessions. Out of these 16 studies, only one used isometric strength training as the primary mode of exercise during a chronic exercise program, producing an effect size of 0.65. It should be noted that the participants within this study had been diagnosed with various intellectual disabilities. Two of the studies reviewed, 1 acute and 1 chronic, did not focus on resistance training as the primary form of exercise, but rather incorporated resistance exercise combined with aerobic exercise. However, these studies incorporating resistance exercise and aerobic exercise through circuit training into the programming reported a significant increase in executive function producing an average effect size of 0.745.

These results not only show that chronic exercise can positively affect cognitive functioning using a variety of designs, it also shows that chronic and acute resistance exercise used in combination with aerobic training can have a positive effect on cognitive functioning. Though only one study was identified within this meta-analysis that used resistance exercise in isolation, a positive effect was seen on executive function following a 6 week isometric strength training program. Furthermore, all of the studies incorporating acute resistance exercise programs saw a positive effect on cognitive performance.

Although no research exists exploring the effects acute resistance exercise has on preadolescents, there are several recent studies which have examined the effects of a single session of aerobic exercise on cognitive performance in preadolescent populations. Hillman, Pontifex, Raine, Castelli, Hall, and Kramer (2009) identified the effect an acute bout of moderate walking has on cognition and academic achievement in a preadolescent population. Twenty participants, 12 boys and 8 girls were selected following physical and neurological screening. The average age among participants was 9.5 years. Cognitive performance and academic achievement were measured using the modified flanker task, assessing inhibitory control, and the Wide Range Achievement Test 3rd Edition (WRAT-3), a written assessment of achievement for the areas of reading, spelling, and arithmetic. A within-subjects design was used requiring all participants to attend two randomly assigned counterbalanced sessions for the study. The resting session consisted of 20-min of seated rest followed by the modified flanker test and the WRAT-3. During the exercise session participants would walk on a treadmill at sixty percent of their estimated maximal heart rate for 20-min followed by the cognitive tests in the same order taken for the resting session.

Following exercise, participants scored significantly higher in the reading domain of the WRAT-3, compared to the resting session. No significant differences were identified in the spelling and arithmetic domains between sessions. For the modified flanker task, it was identified that performance significantly improved by nearly 5% following exercise compared to following rest. These findings show that acute exercise does have a positive effect on cognitive control and reading in a preadolescent population, offering a new way in which cognitive performance and academic achievement can be improved during childhood.

Pesce, Crova, Cereatti, Casella, and Belluci (2009) and Ellemberg and St-Louise-Deschenes (2010) have also conducted studies in which a positive effect of acute exercise on cognitive functioning was identified. Pesce et al. (2009) identified the benefits an acute bout of exercise can have on memory within a preadolescent population. The study included 60 middle school children, between the ages of 11 and 12 years. The cognitive task was a 20 question free-recall memory test, consisting of immediate and delayed recall. All participants attended 4 sessions within the study. The first session for the study was an introduction to the memory test explaining how the test works and what is expected from participants. In order to account for potential learning effects, the baseline session, solely consisting of the memory test, was conducted during the third session while the second and fourth sessions consisted of either a team activity or individual aerobic activity (circuit training) prior to the memory test. Exercise intensity between sessions two and four were held constant and kept equivalent through the use of heart rate monitors and ratings of perceived exertion in order to maintain moderate to vigorous intensity throughout the two exercise sessions. Pesce et al. concluded that immediate recall performance was improved as compared to the baseline test following the team activity, whereas the delayed recall performance was greater in just the recency portion of the word list for both aerobic exercise and team training. These results show the benefits an acute bout of exercise can have on memory retention within a preadolescent population, with implications of increased academic performance in educational settings.

Ellemberg and St. Louis-Deschenes (2010) identified the effects an acute bout of exercise has on the cognitive development of two different age groups of children. Cognitive performance was tested using a choice response task measuring reaction times following an acute bout of aerobic exercise in samples of 7- and 10-year olds. Within each age group 18 participants performed 35-min of aerobic exercise followed by the choice response and reaction time tests, while the other 18 participants within each age group watched television prior to completing the same cognitive tests. It was discovered that both groups of children saw a significant increase in performance after completing the acute bouts of aerobic exercise compared to the groups that watched television prior to the tests. It was also identified that the improvements in cognitive performance were greater for the 10-year old participants compared to those of the 7-year old group. An important contribution of this study is that the results show that greater effects may be seen in a preadolescent population that is slightly older.

After examining the available literature related to exercise and cognitive performance in a preadolescent population, it is apparent that more research needs to be conducted in the area of acute bouts of exercise and their effects on cognitive performance. Additionally, while the majority of previous research with preadolescents focuses on acute bouts of aerobic exercise, evidence from research with older adults (discussed next) suggests that a positive relationship may exist between acute bouts of resistance training and cognitive performance within a preadolescent population.

Aerobic vs. Anaerobic Exercise

Aerobic and anaerobic exercise are categorized based upon the ways in which oxygen and energy are used during bouts of exercise. Aerobic exercises such as running, biking, and walking are typically associated with oxygen being used to fuel metabolism within muscles, allowing continual muscle contraction for extended periods of time. Anaerobic exercises such as sprinting and resistance exercise are performed at a higher intensity in which oxygen is unable to circulate within the muscles at a quick enough rate to meet the demands of the activity. Anaerobic exercise results in other forms of energy being used during muscle contraction, impairing muscle function quicker than aerobic exercises due to increased production of lactic acid and depletion of the high energy bonds within adenosine triphosphate. During anaerobic exercise it is necessary to maintain an intensity level high enough to primarily use the anaerobic energy system in order to truly be considered anaerobic. While this intensity level is dependent on exercise mode, an activity such as resistance exercise would require an intensity that is moderate to high. Resistance exercise at too low of an intensity, while typically considered an anaerobic mode, may actually be physiologically aerobic.

Past research has focused almost exclusively on aerobic exercise and a positive effect on cognitive functioning has been identified in all ages (Etnier et al., 1997). However, researchers have begun to look at anaerobic exercise as another way in which cognitive performance may be positively affected.

Chang and Etnier (2008) showed that a positive effect may exist within a middle-age sample. Forty-one participants were randomly assigned to either a resistance exercise session or a control session to test the effect of acute resistance exercise on cognitive performance. The first session was used to determine appropriate weights that would be used for each exercise and also addressed health concerns that may arise during the exercise session. The first session consisted of determining appropriate weights for each of the resistance training exercises being used by determining a 10 max repetition for each movement by having the client lift a weight for 10 repetitions with moderate effort. In session two, the participants were randomly assigned to either the resistance exercise group or the reading control group. The control group was asked to read a pamphlet pertaining to resistance exercise for approximately the same duration of time the resistance exercise program would take, while the resistance exercise group was taken through the predetermined strength-based exercises. The resistance exercise program consisted of six different exercises using two sets of ten repetitions, incorporating a full body workout. The sessions lasted approximately 45 minutes and the resistance exercise group was kept at a moderate intensity, based on the weights assigned.

Immediately before and after completing the 45 minute sessions, both groups completed the Stroop Test, a series of tests measuring processing speed and inhibition. The Stroop Test consists of a word condition, a color condition, and a color word condition. Participants also took the Trail Making Test, a test of general brain function requiring the participant to connect a series of numbers and letters in a progressive order. It was determined that an acute bout of resistance exercise has significant benefits on processing speed (word and color components of the Stroop Test). Results from the color word component of The Stroop Test and from the Trail Making Test were not significant. While the results from this study show a positive effect of resistance exercise on cognitive functioning, the average age of the participants within the study was 49.1 years, making it unclear as to whether similar effects would be seen in a younger population.

