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The effects of exercise participation on cognition in adults

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THE EFFECTS OF EXERCISE PARTICIPATION ON COGNITION IN ADULTS

by

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DEDICATION

This work is dedicated to the amazing, strong, and brilliant women in my life, both past and present. You make my heart full, my mind strong, my laughter deep, and my life meaningful. It is a joy to share in your lives; thank you for being in mine.

At the head of this group is my mother. To my mom, Carol Hastie – you were the first person to tell me I could achieve this dream and you were a constant voice of encouragement and unconditional love. You were my first teacher and my best teacher. I love you.

ABSTRACT

Current research supports that regular participation in exercise not only benefits physical fitness parameters, but also that there are multiple beneficial effects on cognition and brain health. Few studies have been conducted on adults and many lack the specifics of the exercise prescription needed in order to elicit improvements in cognition. The purpose of this study was to examine the relationship between the different dimensions of physical fitness and cognitive improvements. Thirty-seven adults enrolled at a northwest community college were recruited for this study. Participants were divided amongst three exercise treatment groups: cardiovascular training (CVT), strength training (ST), and mixed method training (MMT) and a control group (C) for the duration of the eight-week study. A comprehensive physical fitness evaluation was performed at the beginning and at the end of the eight week training session. In addition, a cognitive evaluation of participants' "mental fitness" was also administered at the beginning of the study and at the end of the eight week training session, utilizing five assessments: 1) response speed and impulse control; 2) divided visual attention; 3) mathematical word equations; 4) memory span; and 5) grammatical reasoning.

The results of this study indicated that cardiorespiratory exercise training and mixed method circuit training were highly influential on some aspects of cognition (memory span and problem solving ability) as evidenced by statistically significant ($p \leq 0.1$) changes in cognitive measures after eight-weeks. Cardiovascular training also offered an additional benefit in the area of divided visual attention response time. Both the cardiovascular training and mixed method training groups showed common statistically significant improvements in body composition and muscular endurance, while only the mixed method training group experienced statistically significant improvements in cardiorespiratory fitness and muscular strength. An additional

interesting finding is that the control group was the only group to see a statistically significant increase in systolic blood pressure over the eight-weeks of the study and was also the only group to experience a significant decline in response speed to visual stimuli.

These findings offer a rich future of research possibilities which is increasingly important in our nation as we experience the highest rates of obesity in our history. Exercise may not only offer an opportunity to improve physical fitness, manage body weight, and reduce the risk of chronic disease, but it may also offer an opportunity to improve our mental fitness as well.

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for all of you. You have been my ultimate supporters in life and all of my pursuits. Mom, Meghan, Matt, Kevin, Dad, and Grandmommy – this accomplishment was born out of your love, support, and belief in me. I am blessed beyond belief to have you in my life and it is with you that I will celebrate.

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CHAPTER 1

Introduction

An emerging body of research across multiple disciplines has begun to investigate the cognitive benefits associated with participation in physical exercise. Physiologists, biologists, neuroscientists, psychologists and educators are amongst the growing number of professionals interested in describing the relationship between physical and mental fitness. A large number of studies support the numerous cardiovascular, musculoskeletal, and metabolic benefits of exercise. Specifically, benefits of regular exercise include a reduced risk of developing cardiovascular disease, type II diabetes, hypertension, dyslipidemia, metabolic syndrome, osteoporosis, and some forms of cancer (American College of Sports Medicine, 2010; Myers, 2003; Spirduso, Poon, & Chodzko-Zajko, 2008). Research also indicates a reduction in the risk of stroke, heart attack, debilitating falls, and other causes of early mortality (American College of Sports Medicine, 2010). With regards to cognitive well-being, research indicates that exercise is associated with a reduction in stress, anxiety, and depression (Schloesser, 2010; Tomporowski, 2003). In fact, exercise has become a common treatment for Seasonal Affective Disorder (SAD), mild to moderate depression, and Attention Deficit Disorder (ADD) (Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005; Pinchasov, Shurgaja, Grischin, & Putilov, 2000; Reynolds & Nicolson, 2007; Spirduso et al., 2008).

While it is widely accepted that exercise is an effective treatment for the prevention of many chronic diseases and is becoming a more common-place treatment for a variety of medical conditions and disorders, research surrounding the cognitive benefits of exercise is underdeveloped. Presently, the field is yet unaware of how significantly exercise can promote or sustain positive cognitive changes. I have a particular interest in investing both the cognitive and physical benefits of exercise. Having received both my Bachelor's and Master's degree in the field of Exercise Science, I have long held the belief that exercise is a powerful and accessible tool that can positively impact one's health and longevity. In my professional role as program director and professor of an undergraduate exercise science program, I have become increasingly interested in the cognitive sciences. It is through this interest that I have become curious about the linkages that exist between our physical bodies and our minds. Specifically, I believe that there is great value in exploring the relationship between the well-known physiological improvements experienced with regular exercise and the not yet well understood cognitive benefits of exercise. The research reviewed for this study provides evidence that there are significant neurological and chemical benefits experienced in the brain as a result of exercise participation. Additionally, these benefits are manifested uniquely at different ages throughout the lifespan. These benefits appear to impact both brain physiology and cognition. While several studies have shown these benefits manifest to some degree in children and in older adults (65 years of age and older), a chasm exists in the research related to both young adults (ages 18-40) and middle age adults (ages 41-60) (Cassilhas et al., 2007; Castelli, Hillman, Buck, & Erwin, 2007; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Dwyer, Sallis, Lazarus, & Dean, 2001; Hill, Storandt, & Malley, 1993; Hollar et al., 2010; Ozkaya, Aydyn, Toraman, Kyzylay, & Cetinkaya, 2005; Tomporowski, Davis, Miller, & Naglieri, 2008). While it is well understood in the exercise science community how to effectively prescribe exercise to elicit improvements in cardiovascular and muscular health and fitness, the exact exercise prescription needed to elicit cognitive improvements remains elusive. Specifically, there is a need for research to address the optimal intensity, type, duration, and length of participation in exercise needed to elicit and sustain cognitive benefits.