Chang, Ku, Tomporowski, Chen, and Huang (2012) conducted a study in order to identify the effects of acute resistance exercise on goal planning by late- to middle-aged adults (M=57.2 years). Fourteen men and 16 women were included in the study following a screening process to assure normally functioning physical and mental capabilities in addition to screening for health concerns and current fitness levels. Participants attended three sessions during the study. Planning was tested using the Tower of London Task (TOL). The resistance exercise consisted of a ten minute warm-up followed by 20 minute of resistance training at a moderate intensity, based on the previously determined weights for each exercise. The exercise program consisted of two sets of ten repetitions for seven different exercises targeting all major muscles. In the exercise session, participants completed the TOL task as a pretest, followed by the resistance exercise, and ended with the TOL task as a posttest. During the control session participants completed the TOL as a pretest, followed by 20 minutes of reading, and ended with the TOL task as a posttest.

Following a 20 minute bout of resistance exercise, a significant decrease was seen on the number of moves made during the TOL. An increase in initial move time for each problem was also identified following the exercise session with no significant increase in total time taken showing an increase in planning prior to beginning each problem within the TOL. These results show that acute resistance exercise has a positive effect on planning within a late- to middle-aged adult population.

Chang and Etnier (2009), having already identified a positive affect between acute anaerobic exercise and cognitive performance, conducted a study to explore a possible dose-response relationship between anaerobic exercise intensity and cognitive function. Sixty-eight participants (M=25.95 years) were randomly assigned into one of four groups: a control group, 40%, 70%, or 100% of a ten-repetition maximal resistance exercise session. The exercise sessions consisted of two sets of ten repetitions for six different exercises targeting all major muscles within the upper body. To ensure the appropriate intensity was used for each group heart rate monitors, ratings of perceived exertion (RPE), and the felt arousal scale (FAS) were used. RPE and FAS are two ways in which participants can self-evaluate their effort during exercise. The cognitive tests used were the Stroop Test and the Paced Auditory Serial Addition Test (PASAT). The PASAT is a measure of information processing and attention.

Participants were required to attend two days of testing. On day one participants performed the Stroop test and PASAT for baseline measurements. During day two, resting heart rate was recorded followed by performance of the Stroop Test and PASAT for the pretest. For the exercise groups, participants performed the prescribed exercises at the assigned percent of their ten-repetition max (10 RM) while heart rate, FAS and RPE were recorded. If assigned to the control group participants watched a movie for the same amount of time as the exercise sessions. After exercising or watching the video, participants completed the Stroop Test and PASAT a second time as a posttest measure.

Chang and Etnier (2009) determined that there is a linear relationship between basic information processing and acute anaerobic exercise intensity. As intensity level increased within the assigned groups so did scores on three levels of The Stroop Test. When it came to testing attention and slightly more complex information processing using the PASAT, it was determined that cognitive performance increases curvilinearly with exercise intensity. The greatest positive effect was seen following anaerobic exercise at70% of participants' 10 RM and effects decreased within the 100% of 10 RM group. Chang and Etnier identified a dose response relationship between acute anaerobic exercise intensity and cognitive performance. Anaerobic exercise intensity has a linear positive affect on basic information processing, but for more complex information processing the relationship is curvilinear and 70% of 10 RM is ideal for the largest positive effect on attention.

Pontifex, Hillman, Fernhall, Thompson, and Valentini (2009) conducted a study to determine the effects an acute bout of aerobic and anaerobic exercise would have on working memory. Twenty-one participants (*M*=20.2 years) attended four sessions including a baseline, aerobic, anaerobic, and a control, with the order of the latter three sessions being counterbalanced. Working memory was measured among participants through the use of a modified Sternberg task, requiring participants to identify a previously presented letter in a set of three, five, or seven letters at an increasing difficulty. Participant's cardiorespiratory fitness was assessed using a VO_2 max test. Day one (baseline testing) consisted of VO_2 max testing followed by strength testing used to identify a one repetition max (1 RM) for all exercises used during the resistance session. The program used during the resistance session consisted of seven different exercises targeting all major muscles. During sessions two, three, and four all participants took the modified Sternberg task immediately before, immediately after, and thirty minutes after the assigned conditions for the session. The anaerobic session included the seven resistance exercises used during the strength assessment, this time consisting of three sets of eight to twelve repetitions at 80% of their respective predetermined 1 RMs. The anaerobic session lasted for approximately 30 minutes. The aerobic session required participants to run on a treadmill at 60-70% of their VO_2 max for 30 minutes. During the control session participants sat quietly for 30 minutes and were allowed to read magazines.

Pontifex et al. (2009) determined that immediately following and 30 minutes after an aerobic exercise session a positive effect on working memory exists. A similar effect was not seen for the anaerobic and control sessions. While a significant effect was not seen for acute anaerobic exercise and cognitive performance by Pontifex et al., it should be noted that only working memory was measured as a component of cognition. Previous research in adult samples has identified a positive effect on cognitive performance in domains other than working memory following resistance exercise suggesting that additional cognitive measures may have resulted in different effects. Further research following a similar design but measuring additional components of cognitive performance may result in various effects leading to a better understanding of acute resistance exercise on a preadolescent population.

Future Directions

When studying cognitive performance and how exercise influences a person's ability to think, it is important to acknowledge factors that contribute to cognitive functioning throughout all stages of human development. Development of cognitive function begins at birth and continues throughout the lifespan of a normal functioning person, though the rate at which development occurs changes with age. The largest gains in cognitive development occur during childhood and continue through adolescence, beginning to slow in the mid-thirties.

After reviewing the existing literature on exercise and cognition it is apparent that acute bouts of resistance exercise can have a positive effect on information processing and attention within young, middle, and older adults. The majority of research identifying an effect between resistance exercise and cognitive performance uses the term "strength" when describing the exercise program used. While participants will gain strength via resistance exercise at varying rates based on repetitions and intensity, it should be understood that the ACSM has identified additional benefits such as muscular endurance and hypertrophy as likely outcomes to resistance exercise at higher repetitions. Higher repetition sets are commonly seen in the literature on resistance exercise and cognition, suggesting that strength training may not be an accurate term. The phrase resistance exercise should be used as a more general term encompassing the endurance, strength, and hypertrophy benefits muscles may receive. No research exists that attempts to determine the effect acute resistance exercise may have on cognitive performance in a preadolescent population. Now considered to be beneficial to the overall health and development of children, resistance training may offer a cost effective way in which cognitive performance can be increased in and out of the classroom. In terms of performance within schools it has also been identified that aerobic exercise at a moderate intensity has a positive effect on academic achievement within a preadolescent population. While there is no existing research on acute resistance exercise and academic achievement in a preadolescent population either, existing literature suggests this may be a population with promising outcomes.

CHAPTER III

METHODS

Participants

Fifty 3^{rd} graders participated in this study (27 female, 23 male) with a mean age of 8.32 yrs (SD=.54). The output from the statistical analyses for all outcome variables is located in Table 1.

Upon receiving approval through the Institutional Review Board, participants were recruited from Greensboro Day School, a private non-sectarian college preparatory Kindergarten through High School. Participants were between the ages of 8 and 9 years of age and functioning at a cognitively normal level for their age range. Principals and teachers of Greensboro Day School were contacted directly and briefed on the goals and expectations of the study. Participation in this study was voluntary and signed consent forms were collected from a parent or legal guardian of all interested participants and signed assent forms were collected from the children.

Procedure

Upon acceptance into the study participants were randomly assigned to either a control group or a treatment group. An analysis of variance was used to confirm that the two groups were equal based on z-scores attained from the pre-test.

Participants attended three days of testing. On day one participants, regardless of group, were introduced to the cognitive tasks. Introductions to the cognitive tasks consisted of an informational presentation and demonstration as to what was expected from each participant for each of the four cognitive tasks. Following this introduction and answering of any questions, participants were asked to perform the cognitive tests as the pre-test measure. Introductions to the resistance exercises took place immediately following the pre-test and included demonstrations of proper form for the seven exercises as well as guided practice of the movements without weights.

On day two an indirect 10 repetition maximal lift for each exercise was determined for each participant (see below), irrespective of assigned group.

On day three, the post-testing day, participants arrived at the school gymnasium during their usual 45 minute physical education class. The participants randomly assigned to the control group moved to the nearby computer laboratory to complete the measures of cognitive performance. Upon completion of the cognitive tasks participants in the control group immediately moved back to the gymnasium and began the resistance exercises. Participants randomly assigned to the treatment group remained in the gymnasium, after the control group had left for the computer lab, and began the resistance exercises. Upon completion of the resistance exercises, participants in the treatment group immediately moved to the computer laboratory for the cognitive testing. It should be noted that at least two weeks had elapsed between pre-testing and post-testing.

Resistance Exercise Protocol

Determination of Weight

The resistance exercise protocol followed the guidelines set forth by the ACSM in regards to resistance exercise in youth. All resistance exercises remained within the 6-15 repetition range and no 1 repetition maximal lifts were used. A moderate intensity, as determined by the ACSM, was used for each exercise. The weight for each exercise constituting this intensity was determined by identifying a 15 repetition low to low-moderate intensity lift for each of the seven exercises for each participant. The low to low-moderate intensity for each participant was determined through a combination of participant feedback and the judgment of the trainers working with them. Determination of the proper weights was accomplished through the use of dumbbells ranging from 1 to 10 lbs increasing in 1lb increments. In identifying the proper weight to be used for each exercise, participants were assigned dumbbells of varying weight as way to gauge the strength of each participant. The weight of the dumbbells used for the baseline session was chosen through a combination of participant feedback, too light or heavy, and the judgment of either an ACSM or National Strength and Conditioning Association (NSCA) certified fitness trainer. Following the guidelines for proper resistance training technique, the weight used by each participant for the 15 repetition lifts was either increased, decreased, or kept the same based on the observations of the certified trainers. The weight determined to be appropriate for a low to low-moderate intensity for 15 repetitions for each of the seven exercises was the weight deemed appropriate as a moderate intensity for the resistance training day.

Resistance Exercise Session

During the post-testing session participants warmed up using very light weight/no weight by quickly performing 1 set of 10 repetitions for each exercise. This warm-up was also used to remind participants of proper form before executing each exercise. Following the warm-up participants completed 2 sets of 10 repetitions at their previously determined 10-repetion maximal lift for 7 resistance exercise incorporating all major muscle groups. The resistance exercises used during the session were:

1.	Bodyweight squat	2 x 10
2.	Standing shoulder press	2 x 10
3.	Chest press	2 x 10
4.	2 point row	2 x 10 each arm
5.	Overhead tricep extension	2 x 10
6.	Bicep curl	2 x 10
7.	Bodyweight lunges	2 x 10 each leg

Measures

The Psychology Building Language Experiment (PEBL) was used as a way to administer all cognitive tasks. PEBL is a free software created by Dr. Shane T. Mueller as way to administer multiple cognitive tasks in one program with the option for customization through the creation and addition of new source codes. PEBL was chosen for this study due to its ability to chain cognitive tasks together and for its customizability of instructions prior to each measure. Due to the young age of the sample tested, many of the written directions for each cognitive task were modified to ensure understanding. The four tasks used to measure cognitive performance were the Tower of London, the Stroop test, the Corsi span, and the trailmaking task. Four different orders of these tests were created and randomly assigned to the participants within each treatment group, making sure that an approximately equal number of the different orders were represented in each group. The order of tests used during pre-test was used again for the same participants at post-test.

The Tower of London task was used as a measure of planning and problem solving. During this computer-based task participants were required to arrange 3 colored discs in a workspace to match the arrangement of a presented model in as few moves as possible. The difficulty of each trial increased across trials and participants had 60 seconds to complete each trial. The test contained 15 trials and time for completion of each trial (TOL Time), first time of movement for each trial (TOL First Time), and total steps were recorded for each participant (TOL Steps).

The Stroop Test was used to measure attention and processing speed on three increasingly challenging cognitive tasks, Stroop D, Stroop W, and Stroop C. Time taken for completion and errors made were recorded for each task. The Stroop D contained a random sequence of twenty-four colored dots (blue, red, yellow, and green) presented on a computer screen. Participants were required to identify the color of each of the stimuli using the numbers one through four on their keyboard. The key to the matching of each number with each color was displayed on the monitor throughout the Stroop Test. The Stroop W consisted of a random sequence of twenty-four words (not the names of colors) presented in blue, red, yellow, or green font. Participants were required to identify the color of each word, ignoring the word itself, using their keyboard. The Stroop C consisted of a random sequence of twenty-four words (the names of colors) presented in blue, red, yellow, or green font. Participants were required to identify the color of each word using their keyboard, ignoring the word itself. For all tasks, participants began at the top left of the screen and worked their way through the stimuli moving to the right and down.

The Corsi Span was used to assess memory. The Corsi Span is a computer-based test in which participants see a number of boxes randomly dispersed on a screen. In each trial some of the boxes, beginning with two boxes, would light up in a sequential order. Participants were required to recall the order in which the boxes lit up by clicking the appropriate boxes in the same order in which they had been displayed. Each time a participant correctly finished two trials of the same difficulty (number of boxes) another trial would begin with one additional box illuminated. Each time a participant answered incorrectly the next trial would have one fewer box. Upon incorrectly responding to two trials of the same difficulty the test ended with errors and memory span being recorded.

The trail making task was used to test task switching and visual attention during two increasingly difficult tests. The first test contained the numbers 1-18 randomly dispersed across a computer screen. Participants were asked to click each number sequentially beginning with the number 1 and continuing in order to the number 18. The second task required participants to alternate sequentially clicking a series of randomly placed numbers and letters on a computer screen. Participants would click 1 followed by

A followed by 2 followed by B and so on until reaching the number 9. Completion time and errors made were recorded for both tasks.

Statistics

A mixed repeated measures analysis of variance (ANOVA) was used in order to determine the differences in performance as a function of treatment group (exercise or control), session (pre-test or post-test),and their interaction. The dependent variables were: TOL Steps, TOL First Time, and TOL Total Time, Stroop D Time, Stroop D Errors, Stroop W Time, Stroop W Errors, Stroop C Time, Stroop C Errors, Corsi Span (working memory), Trails A Time, Trails A Clicks, Trails B Time, and Trails B Clicks.