Statement of the Problem

The purpose of this study was to examine the interaction of physical exercise with cognitive improvements in adults. While the aim of this research study was not to determine the exact exercise prescription needed to improve cognition, it explored key factors and elements related to the interaction of exercise and cognition. Specifically, I used a quasi-experimental design to compare the effects of three exercise "treatments" and the associated changes in cardiorespiratory endurance, muscular fitness, and body composition with accompanying cognitive improvements as indicated by standard cognitive assessments. An objective of this study was to add to the growing body of literature related to the association of exercise participation and beneficial cognitive growth, specifically addressing an adult population.

Research Questions

In this study, I addressed the following questions:

1) How do adults participating in cardiorespiratory, muscular fitness, and mixed method training (circuit training) regiments compare with one another and with the control group (no training) in terms of their overall cognitive changes after eight weeks of training?
2) Among those adults in the treatment groups who show improvements in physical fitness, are there any corresponding, common cognitive improvements?

Key Terms

The terms "physical activity" and "exercise" are often used synonymously. However, they actually hold different and important definitions. According to a recent publication by the American College of Sports Medicine (2010):

- **Physical activity** is bodily movement produced by the contraction of skeletal muscles that results in a substantial increase over resting energy expenditure.

- **Exercise** is a type of physical activity consisting of planned, structured, and repetitive bodily movements done to improve or maintain one or more components of physical fitness (p. 2).

The methodology of this study incorporated exercise, as a fully planned and structured activity that was intended to improve fitness.

Cognition is a complex term to define, as it can include any of the mental processes involved in knowing and comprehending information. Cognition is typically described as including the components of attention, retrieval (memory), information-processing speed, executive function, problem solving, and learning (Spirduso et al., 2008). For the purposes of this study, I will define *cognition* as the mental processes that involve thinking, knowing, remembering, judging and problem-solving.

Physical fitness is associated with a defined, specific set of attributes or characteristics that relate to how well someone is able to perform physical activity (American College of Sports Medicine, 2010). Cardiovascular fitness, muscular fitness, body composition and flexibility are considered to be components of health-related physical fitness and are commonly assessed to chart performance gains or losses, to rank or rate fitness levels according to normalized standards, and to identify potential areas for improvement. The following definitions of each of the health-related components of fitness are widely accepted in the exercise science community:

- **Cardiovascular fitness** is defined as the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity;
- **Muscular fitness** is divided into two categories: muscular strength and muscular endurance.

  - **Muscular strength** is defined as the ability of muscle to exert force;
  - **Muscular endurance** is defined as the ability of muscle to continue to perform without fatigue.
- **Body composition** is a measure of the relative amounts of muscle, fat, bone and other components of the body; and
- **Flexibility** is the range of motion available at a joint (American College of Sports Medicine, 2010).

Limitations

One limitation of this study was the quasi-experimental design. Quasi-experiments are studies that aim to evaluate interventions but do not use randomization. The lack of random assignment is one of the weaknesses in the design of this study. With regards to the internal validity of quasi-experiments, Harris et al. (2006) identified two major threats: confounding variables and regression toward the mean. There is an inherent difficulty in controlling for confounding variables in quasi-experimental studies. Two particularly important confounding variables that can significantly impact cognition are mental stress and extreme fatigue. Both of these variables pose a significant limitation in the assessment of cognition and cognitive processes. In order to minimize the impact of these variables, participants reporting significant emotional trauma in the preceding three months were not included in this study (see *Delimitations*). Confounding variables that could not be controlled for included: participants' attitudes towards exercise, nutritional status, stress, and academic anxieties related to cognitive testing.

Another limitation and potential threat to internal validity was the statistical phenomenon of regression toward the mean. The use of a control group is widely accepted as a method for minimizing the impact of the phenomenon (Harris et al., 2006), and was implemented in this study to control for regression toward the mean. Regression towards the mean is a phenomenon that occurs when a nonrandom sample from a population is utilized. Natural variation between pre and post tests can sometimes appear as significant changes. Examining data from a control group is beneficial in determining whether the observed changes are due to this statistical phenomenon or changes due to the treatment.

Another inherent threat to internal validity is attrition. College students lead very busy and complicated lives and sometimes choose to not attend class or to withdraw from their college courses. Family or personal difficulties, illness, childcare issues, and other unpredictable situations might impact participation quality and quantity. Students who withdrew from their physical education course or who did not attend more than 75% of all class meetings were not included in the final analysis of data. Participation quality was judged by the instructor of record for the course.

In addition, the time frame of the study was limited to eight weeks. This time frame was selected for several reasons: it correlates with the college's ten week academic term and allowed for more convenient access to students during expected attendance periods; it supported participant recruitment, and it provided adequate opportunity for follow-up testing before scheduled holiday breaks. However, the brevity of this study was potentially influential in the magnitude of observed changes. Future studies with a longer treatment period may yield evidence of more substantial changes.

Delimitations

A delimitation and potential threat to the external validity of this research is the fact that study participants did have knowledge that they were participating in a research experiment.

Informed consent to this study was required, so it was not possible to eliminate this element, however, every effort (e.g., standardized testing conditions; eliminating encouragement to “improve” one’s score through praise, etc.) was made to minimize these potential effects.

Other delimitations in this study included the following: the specific selection of adults enrolled as “degree seeking” students at a single northwest community college; the eight-week study time frame to match the academic term calendar and to allow for participant recruitment and follow-up; and self-imposed eligibility limitations to not include potential participants with cardiovascular or musculoskeletal disease. In addition, any participants who self-reported that they experienced significant emotional or mental trauma in the preceding three months, which may have impaired their ability to think clearly or make decisions, were eliminated. Participants were also asked to rate how well rested they felt on the day of the testing using a Likert-type scale. Those participants reporting being not well rested on the day of the testing were rescheduled.