CHAPTER IV

RESULTS

Primary Analysis

Tower of London

There was a significant main effect for session for first time, $F(1,48)=74.08$, $p<.05$ but no treatment group main effect, $F(1,48)=1.36$, $p>.05$, or treatment group x session interaction effect, $F(1,48)= .43$, $p>.05$. Examination of the means for the main effect for first time indicate that performance improved from baseline (M=4493.72 sec, SD=3572.98) to post-test day (M=3572.98 sec, SD=98.93). There was also a significant main effect for session for total time, $F(1,48)=21.68$, $p<.05$, indicating that total time improved from baseline (M=16971.16 sec, SD=702.77) to post-test (M=13555.33 sec, SD=663.4). A significant main effect for treatment group for total time, $F(1,48)=700.78$, $p<.05$, was identified indicating that time was greater for the treatment group (M=15514.8, SD=798.93) than for the control group (M=15011.691, SD=831.55). There was no significant treatment x session interaction for total time, $F(1,48)=0.15$, $p>.05$. For steps, the main effect for session, treatment group main effect, and treatment group x session interaction effect were not statistically significant, $F's(1,48)<0.38$, $p's>.05$.

Stroop Task

There was a significant main effect for session for Stroop D time, $F(1,47)=34.81$, $p<.05$, indicating that performance improved from baseline (M=68.57, SD=4.23) to post-test (M=50.32, SD=2.96) and a significant main effect for treatment group, $F(1,47)=34.81$, $p<.05$, indicating that time was greater for the control (M=59.72, SD=4.72) than for exercise group (M=59.17, SD=4.63) (see Figure 1). The treatment group x session interaction was not significant for Stroop D, $F(1, 47)=0.69$, $p>.05$. For Stroop D errors the main effects for session and treatment group and the treatment group x session interaction effect were not statistically significant, *F's*(1,47)<1.5, *p's*>.05.

There was a significant main effect for session for Stroop W time, $F(1,46)=19.57$, $p<.05$, indicating that performance improved from baseline (M=60.79, SD=3.2) to post-test day (M=49.96, SD=3.46). However, there was no significant main effect for treatment group, $F(1,46)=.002$, $p>.05$, nor was the treatment group x session interaction significant, $F(1,46)=1.69$, $p>.05$. There was no significant main effect for session for Stroop W errors, $F(1,46)=1.44$, $p>.05$, and no significant main effect for treatment group, $F(1,46)=0.63$, $p>.05$. However, the treatment group x session interaction was significant for the Stroop W errors, $F(1,46)=4.7$, $p<.05$, indicating that the control group showed a greater increase in number of errors committed from baseline (M=3.74, SD=1.85) to post-test (M=8.61, SD=2.33) than did the exercise group from baseline (M=8.88, SD=1.77) to post-test (M=7.48, SD=2.24) (See Figure 1).

There was a significant main effect for session for Stroop C time, $F(1,46)=18.54$, $p<.05$, indicating that performance improved from baseline (M=68.11, SD=4.15) to post-test (M=53.41, SD=3.12). However, there was no significant main effect for treatment group, $F(1,46)=0.28$, $p>.05$, or treatment group x session interaction significance, $F(1,46)=0.78$, $p>.05$. For Stroop C errors, the main effect for session, treatment group main effect, and treatment group x session interaction effect were not statistically significant, *F's*(1,46)<2.05, *p's*>.05.

Corsi Task

There was no significant main effect for Corsi Span for session, $F(1,47)=.001$, $p>.05$, and no significant interaction of treatment group x session, $F(1,47)=1.46$, $p>.05$. The treatment group main effect was significant, $F(1,46)=5.15$, $p<.05$, indicating that performance for memory span was better for the control group (M=5.15, SD=.165) than for the treatment group (M=4.62, SD=.162).

Trail Making Task

There was no significant main effect for session for Trails A time, $F(1,47)=1.75$, $p>.05$, no significant treatment group main effect, $F(1,47)=1.89$, $p>.05$, and no significant treatment group x session interaction, $F(1,47)=.056$, $p>.05$. There was no significant main effect for session for Trails A clicks, $F(1,47)=0.89$, $p>.05$, no significant treatment group main effect, F(1,47)=1.5, p>.05, and no significant treatment group x session interaction, $F(1,47)=0.61$, $p>.05$.

There was a significant main effect for session for Trails B time, $F(1,47)=7.17$, $p<.05$. Examination of the means indicated that time decreased from baseline (M=28797.49, SD=1859.21) to posttest (M=24270.1, SD=1450.54). There was no significant treatment group main effect for Trails B time, $F(1,47)=0.8$, $p>.05$, and no significant treatment group x session interaction, $F(1,47)=1.43$, $p>.05$. There was no significant main effect for session for Trails A clicks, $F(1,47)=0.21$, $p>.05$, no significant treatment group main effect, $F(1,47)=1.83$, $p>.05$, and no significant treatment group x session interaction, $F(1,47)=0.36$, $p>.05$.

Table 1 Primary Analysis

Cognitive Measure	Effect	df	F	Sig.	Partial Eta Squared
TOL Steps	Session	(1,48)	0.33	0.57	0.01
	Treatment Group		0.38	0.54	0.01
	Session x Treatment Group		0.01	0.91	0.00
TOL First Time	Session	(1,48)	74.08	0.001	0.61
	Treatment Group		1.36	0.25	0.03
	Session x Treatment Group		0.43	0.52	0.01
TOL Time	Session	(1,48)	21.68	0.001	0.31
	Treatment Group		700.78	0.001	0.94
	Session x Treatment Group		0.15	0.7	0.003
Stroop Time D	Session	(1,47)	34.81	0.001	1.00
	Treatment Group		34.81	0.001	0.43
	Session x Treatment Group		0.69	0.41	0.01
Stroop Time D Errors	Session	(1,47)	0.68	0.41	0.01
	Treatment Group		0.54	0.47	0.01
	Session x Treatment Group		1.5	0.23	0.03

Cognitive Measure	Category	df	F	Sig.	Partial Eta Squared
Stroop Time W	Session	(1,46)	19.57	0.001	0.29
	Treatment Group		0.002	0.97	0.00
	Session x Treatment Group		1.67	0.2	0.04
Stroop Time W Errors	Session	(1,46)	1.44	0.24	0.03
	Treatment Group		0.63	0.43	0.01
	Session x Treatment Group		4.7	0.04	0.09
Stroop Time C	Session	(1,46)	18.54	0.001	0.29
	Treatment Group		0.28	0.6	0.01
	Session x Treatment Group		0.78	0.38	0.02
Stroop Time C Errors	Session	(1,46)	2.05	0.16	0.04
	Treatment Group		1.73	0.19	0.04
	Session x Treatment Group		0.6	0.44	0.01
Corsi Span	Session	(1,47)	0.001	0.98	0.00
	Treatment Group		5.15	0.03	0.09
	Session x Treatment Group		1.46	0.23	0.03

Cognitive Measure	Category	df	F	Sig.	Partial Eta Squared
Trails A Time	Session	(1,47)	1.75	0.19	0.04
	Treatment Group		1.88	0.18	0.04
	Session x Treatment Group		0.56	0.46	0.01
Trails A Clicks	Session	(1,47)	0.89	0.35	0.02
	Treatment Group		1.49	0.23	0.03
	Session x Treatment Group		0.61	0.44	0.01
Trails B Time	Session	(1,47)	7.17	0.01	0.13
	Treatment Group		0.8	0.38	0.02
	Session x Treatment Group		1.43	0.24	0.03
Trails B Clicks	Session	(1,47)	0.21	0.65	0.004
	Treatment Group		1.83	0.18	0.04
	Session x Treatment Group		0.36	0.55	0.01