Summary

The methods of exercise that have long been appreciated for their benefits on cardiovascular and musculoskeletal health, may hold a new key in sustaining, and possibly even improving, cognitive health. The importance of the health, function, and longevity of the human mind as it relates to quality and quantity of life cannot be argued. What remains to be seen is whether participating in regular physical exercise can contribute to long term brain health and cognitive function. Specifically, it is a goal of this study to determine whether different modes of exercise are influential in improving cognition, in conjunction with physical fitness improvements, and how these cognitive changes are manifested in an adult population.

CHAPTER 2

Review of the Literature

Introduction

It is common knowledge that regular exercise is an effective modality for a healthy life expectancy and reducing the incidence of chronic disease and certain cancers. Exercise is now a common approach in the medical community for managing a variety of conditions and disorders that can significantly impact one's physical health and well-being (American College of Sports Medicine, 2010). However, the effect that exercise may have on cognition is not as well understood. New and exciting research is beginning to explain the complex relationship exercise may have in influencing our abilities to process, retain, and analyze information. Current research indicates that significant neurological and chemical reactions result from participation in exercise. The resultant changes in cognition as a result of regular exercise also appear to manifest differently throughout the lifespan and are influenced to a certain degree by differing types and intensities of exercise. The research to date certainly indicates that a relationship between physical fitness and cognition exists, but the specifics of that relationship remain unclear.

The purpose of this literature review is to explore the effects of exercise on cognition and the capacity to learn throughout the lifespan. In addition, it explains research findings related to how differing modes, intensities, and durations of exercise influence cognitive processes. Evidence from the research reviewed supports the existence of a link between exercise participation and improved cognition at all stages of life. Specifically, the following will be addressed: a) the biological mechanisms that underlie cognitive improvements resultant from exercise; b) the effects of exercise on cognition in children and adolescents; c) the effects of exercise on the adult mind, d) the effects of exercise on the aging mind; and e) potential mediating factors of the relationship between exercise and cognition.

Biological Mechanisms Associated with Cognitive Improvements

The brain is affected in a multi-dimensional manner as a result of exercise. These effects include stimulating brain plasticity mechanisms, increasing neuron development, increasing brain metabolic capacity, augmenting antioxidant defenses, and improving brain vascularization (Berchtold, Castello, & Cotman, 2010a, 2010b; Ploughman, 2008; Radak et al., 2006; Woodlee & Schallert, 2006). While it is true that mental resources are viewed as a limited capacity system, research has indicated that they can be expanded in capacity through exercise (Spirduso et al., 2008).

Currently, there are three well-supported viewpoints that explain how cognition is beneficially impacted by exercise. First, exercise stimulates the formation of new blood vessels in the brain (angiogenesis) and enhances blood flow throughout the brain (Ploughman, 2008). These two factors contribute to increased oxygen saturation throughout the entire brain and are predominantly beneficial in the frontal lobe which is associated with task performance, memory, and executive function. In a comprehensive review paper by Lista and Sorrentino (2010), the underlying biological systems of the brain were reviewed as they relate to the effects of exercise on cognition. Their research supports that both acute and long term exercises cause increased blood flow to the brain and enhanced vascularization, resulting in improved cognitive processes (Lista & Sorrentino, 2010).

Second, exercise facilitates an increase in brain neurotransmitters, such as serotonin and norepinephrin (Kramer, Erickson, & Colcombe, 2006; Ploughman, 2008). These neurotransmitters facilitate increased levels of arousal and can improve information processing.

Serotonin may play an even bigger role as it is also associated with enhanced neuron proliferation (Kramer et al., 2006; Lista & Sorrentino, 2010). While acute stress can have a positive impact on memory function, chronic stress has been shown to have deleterious effects on cognition and can lead to neuronal cell death and decreased hippocampus volume (Lupien, McEwen, Gunnar, & Heim, 2009; Spirduso et al., 2008). The presence of serotonin, associated with feelings of well-being and stress reduction, might not only help to improve information processing, but might also serve to have protective benefits for neurons during times of chronic stress.

The third way in which exercise is thought to influence cognition is that exercise enhances neurotrophic factors that support the growth and survival of brain cells, specifically in the hippocampus which is a critical brain area involved in learning and memory (Ploughman, 2008; Woodlee & Schallert, 2006). One of these critical neurotrophic factors, brain-derived neurotrophic factor (BDNF), is linked with improvements in neuroplasticity, neuroprotection, and brain growth (Berchtold et al., 2010a, 2010b; Lista & Sorrentino, 2010). Increases in BDNF levels, as a result of increased exercise, were shown to stimulate brain cell proliferation, improve memory, and enhance learning capacity. However, these benefits appear to last for a finite amount of time. BDNF levels decline significantly after about six weeks if exercise is not continued (Radak et al., 2006).

While additional research still needs to be done to ascertain the specific amount, intensity, and types of exercise needed to optimize these biological mechanisms for cognitive improvement, there is a strong and convincing link between exercise and increased brain vitality. Exercise may serve as a highly influential modality to “prime” the brain for learning (Spirduso et al., 2008). Further research still needs to be done to accurately quantify how brain development, functional capacity and cognitive performance occur.

Effects of Exercise on Cognition in Children and Adolescents

Research findings surrounding the effect of exercise on academic achievement in children are currently inconclusive. Numerous studies have indicated that there is a positive association between academic achievement and participation in exercise (Castelli et al., 2007; C.L. Davis et al., 2007; Dwyer et al., 2001; Hollar et al., 2010; Tomporowski et al., 2008). However, some studies have indicated no relationship or mixed and inconsistent findings (Coe et al., 2006; Daley & Ryan, 2000). In a recent review of the literature, Tomporowski et al. (2008) concluded that exercise does facilitate children's executive functioning process and children with high fitness levels demonstrate faster task performance speed. Dwyer et al. (2001) found that children's fitness measures were positively correlated with scholastic achievement. Castelli et al. (2007) found similar results specific to aerobic fitness levels being highly correlated with reading, math, and total academic achievement scores. In fact, children that performed well on two or more measures of physical fitness tended to score higher on math and reading exams when compared to students with lower levels of physical fitness (Castelli et al., 2007). Childhood obesity intervention programs involving exercise and nutritional counseling have also shown similar results in improved math scores (Hollar et al., 2010).

While many researchers have supported the idea that exercise enhances cognitive processes in children, some inconsistencies have been found. In studies that have shown little or no effect on cognition due to exercise, the authors have indicated that this may in part be due to participants not reaching a minimal threshold of intensity or time of participation. Davis et al. (2007) found that children who participated in higher doses (40 minutes) of exercise showed greater improvements in cognitive scores over control groups (20 minutes). Coe et al. (2006) failed to show that participation in physical education class produced higher levels of academic achievement, but they were able to show that students who performed vigorous exercise outside of school time that met the *Healthy People 2010 Guidelines for Physical Activity* (Promotion, 1996) did show improvements in academic achievement. Collectively, these results seem to indicate that higher levels of intensity and greater durations in exercise time are needed in order to elicit meaningful cognitive changes. An unrelated, but important finding of Coe, et al.'s study was that although academic achievement did not improve as a result of physical education class participation, the decreased academic class time resulting from the addition of physical education class did not translate into decreased academic performance. This finding is supported in other literature findings, indicating that physical education class time for children, at the very least, does not detract from student learning (Coe et al., 2006; Tomporowski et al., 2008). In light of the many physiological benefits of exercise for children, a convincing argument can be made for the regular inclusion of physical activity in schools. With childhood obesity on the rise, school based physical education programs are a proactive measure that can engage students in regular exercise and assist them in developing lifelong healthy lifestyle habits (Trost & Mars, 2010).

Effects of Exercise on Cognition in Adults

Research examining the impacts of exercise on cognition in healthy young and middle-aged adults is currently lacking. In one recent study, researchers were able to show that cardiorespiratory fitness levels among young adult males (age 18) were positively correlated with higher levels of intelligence, although similar findings were not found with regards to muscular strength (Åberg et al., 2009). When this data was evaluated using a statistical predictive model, researchers also determined that cardiovascular fitness levels at age 18 were predictive of future academic achievement. An individual's fitness level may also play a role in the speed and accuracy of calculating simple math problems. Young adults with higher fitness levels performed significantly better than did individuals with lower fitness levels (Tomporowski, 2003). Both of these findings may be of particular importance because, during early adulthood, the brain is highly plastic, creating the capacity for significant cognitive development.

Trockel et al. (2000) evaluated several self-reported health-related variables and the effects on academic performance in college students. Strength training participation, along with sleep habits and spiritual study time, were positively associated with higher academic performance as evidence by higher GPA. Exercise participation was not evaluated for duration of participation or intensity and researchers were not able to unequivocally conclude that the resultant higher GPA was in fact due to strength training participation, or whether those with higher GPA's tend to participate in more positive lifestyle practices.

Longitudinal data examining the impact of exercise on cognition is sparse in the literature. One Australian study by O'Callaghan, O'Callaghan, Williams, Bor, and Najman (2012) reported data from a birth cohort involving the measurement of IQ at age 14 and a follow-up assessment of IQ and a physical activity self-report assessment at age 21. Contrary to research findings by Coe et al. (2006) and Davis et al. (2007), O'Callaghan, et al. (2012) found that higher levels of vigorous exercise were not associated with higher IQ scores. In fact, increased levels of less vigorous exercise were found to be associated with higher IQ scores, even after controlling for previous cognitive ability and socioeconomic status. The authors suggest that employment forms that tend to involve the most vigorous levels of activity are often linked to lower levels of IQ and educational achievement. In addition, the authors state that vigorous physical activity requires a commitment of energy that may place too great of a demand on participants, thus negatively impacting IQ scores (O'Callaghan et al., 2012).

A small number of research studies have been completed utilizing middle-age adults as participants. The research that has been completed indicates that cognitive benefits from regular exercise continue to be experienced well into adulthood. In a study of middle-aged adults (average age of 50 years), researchers found that moderate intensity resistance training had a positive impact on cognitive processes (Chang & Etnier, 2009). Similar findings were concluded with regards to aerobic exercise and have shown that submaximal aerobic exercise performed for up to sixty minutes per session appears to facilitate certain aspects of cognition (Tomporowski, 2003). Specifically, this research indicates that aerobic exercise improves information processing abilities, complex problem solving skills, and attentional processes (Colcombe & Kramer, 2003; Spirduso et al., 2008). Tomporowski (2003) also notes that following aerobic exercise, people are also better able to concentrate. Etnier, Nowell, Landers and Sibley (2006) indicated that higher fitness levels in general have a positive association with improved cognitive performance.

Attenuating Effects of Exercise on Cognitive Decline in Older Adults

The aging process involves the deterioration of numerous physiological and psychological systems and processes (American College of Sports Medicine, 2010). Cognitive function is most certainly among these processes. Neuronal loss begins as early as the third decade of life and results in declining cognitive performance with age (Colcombe & Kramer, 2003). Certain cognitive functions appear to be affected to a greater extent, including attention, short-term memory, long-term memory, and central executive functions (Cassilhas et al., 2007). Many researchers have shown that exercise can improve cognitive function in older adults, or at the very least, delay the cognitive decline normally experienced with advancing age (Cassilhas et al., 2007; Hill et al., 1993; Ozkaya et al., 2005).

In a comprehensive, meta-analysis performed by Colcombe et al. (2003), the authors suggest that the largest effects of exercise on cognition in older adults appear to occur in the area of executive function (i.e., ability to plan, formulate goals and objectives, prioritize, remember steps needed to complete complex tasks, control behavior, etc.). Typically, executive function is one of the areas most affected by the aging process. These effects are even more pronounced in older adults with dementia, Alzheimer's, or those who have experienced a stroke. Data from one of the largest and longest running longitudinal studies, the Framingham Study, indicated that untreated elevated blood pressure in patients (ages 55-88) was a significant predictor of cognitive function (M.F. Elias, Wolf, D'Agostino, Cobb, & White, 1993). Regular aerobic exercise has been shown to be a clinically effective treatment of hypertension (Spirduso et al., 2008). Given both the cardiovascular and cognitive benefits of regular exercise, this may point to a dual benefit of exercise in long term health care.