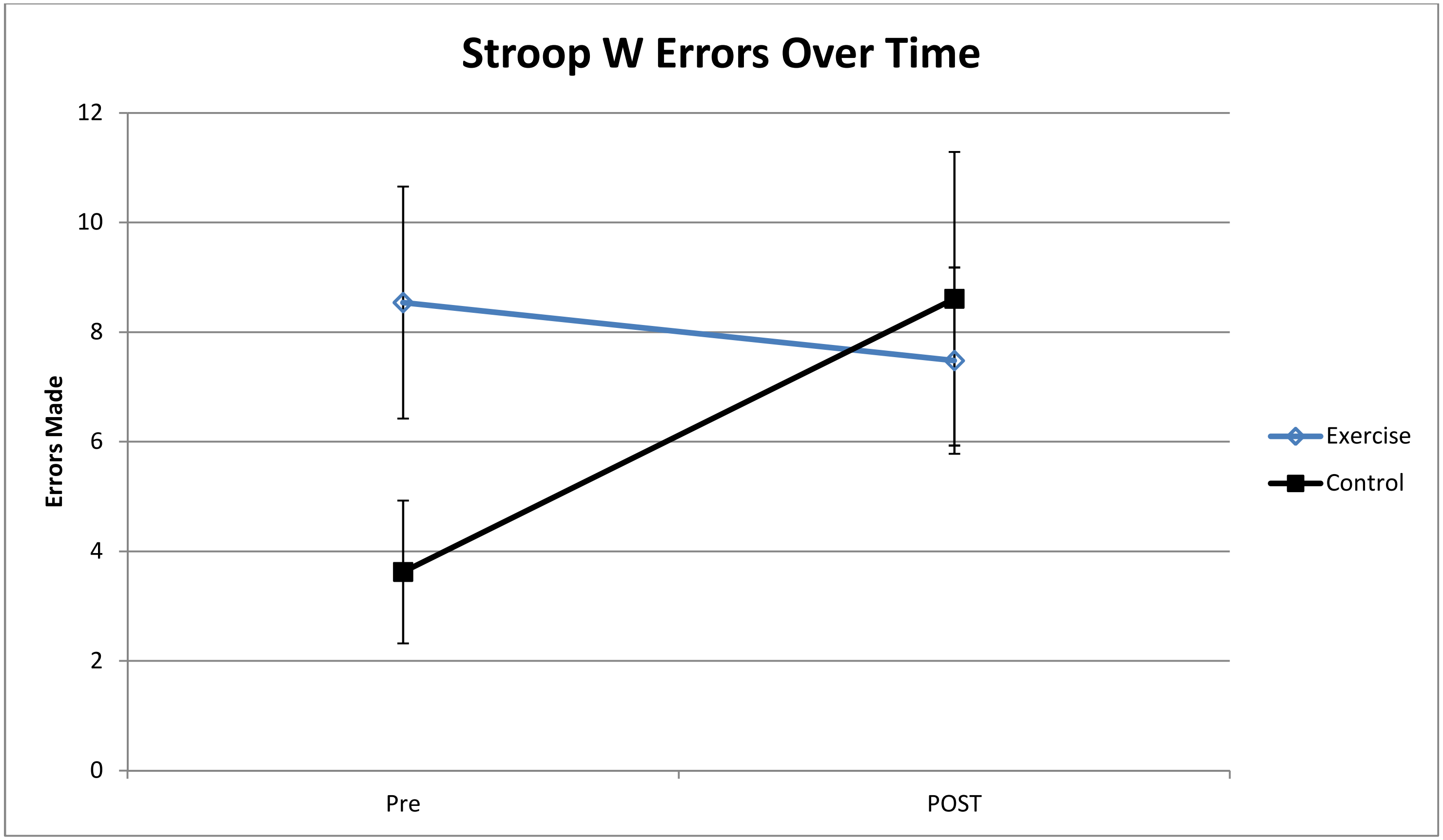
Table 2 **Means and Standard Deviations**

Cognitive Measure	Day 1 Exercise		Day 2 Exercise		Day 1 Control		Day 2 Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TOL Steps	82.30	12.43	84.73	16.34	85.17	20.24	87.46	21.14
TOL First Time	4652.85	1045.07	3662.11	882.09	4334.59	870.47	3483.85	417.07
TOL Time	17363.18	5053.08	13666.42	5287.04	16579.13	4868.27	13444.25	3932.70
Stroop Time D	69.57	34.81	48.76	19.84	67.50	22.90	51.89	21.62
Stroop D Errors	8.48	9.43	8.00	10.17	5.21	6.84	7.67	11.20
Stroop Time W	62.94	23.70	45.07	23.06	58.64	20.31	48.84	24.85
Stroop W Errors*	8.88	10.43	7.48	8.32	3.74	6.77	8.61	13.66
Stroop Time C	64.89	27.79	53.22	20.14	71.33	29.75	53.60	23.02
Stroop C Errors	10.44	13.08	11.68	15.56	5.00	6.04	9.17	12.19
Corsi Span	4.72	0.98	4.52	1.01	5.04	0.69	5.25	1.26
Trails A Time	20448.00	9682.50	18612.96	4880.75	17740.75	4308.84	17228.17	3112.81
Trails A Clicks	22.00	3.23	22.12	4.37	20.50	3.15	21.75	3.86

Cognitive Measure	Day 1 Exercise		Day 2 Exercise		Day 1 Control		Day 2 Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Trails B Time	31097.48	15174.91	24546.44	7614.72	26497.50	10280.17	23993.75	12250.99
Trails B Clicks	22.96	4.61	22.84	5.44	21.12	3.48	22.00	4.22

NOTE: * indicates significant treatment group x session interaction

Figure 1 **Stroop W Error Treatment Group X Session Interaction**



CHAPTER V

DISCUSSION

Research into the effects an acute bout of exercise has on cognitive performance has primarily focused on aerobic exercise and on adult samples (Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997, Lambourne & Tomporowski, 2010, Chang, Labban, Gapin, & Etnier, 2012). While research on resistance exercise and its relationship to cognitive performance is limited, positive results have been identified in the few studies utilizing this mode of physical activity with adults (Chang & Etnier, 2008, Chang, Ku, Tomporowski, Chen, & Huang, 2012, Chang & Etnier, 2009). Similar to adults, younger samples have been shown to experience cognitive benefits following aerobic exercise (Tomporowski, 2003, Hillman, Pontifex, Raine, Castelli, Hall, & Kramer, 2009, Pesce, Crova, Cereatti, Casella, & Belluci, 2009, Ellemberg & St-Louise-Deschenes, 2010). Largely because safety concerns have prevented research on the ways in which acute resistance exercise can benefit cognition in younger samples (Behm, Faigenbaum, Falk & Klentrou, 2008), it is unclear what the relationship between resistance exercise and cognitive performance may be for children. Based on the existing body of research, it was the purpose of this study to identify the effect an acute bout of resistance exercise has on the cognitive performance of a preadolescent sample.

In this study, a resistance exercise session consisting of seven exercises encompassing all major muscle groups was created in order to determine the effect this mode of physical activity has on the cognitive performance of a preadolescent population. Participants completed all of the cognitive tests at a baseline session and then again during a post-test session. In the control group at the post-test, participants completed four cognitive tasks measuring task switching, problem solving, inhibition, processing speed, working memory, and visual attention immediately before participating in the resistance exercise session. The exercise group completed the same cognitive tasks immediately following the resistance exercise session at the post-test.