Both aerobic and strength training exercise appear to have a significantly positive effect on cognition in older adults (Hill et al., 1993; Ozkaya et al., 2005). Cassilhas et al. (2007) verified equally positive benefits on cognition in older adults with both moderate and vigorous intensity strength training programs. Similar improvements were also found in older adults who walked more city blocks per week (Kramer et al., 2006). Researchers found an inverse relationship between the number of blocks walked each week and cognitive decline. Aerobic exercise has also been shown to increase brain volume in the frontal and temporal lobes of the brain in older adults (Kramer et al., 2006). The aging process typically takes a toll on brain volume in the cerebral cortex which compromises one's information processing ability. If by participating in regular exercise older adults are able to not only stop this loss, but to possibly reverse it, indicates a positive trend towards cognitive maintenance in older adults.

Type of exercise does appear to be influential when considering cognitive benefits. While both aerobic and strength training appear to have a positive effect on cognition, stretching does not benefit the brain in a similar manner. Colcombe et al. (2003) randomly assigned older adults to either a walking group or stretching group. Those who participated in the walking group demonstrated better cognitive abilities than the stretching group and showed increased activity in the frontal and parietal lobes of the brain. These areas are of specific importance because they are responsible for attentional control and task performance. Similar results were found with regard to yoga participation in older adults. Older adults showed no improvements in cognitive abilities as a result of participation in regular yoga classes, however, physical improvements in flexibility and balance, along with improvements in perceived quality of life were recorded (Oken et al., 2006).

According to these findings, it appears that both strength training and cardiovascular training improve cognitive function in older adults and can assist with slowing, or reversing, the deleterious effects of age-related cognitive decline. It is also important to note that the benefits of exercise can potentially be gained while participating at both vigorous and moderate intensity levels.

Potential Mediating Factors of the Relationship Between Exercise and Cognition

As evidenced by the current body of literature, the relationship between cognition and exercise is certainly complex and multi-faceted. While it seems plausible to say that there seems to be a positive relationship between exercise participation and cognition, the nature of this relationship is still not entirely clear. A critical next step in the research is to identify the mechanisms that underlie this relationship. With regards to this research, a mediator can be described as a third variable that potentially explains the causal relationship between exercise and cognition (Etnier, 2008).

Several potential mediators to the relationship between exercise and cognition are possible. Etnier (2008) suggests that we can classify these mediators into categories including physiological, psychological, and behavioral mediators. According to the current body of research, potential physiological mediators include aerobic fitness levels, specific hormones (i.e., cortisol, estrogen, and testosterone), lipid profiles, arterial stiffness, cerebral blood flow, blood pressure, cerebral structure, insulin-like growth factor I, catecholamines (epinephrine and norepinephrine), and neurotrophines (BDNF) (Etnier, 2008). It is likely that these mediators work in concert to impact the biochemistry of brains and their release may be activity dependent (Hopkins, Davis, Vantieghem, Whalen and Bucci, 2012).

Potential psychological mediators include depression, quality of life, pain, stress reactivity, and self-efficacy. Hopkins, et al. (2012) state that it is difficult to dissociate the effects of exercise on cognition from the influence exercise has on mood and anxiety. Several studies support the fact that exercise positively influences mental health (Schloesser, 2010; Tomporowski, 2003), but often these studies involve cognitive testing immediately following exercise. A large weakness in these study designs is that it is difficult to ascertain if the resultant improvements in mood and stress levels are temporal. It is also not well understood whether the resultant changes in cognition are due to positive changes in mood and/or a reduction in stress. Etnier (2008) and Hopkins (2012) both suggest that psychological mediators are most likely influential in attentional control, inhibition control, speed-accuracy trade-offs, motivation, persistence, effort, and fatigue.

Behavior mediators include sleep patterns, drug and medication usage, and eating habits, all of which likely have an indirect effect on other mediators. When interpreting research on exercise and cognition, it is wise to consider how these behavioral mediators may influence the observed data. Specifically, it is important to consider that behaviors such as eating more healthfully, not abusing drugs, reduced dependence on prescription medications, and better sleep habits are more commonly practiced by those who also value regular exercise.

If it is known that exercise influences each of these mediators and that cognition is influenced by these mediators, then the first step has been made to at least begin to put together a model of the relationship between exercise and cognition. However, it is not enough to say that these variables at least seem to be in the same circle of influence; this gives very little understanding of what this relationship actually looks like. Clearly more research needs to be done to examine each of these mediators in a selective manner. Further research will do much to help illuminate and define this relationship so that exercise scientists can begin the process of developing specific exercise prescriptions for cognitive health, just as they now do to improve fitness and physical health.

Conclusions

Evidence from the research reviewed supports the existence of a link between exercise participation and improved cognition at all stages of life. Exercise elicits a multi-dimensional response in the brain that affects everything from levels of circulating neurotransmitters, to brain cell proliferation and neurogenesis. While a substantial amount of research has focused on the effects of exercise on children and older adults, there appears to be a limited amount of information on the effects of exercise on young and middle age adults. One of the weaknesses of the current literature is that cognitive measures vary widely from study to study, as do the constructs of cognition. Most studies limit cognitive testing to a single aspect (i.e., memory, or processing speed, or problem solving) and rarely address the multi-dimensional nature of cognition. In addition, few studies have administered comprehensive assessments of all fitness components (i.e., cardiorespiratory fitness, muscular fitness, body composition, and flexibility) to examine the relationship between changes in cognition and exercise-induced improvements related to all parameters of fitness.