Regardless of the randomly assigned condition participants were placed in, control or treatment, learning effects did occur. Learning effects were defined within this study as increased performance during the completion of post-test and these improvements were likely due to familiarity and skill gained during the pre-testing session. The length of time between initially completing a cognitive task and taking it again during post-test can often determine the degree to which learning effects will affect the outcome, and it usually agreed that the more time there is between tests, the weaker the strength of the learning effects will be. The time between baseline and post-testing was at least two weeks in this study, and we anticipated that this length of time would diminish the strength of potential learning effects. However, given the observed improvements in performance on all tasks, it is evident that participants were able to complete the cognitive tasks more efficiently during post-testing than during baseline. It is likely that these learning effects overshadowed the effects of the resistance exercise on cognitive performance and, hence, were a contributing factor to the lack of significance identified within the majority of the cognitive tasks.

A significant difference was identified between groups for Stroop W Errors, indicating that participants in the control group made significantly more errors from baseline to post-test, while participants in the treatment group made fewer errors from baseline to post-test. A main effect was identified for completion time, or overall speed, for both the control group and the exercise group from baseline to post-test with both groups showing improvements. However, while the exercise group saw a slight decrease in errors made during Stroop W, the control group experienced a significant increase in errors made from baseline to post-test. Therefore, data suggests that while both groups showed improvements in processing speed, only the exercise group was able to maintain and even increase their accuracy and attentiveness from baseline to post-test on the Stroop W while also experiencing an improvement in speed of performance. These findings indicate that while familiarity with a task increased speed to completion at the expense of accuracy, resistance exercise may be an effective way of helping children to improve speed while maintaining both precision and attentiveness. Although the findings for Stroop W Error provide some limited support for the hypothesis that a single session of resistance exercise will have a positive effect on cognitive performance of a preadolescent sample, the hypothesis was not supported for the other cognitive outcomes.

Meta-analyses have determined that aerobic exercise consistently results in improvements in various components of cognitive performance in all age groups (Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997, Lambourne & Tomporowski, 2010) and research on resistance exercise and cognition (previously discussed) suggests that this mode of exercise can have a positive effect on certain domains of cognitive performance in adult samples as well. Considering aerobic exercise has been shown to improve cognitive performance in children and adults, and that resistance exercise has been shown to improve cognitive performance in adults, it appears likely that resistance exercise would improve cognitive performance in a preadolescent sample. Considering no research currently exists examining the relationship between resistance exercise and cognitive performance in preadolescents, the design of this study was established based on the existing research using adult samples.

There are several studies that have shown beneficial effects of resistance exercise on cognitive performance. Although the subjects in all of these studies were adults, these studies are similar to this study in that many aspects of the designs, including mode of exercise, duration of exercise session, delay prior to cognitive testing, and time testing occurred are the same. Chang and Etnier (2008) determined that processing speed significantly increased following an acute bout of resistance exercise. While the design of Chang and Etnier (2008) was similar to this study in mode of exercise and cognitive tasks used, the sample was considerably older, 49.1 years old, and the duration of the resistance exercise session was longer, 45 minutes. Furthermore, since the sample tested were adults with no restrictions on intensity of exercise, it is likely that the significance identified within Chang and Etnier (2008) that was not identified within the preadolescent sample may have been due to the intensity being too low for an effect to be seen in this study.

Chang and Etnier (2009) identified a dose response relationship between resistance exercise and basic information processing, that is as intensity increased, so did cognitive performance. Chang and Etnier also determined that for attention and more advanced processing the intensity that yields the most significant results is moderate. In addition, the findings within Chang and Etnier (2009) are similar to the identified interaction effect within the Stroop W Errors, suggesting that this specific mode, intensity and duration of exercise may benefit attention and various levels of processing in all age ranges, including preadolescence. However, although the intensity was prescribed to be moderate, it is likely that the actual intensity used within this study was low-moderate due to the safety concerns that arise when preadolescents perform resistance exercises at too high of an intensity. Pontifex et al. (2009) conducted a study using an older sample, (M=20.2) and determined that no significant effect exists for working memory following a 30 minute bout of resistance exercise. However, the intensity of the resistance exercise was slightly greater, high-moderate, and the duration of the session was similar to that used in this study.

Based on the Chang et al. (2012) meta-analysis, this study was designed in a way to maximize effect size while working within the constraints of the available resources. The ideal duration for an exercise session is mixed as some research has seen positive findings with an 11 to 20-minute session while others have identified that a longer duration leads to greater effect sizes. In accordance with the findings of previous research along with the availability of participants, a 25-minute resistance exercise session was used. The time of day that testing occurs was also taken into account within the design of this study as research has shown that cognitive performance tends to be better following exercise when taking place in the morning. For this reason, all participants were tested in the morning, prior to lunch during their normal school day. The delay taking place between the exercise session and cognitive tasks was also taken into account within the design of the study. Since a 1-15 minute delay has been identified as resulting in the greatest effect size within meta-analytic reviews, participants within the study had a short delay of approximately 1-3 minutes between exercise and cognitive testing in order to maximize effect size. The final major moderator taken into account within the design of this study is intensity. Previous research has identified mixed results as to what intensity yields the greatest effects sizes, with most studies finding the best results with moderate to vigorous. In order to maximize effect size within the study while following the safety guidelines put into place by the ACSM the intensity chosen was moderate. Unfortunately, though the intensity prescribed was moderate, the actual intensity of the resistance exercise sessions may have been slightly lower as a way to err on the side of caution while the preadolescent sample was performing the resistance exercises as a way to prevent injury. Furthermore, while ratings of perceived exertion were used as way to monitor intensity in addition to the prescribed weights, it was apparent that due to the group setting of the exercise social influence among participants made the ratings of perceived exertion unusable.

Limitations

One factor that may have impacted results in regards to the design of the study is the duration of each resistance exercise session. As discussed above the resistance exercise sessions were approximately 25 minutes long, and while all of the exercises were completed within this time frame, sessions did seem rushed at times. While some of the existing studies utilizing resistance exercise as a way to impact cognitive performance have sessions of a similar length, approximately 25 minutes, others using differing modes have designs allowing for slightly longer exercise sessions. It should be noted that these findings come from meta-analytic reviews looking at both aerobic and resistance exercise sessions making it difficult to identify the ideal duration to be used for a resistance exercise session in a preadolescent sample. The length of time for the resistance exercise sessions within this study were chosen based on existing research (previously discussed) and the availability of the participants. Access to participants was limited to their 45 minute physical education class, and 20 minutes were necessary for the cognitive testing leaving 25 for the resistance exercise session. It is possible that with more time for the resistance exercise session, additional exercises and/or sets could have been added, potentially increasing the effect and falling in line with the slightly longer exercise sessions that have identified improvements in cognitive performance (Chang & Etnier, 2008).

In conjunction with the time restrictions for the resistance exercise session the size of the groups during the sessions may have been a factor as well. Due to the limited access and time to the participants, the group size during the resistance exercise was approximately 9 subjects per researcher. While research has shown that both individual and group exercise can result in improved cognitive performance, a group this size consisting of preadolescents may have had a negative impact on efficiency of the exercise session. Though researchers were able to keep participants on track while completing the exercises, directions needed to be repeated often to make sure participation did not diminish as socializing among participants was quite high. This irregular participation may have had a negative impact on the effort put forth by participation during the exercise session, potentially decreasing the effect.