The current body of research indicates that exercise could be an important tool for public health initiatives, not only in the area of chronic disease prevention, but also to potentially optimize educational achievements and cognitive performance. What remains unclear is the exact exercise prescription needed to elicit cognitive improvements. In reviewing the research there appears to be a minimum threshold of intensity that must be met in order to gain cognitive benefits through exercise and it appears that this threshold may differ throughout the lifespan. Specifically, research needs to address the optimal intensity, type, duration, and length of participation needed to receive and sustain cognitive benefits. In addition, future research should look to determine when cognitive benefits appear to peak and at what point in the lifespan the greatest improvements can be observed, as related to exercise. It would also be highly beneficial to identify which improvements in fitness level variables (i.e., cardiorespiratory endurance, muscular strength, body composition, etc.) are correlated with the greatest cognitive improvements. This study specifically investigated the comparative cognitive changes amongst three different types of exercise and the relationship between specific fitness level measurements and cognitive changes in adults.

Scholarly interest in the area of cognition and exercise has certainly accelerated in recent years, but still remains open to new and influential research. It is the aim of this study to contribute to this growing field of knowledge and to lend evidence to notion that exercise can greatly impact not only our physical health and performance, but our cognitive health and performance as well.

CHAPTER 3

Methods

Introduction

Current research supports the estimation that regular participation in exercise has beneficial effects on cognition and brain health. However, few studies have been conducted with adults (ages 18-60) and many lack the specifics of the exercise prescription needed in order to elicit improvements in cognition. The purpose of this study was to examine the relationship between the different dimensions of physical fitness and cognitive improvements in an adult population. Specifically, three exercise treatments were applied to determine the nature of the potential cognitive benefits as they related to specific modes of exercise utilizing a quasi-experimental design. In addition, the natures of the changes in cognitive growth over the course of the study were evaluated. As previously stated, the specific research questions that were investigated are:

1) How do adults participating in cardiorespiratory, muscular fitness, and mixed method training (circuit training) regiments compare with one another and with the control group (no training) in terms of their overall cognitive changes after eight weeks of training?
2) Among those adults in the treatment groups who show improvements in physical fitness, are there any corresponding, common cognitive improvements?

Setting

This study was completed at a large, northwest college. The college offers a wide variety of instructional programs including transfer credit programs, career and technical degree and certificate programs, continuing education noncredit courses, programs in English as a Second

Language (ESL) and International ESL, GED programs, and customized training for local businesses. Of the nearly 38,000 students enrolled in courses in 2011-2012, approximately 82% were students taking credit-bearing courses (Taylor, Sandoz, & Marsh, 2011). A few key distinctions between students at this college compared to a four year university is that 51% of the students were attending school part-time, the average age of the student population was 35 years of age, and the majority of students were considered to be non-traditional. The Physical Education Department offers a variety of course offerings in fitness, strength training, aerobics, martial arts, yoga, individual and team sports, outdoor activities, athletics and rehabilitative therapies. Approximately 40% of students at this college enroll in physical education courses annually (Bates, 2010/2011).

Research Design, Participants and Sampling Strategy

Participants of this quasi-experimental eight-week study participated on an at-will basis. All participants, with the exception of the control group, were enrolled in a physical education course that met for a total of three hours per week. The control group consisted of students enrolled in a beginning level general health course (no physical activity requirement). Both cognitive and fitness component assessments were performed at the beginning and the end of the eight-week period. In the initial session, participants were presented with a brief introduction to the experiment, given the informed consent form, and screened for pre-existing cardiovascular or musculoskeletal conditions utilizing the Physical Activity Readiness Questionnaire (PAR-Q) (American College of Sports Medicine, 2010) (see Appendix A). Students were also provided with a brief description of both the cognitive and physical fitness assessments they would participate in. Participants in the control group received additional directions to not add any physical activity or exercise into their daily lives over the eight-week study. This was confirmed via self-report by the participant at the post-assessment session.

Thirty-seven adults participated in this study. Initially, 78 participants were recruited, of which 37 fully completed the study. Attrition was attributed to multiple causes including illness, students discontinuing enrollment in their physical education courses due to a variety of personal difficulties, and a lack of attendance in courses. The mean age of the participants completing the study was 28.0 $\pm$ 8.2 years of age and 65% were female (see Table 1). Study participants were recruited from physical education courses that met three specific physical education areas: strength training only (ST), cardiovascular training only (CVT), and mixed method (circuit) training (MMT) (see Figure 1 and Appendix B). All study participants reported being sedentary (i.e. inconsistent or no regular exercise in the last month). Control group participants were recruited from a health course that did not involve prescribed physical activity. The control group also reported not currently being involved in any regular physical activity and met the sedentary guidelines. All participants were registered as degree-seeking students. Exercise treatment participants that attended less than 75% of the exercise sessions were excluded from the data upon completion of the study. In addition, the quality of participation was deemed acceptable and sufficient by the instructor of record. All participants who completed the study were entered into a drawing for two $50 gift certificates to the campus bookstore.

Table 1

Participant Demographics by Treatment Group

	Cardiovascular Training Group	Strength Training Group	Mixed Method Training Group	Control Group
Sample Size	10	10	9	8
Mean Age	29.2 $\pm$ 10.8	25.3 $\pm$ 4.3	29.6 $\pm$ 9.0	27.9 $\pm$ 8.3
Gender	Male (0) Female (10)	Male (6) Female (4)	Male (4) Female (5)	Male (3) Female (5)