Future Directions and Implications

Given the lack of current research exploring the effect of resistance exercise on cognitive performance, future research is warranted despite the lack of statistical significance within this study. While it is recommended for preadolescent samples to exercise at no greater than a moderate intensity (Behm, Faigenbaum, Falk, Klentrou, 2008), a design in which levels of intensity are different among groups may result in a better understanding of dose-response relationships between resistance exercise intensity and cognitive performance. For this reason, it is important to determine the appropriate dose of exercise necessary for preadolescents, not only in terms of intensity but in regards to duration as well. Since so little research exists in regards to resistance exercise in preadolescent samples, it is possible that what has been established as an effective dose of exercise for adult samples may not be the same within younger subjects. Other factors that that should be taken into account in future research are the location of the testing and the researcher to participant ratio. While resistance exercise and cognitive tasks were administered in a group setting in this study, a greater effect may be identifiable in a smaller laboratory setting rather than in a school classroom or gymnasium. Additionally, it is likely that a smaller researcher to participant ratio in a laboratory may decrease social interactions and comparisons while increasing intrinsic motivation. Furthermore, future research must use a design that minimizes learning effects, such as a design that does look at change over time but rather differences between groups only. Without a way to understand the degree to which learning effects have impacted outcomes, it becomes unclear as to what the relationship between resistance exercise and cognitive performance may be.

Conclusion

The purpose for performing this study was to explore the effects an acute bout of resistance exercise has on the cognitive performance of a preadolescent population. The findings from this study suggest that an acute bout of resistance exercise may increase processing speed and inhibition in preadolescents, though results are only marginally supportive of this conclusion. Findings also suggest that an acute bout of resistance exercise does not impact task switching, problem solving, working memory, and visual attention in preadolescents.

REFERENCES

Behm, D. G., Faigenbaum, A. D., Falk, B., & Klentrou, P. (2008). Canadian society for exercise physiology position paper: Resistance training in children and adolescents. *Appl. Physiol. Nutr. Metab.*, *33*, 547-561.

Chang, Y., & Etnier, J. L. (2009). Effects of an acute bout of localized resistance exercise on the cognitive performance in middle-ages adults: A randomized controlled trial study. *Psychology of Sport and Exercise*, (10), 19-24.

Chang, Y., & Etnier, J. L. (2009). Exploring the dose-response relationship between resistance exercise intensity and cognitive function. *Journal of Sport and Exercise Psychology*, (31), 640-656.

Chang, Y., Ku, P., Tomporowski, P. D., Chen, F., & Huang, C. (2012). Effects of acute resistance exercise on late-middle-age adults' goal planning.*American College of Sports Medicine*, *44*(9), 1773-1779.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, 87-101.

Committee on Sports Medicine and Fitness. (2001). Strength training by children and adolescents. *PEDIATRICS*, (107), 1470-1472.

Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *JOURNAL OF SPORT & EXERCISE PSYCHOLOGY*, (19), 249-277.

Fagenbaum, A. D. (2009-2010). Youth strength training: Facts and fallacies. *ACSM FIT SOCIETY PAGE*, 2-3.

Faigenbaum, A. D., & Micheli, M. D. (2013). Youth strength training. *American College of Sports Medicine*,*32*(2), 28.

Giedd, J. G., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., Paus, T., Evans, A. C., & Rapoport, J. L. (1999). Brain development during childhood and adolescence: A longitudinal mri study. *Nature America Inc.*, *2*(10), 861-863.

Hedman, A. M., van Haren, N. E. M., Schnack, H. G., Kahn, R. S., & Hulshoff Pol, H. E. (2012). Human brain changes across the life span: A review of 56 longitudinal magnetic resonance imaging studies.*Human Brain Mapping*, (33), 1987-2002.

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children.*Neuroscience* , (159), 1044-1054.

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research*, (1341), 12-24.

Mueller, S. T. (2012). PEBL: The psychology experiment building language (Version 0.12) [Computer experiment programming language]. Retrieved Nov. 2012 from http://pebl.sourceforge.net.

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, (2), 16-22.

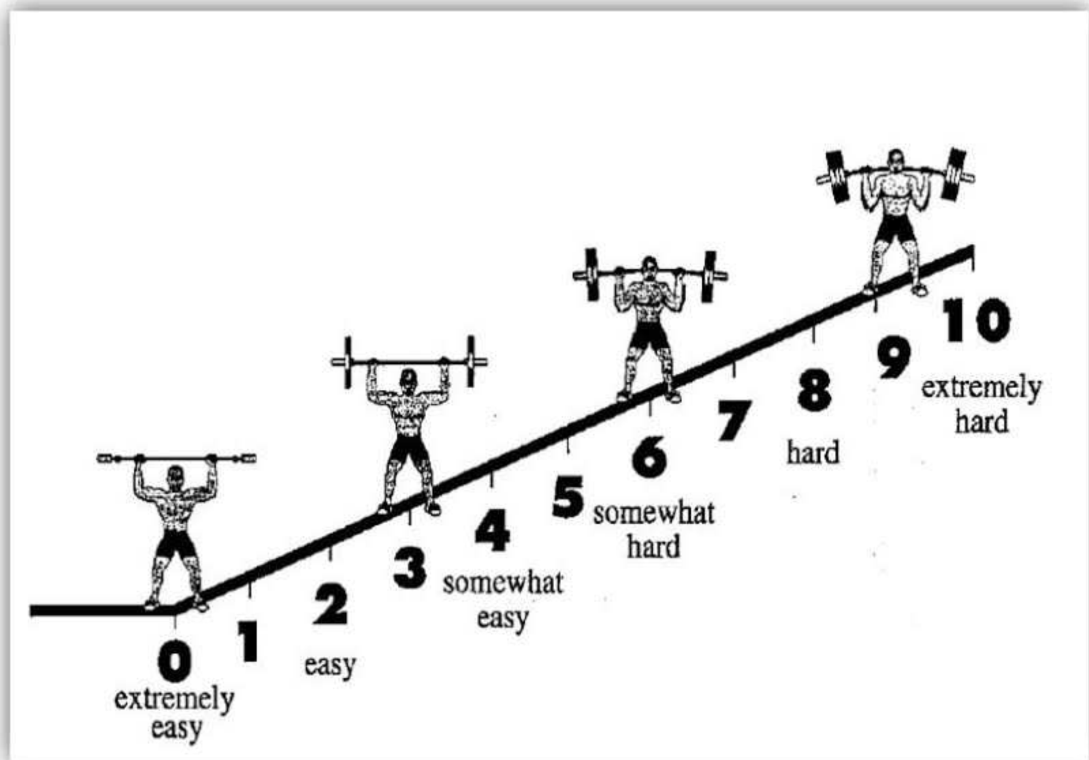
Pontifex, M. B., Hillman, C. H., Fernhall, B., Thompson, K. M., & Valentini, T. A. (2009). The effect of acute aerobic and resistance exercise on working memory. *Medicine & Science in sports & Exercise*, *41*(4), 927-934.

Tomporowski, P. D. (2003). Cognitive and behavioral responses to acute exercise in youths: A review.*Pediatric Exercise Science*, (15), 348-359.

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement .*Educ Psychol Rev*, (20), 111-131.

APPENDIX A

OMNI-SCALE OF RPE



APPENDIX B

PARENTAL CONSENT

Faculty Advisor: Jennifer L. Etnier, Ph.D.
Graduate Student: Michael A. Castellano

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

CONSENT FOR A MINOR TO ACT AS A HUMAN PARTICIPANT

Project Title: The effect of an acute bout of resistance exercise cognitive performance in preadolescents

Project Director: Jennifer L. Etnier

Parent's Name: ______________________

What is the study about?
The purpose of this research study is to investigate the effect of an acute bout of resistance exercise on cognitive performance in children. Your child's participation in this project is voluntary.

Why are you asking my child?
We are asking your child because he/she is between the ages of 7 and 11 and is currently enrolled in the 3rd grade class at Greensboro Day School.

What will you ask my child to do if I agree to let him or her be in the study?
We are asking for permission to record information about your child while in his/her physical education and computer classes. As part of the 3rd grade physical education curriculum, we will teach students to perform resistance exercises at a moderate intensity. Also as part of the 3rd grade computer class curriculum, students will be taking some mental tasks to measure cognitive performance. No extra time will be required outside of class and no grades will be attached to any of the testing. We will randomly assign children to either perform the resistance exercise before or after they do the mental tasks. The data we want to collect will be used to address the research question of whether or not resistance exercise affects cognitive task performance.

We will also ask your child to complete a questionnaire about his/her physical activity participation. The parent/guardian will also be asked to complete brief questionnaire about the child's health and development.

What are the dangers to my child?
The Institutional Review Board at the University of North Carolina at Greensboro has determined that participation in this study poses minimal risks to participants. Your child may skip any questions that he/she does not wish to answer on the physical activity questionnaire.

If you have any concerns about your child's rights, how they are being treated or if you have questions, want more information or have suggestions, please contact the Office of Research Integrity at UNCG toll-free at (855)-251-2351.

Questions about this project or benefits or risks associated with being in this study can be answered by faculty advisor Jennifer L. Etnier, Ph.D., who may be contacted at (336-334-3037) or (jletnier@uncg.edu) or by Michael Castellano, who may be contacted at (224-595-3208) or (macastel@uncg.edu).

UNCG IRB
Approved Consent Form
Valid from:
10/30/13 to 10/20/14

IRB Application
1 of 2
10-30-13

Are there any benefits to society as a result of my child taking part in this research?
The intended benefits for participants in this study are a heightened awareness of the possible effects of acute resistance exercise on cognitive performance.

Are there any benefits to *my child* as a result of participation in this research study?
There will be no direct benefits to participants.

Will my child get paid for being in the study? Will it cost me anything for my kid to be in this study?
There are no costs to you or payments to you or your child as a result of participation in this study.

How will my child's information be kept confidential?
Your privacy will be protected because you and your child will not be identified by name as participants in this project. Data collected will be kept in a locked file cabinet and all computer files will be password protected. All information obtained in this study is strictly confidential unless disclosure is required by law.

All participants will be assigned an identification number to be used on all measures of cognitive performance and on the general questionnaire returned by the parents. The number of reps/sets and the particular weight used for each exercise will be recorded by name to facilitate provision of instruction during the exercise treatment. However, these hard copies will be destroyed upon completion of the study and the data will be stored in an electronic database by ID number. The master list of names and ID numbers will be kept in a file separate from the data from the study.

What if my child wants to leave the study or I want him/her to leave the study?
You have the right to refuse to allow us to record this data or to withdraw your child at any time, without penalty. If your child chooses not to participate or withdraws, it will not affect you or your child's relationship with the school in any way. If you or your child chooses to withdraw, you may request that any data, which has been collected, be destroyed unless it is in a de-identifiable state. Also, your child may skip any questions he or she does not wish to answer or may choose not to complete the physical activity questionnaire.

What about new information/changes in the study?
If significant new information relating to the study becomes available which may relate to your willingness allow your child to continue to participate, this information will be provided to you.

Voluntary Consent by Participant:
By signing this consent form, you are agreeing that you have read it or it has been read to you, you fully understand the contents of this document and consent to your child taking part in this study. All of your questions concerning this study have been answered. By signing this form, you are agreeing that you are the legal parent or guardian of the child who wishes to participate in this study described to you by Jennifer L. Etnier, Ph.D.

_______________________________ Date: _______________
Participant's Parent/Legal Guardian's Signature

UNCG IRB
Approved Consent Form
Valid from:

10/30/13 to **10/20/14**

APPENDIX C

CHILD'S ASSENT

Study Title: The effect of an acute bout of resistance exercise on cognitive performance in preadolescents

My name is ______________________

What is this about?
I would like to talk to you about recording some information about you in your physical education and computer classes. I want to learn about how exercise can help children perform better during thinking games.

Did my parents say it was ok?
If your parents say it's okay for you to be in this study, they will sign a form like this one. Both you and your parents have to say it's okay for you to participate.

Why me?
We are asking you to participate because you are between 7-11 years of age.

What if I want to stop?
You do not have to say "yes", if you do not want to take part. We will not punish you if you say "no". Even if you say "yes" now and change your mind after you start doing this study, you can stop and no one will be mad at you.

What will I have to do?
In your computer class, you will be doing some thinking tasks on the computer. In your physical education class, you will exercise using dumbbells and your own bodyweight. I would like to record information about your performance in both classes. If you agree to be in our study and your parent says it is okay, we are going to ask your parent to give us information about you, we will record information about you during your physical education and computer classes, and we will ask you to complete a questionnaire that asks you about your physical activity participation.

Will anything bad happen to me?
There are minimal risks to recording your data and completing the questionnaire. While taking the questionnaire you may skip any questions you do not wish to answer.

Will anything good happen to me?
You will learn how to do exercises with weights.

Do I get anything for being in this study?
No.

What if I have questions?
You are free to ask questions at any time.

If you understand this study and want to be in it, please sign or write your name below.

______________________________ ______________________
Signature of child Date

UNCG IRB
Approved Consent Form
Valid from:

10/30/13 to **10/20/14**

APPENDIX D

GREENSBORO DAY SCHOOL PARENT LETTER

THE UNIVERSITY *of* NORTH CAROLINA
GREENSBORO
School of Health and Human Sciences
Department of Kinesiology

Dear Parent,

My name is Jennifer L. Etnier and I am a professor at the University of North Carolina at Greensboro and a parent of a third grader, Payton Wagner, at Greensboro Day School. I am working with my master's student, Michael Castellano, to conduct a study to help us understand how participation in physical activity can affect cognitive performance on tasks that are relevant to academic performance. Mrs. Gillian Goodman, Lower School Director, Mrs. Maude Caudle, Computer Specialist, Mrs. Beverly Edwards, Third Grade Lead Teacher, and Mr. Kyle Gilmer, Physical Education teacher at Greensboro Day School, have agreed to let us conduct a study at GDS.

As part of the 3rd grade physical education curriculum students will be taught to perform a series of resistance exercises at a moderate intensity. Also, as part of the 3rd grade computer class curriculum students will be taking a series of mental tasks used to measure cognitive performance. These sessions are scheduled to take place during the regularly scheduled classes on November 14, 15, and 22. We are asking for permission to record your child's data during the exercise sessions and on the cognitive tests. This data will be used to ascertain the extent to which resistance exercise affects cognitive task performance. We will also ask your child to complete a questionnaire that assesses their physical activity behavior.

Data will be recorded without names (i.e., using only identification numbers). We will keep the data confidential and will not report your child's data in any way that could be linked to your child.

If you and your child are willing to allow data collection to occur, please return the Consent for a Minor to Act as a Human Participant form with your signature, the Child's Assent form with your child's signature, and the completed General Questionnaire. Once we have completed the study, we will share the findings with Greensboro Day School.

Thank you for your time and please don't hesitate to call (336-334-3037) or email (jletnier@uncg.edu) if you have any questions or concerns.

Sincerely,

Jennifer L. Etnier, Ph.D.
Parent of Payton Wagner, GDS class of 2023 and James and Max Wagner, GDS class of 2025

Approved IRB
10/30/13