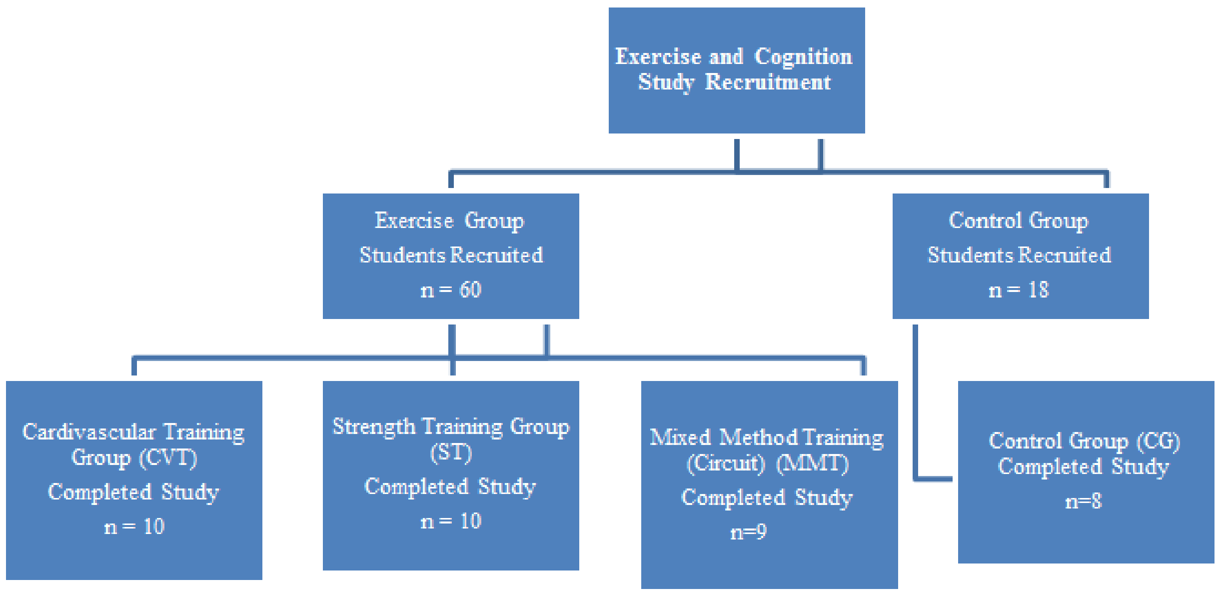

Figure 1. Participant breakdown by treatment group.

Research Ethics

This study was approved by the Internal Review Board at George Fox University and at the college where the participants were enrolled (see Appendices C and D). All participant data was kept confidential. Original data collection forms were shredded after being entered into the electronic spreadsheet except for the signed informed consent document. Electronic data is stored on a computer in a locked private office and a password-protected laptop that only I have access to. Once data entry was completed, participants were assigned an identifying number and the names of participants were deleted. Electronic data will be kept for three years and then deleted.

Two critical documents were distributed to study participants to further ensure the ethical practices of this study. The first was an informed consent letter (see Appendix E). Due to the potentially sensitive nature of cognitive evaluation in an academic setting, consent was required from all participants. The second critical document was the PAR-Q (described in previous section). In the field of exercise physiology, this document is considered a relevant and necessary condition prior to participation in any prescribed exercise program in order to evaluate the safety of participation for individual participants.

Data Collection and Analytical Procedures

The cognitive assessment was administered during a separate appointment time, prior to any exercise, in order to eliminate any acute influences of exercise on cognition. Participants were also asked at this time to indicate how well rested they felt on that day using a Likert-type scale (1 = tired, not well-rested; 2 = somewhat rested; 3 = well rested). Participants who rated themselves a 1 were rescheduled for cognitive testing. Participants were also asked if they had experienced a significant emotionally traumatic event in the previous three months that had impacted their ability to think clearly, make decisions, or process information. Participants who answered yes were eliminated from the final data pool. Five elements of cognition (speed, attention, mental flexibility, memory, and problem solving) were assessed using a web-based assessment tool from Lumosity (www.lumosity.com). Each participant was given a brief overview of the five tests and a brief introduction to the PC computer that was used in the testing. Each of the individual cognitive assessments began with written directions on how to complete the required task and allowed for two practice attempts before the actual assessment began. Participants were also given the opportunity to ask any clarifying questions.

The first task assessed response speed and impulse control utilizing a "Go-No Go" test (see Figure 2). Participants were randomly assigned a target image (a specific piece of fruit) and then were asked to respond as quickly as possible by hitting the space bar when their target image appeared on the screen. Images of other pieces of fruit were displayed intermittently, requiring participants to wait and only respond when their target fruit was displayed. Participants' response speed was measured in milliseconds (ms) and the average time across five trials was recorded.

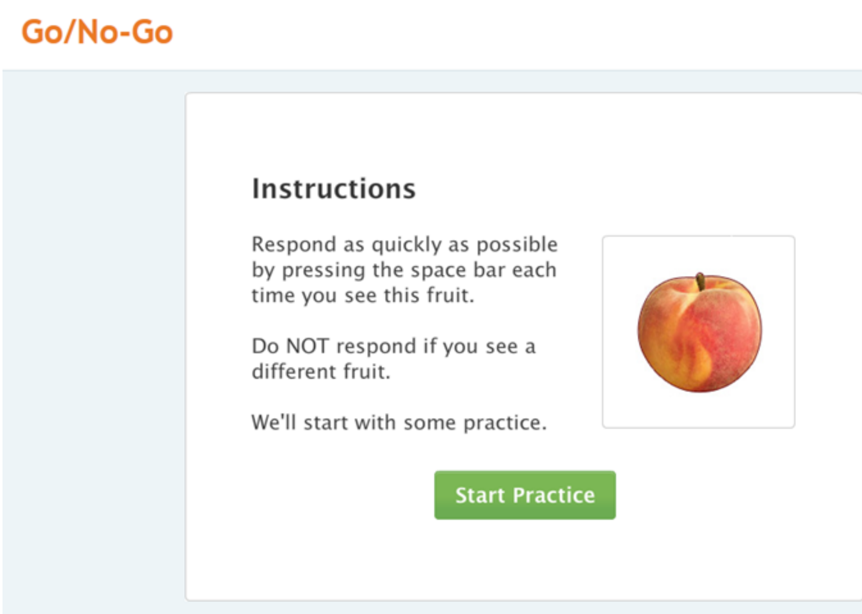

Figure 2. Go-No Go assessment to assess response speed to visual stimuli.

The second cognitive assessment evaluated attention. The Divided Visual Attention (DVA) task required participants to watch the screen as several letters briefly appeared in five bubbles and then disappeared (see Figure 3). Participants were randomly assigned two of these letters to watch for and were asked to identify where the letters had appeared by clicking on the bubbles. Twelve attempts were allowed. Each attempt decreased the threshold time that the letters remained visible (i.e. the letters appeared for progressively less time on the screen). The correct number of trials out of twelve attempts was recorded as well as the lowest threshold time for a correct answer (seconds).

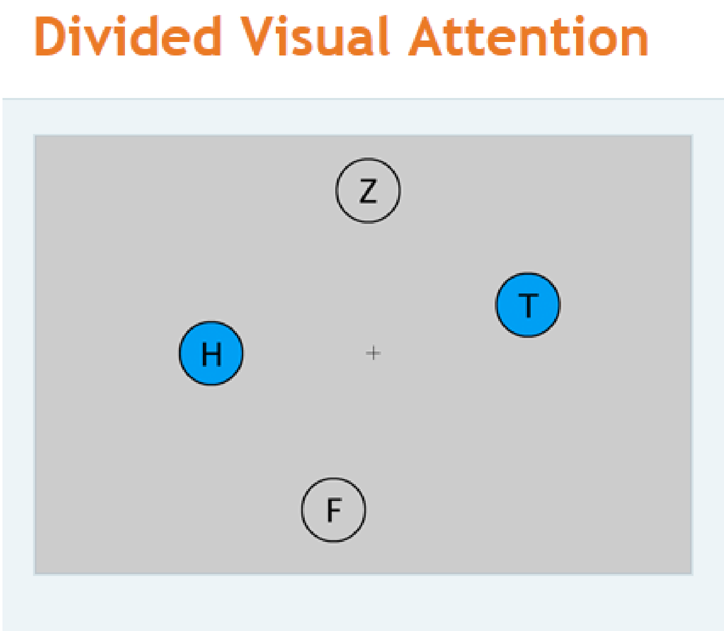

Figure 3. Divided visual attention task to assess attentional abilities with competing stimuli.

Mathematical problem-solving ability was assessed in the third test. Participants were given 45 seconds to answer as many basic mathematical problems (addition, subtraction, multiplication and division with results less than 100) as they could (see Figure 4). Problems were presented in word equations (e.g., nine minus seven). The total number of correct and incorrect trials in the 45-second time period was recorded.

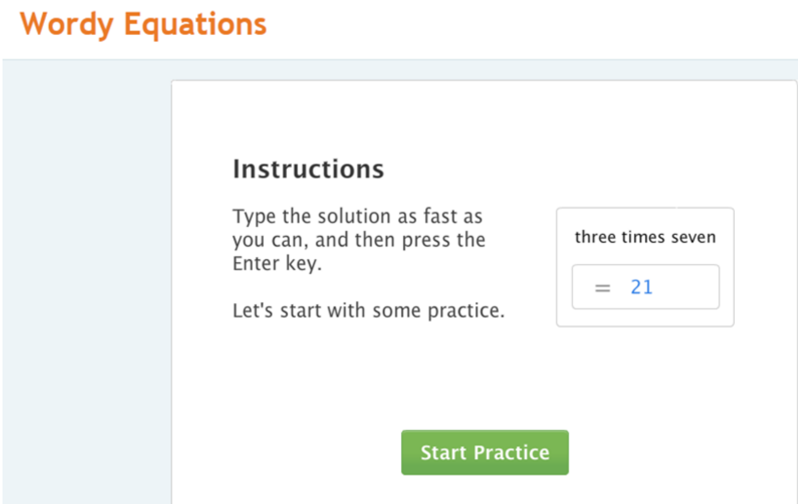

Figure 4. Word equations assessment to assess mathematical problem solving ability

The fourth cognitive assessment examined memory span. A series of bubbles on the computer screen were illuminated in a random pattern. Participants were asked to repeat the pattern by clicking on the bubbles in the correct sequence in which they were illuminated (see Figure 5). The sequences became increasingly longer as participants progressed (e.g. two items, three items, four items, etc.). Two attempts were required at each level and participants continued with increasingly longer sequences until they were unable to repeat the pattern correctly. Memory span was recorded as the greatest number of items the participant could remember. The number of total correct trials was also recorded.

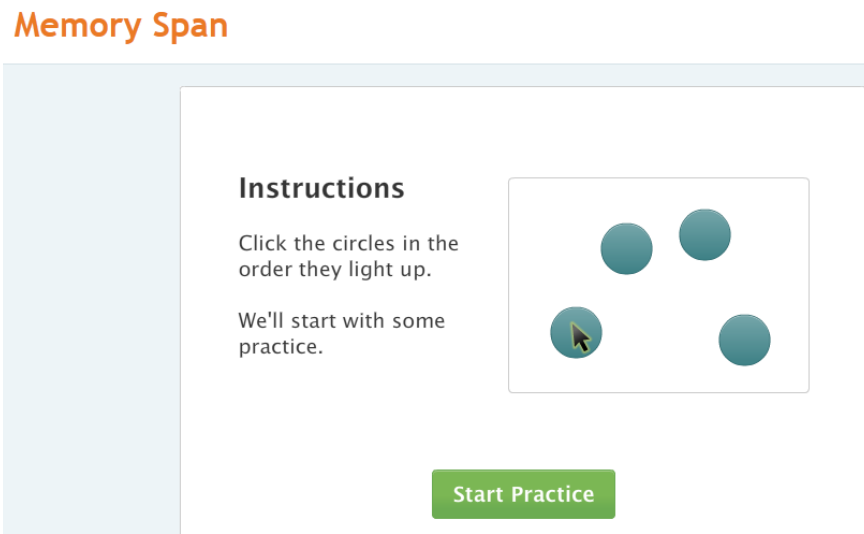

Figure 5. Memory span assessment to evaluate short-term memory of patterns.

The final cognitive assessment assessed participants' decision-making abilities and mental flexibility in a grammatical reasoning test. Participants were asked to respond as quickly as they could to indicate whether a given sentence was either true or false in describing a visual image (see Figure 6). Participants were given 45 seconds to respond correctly to as many scenarios as they could. The net number of correct trials (number correct minus errors), the total number of errors, and the participant's average reaction time (seconds) was recorded.

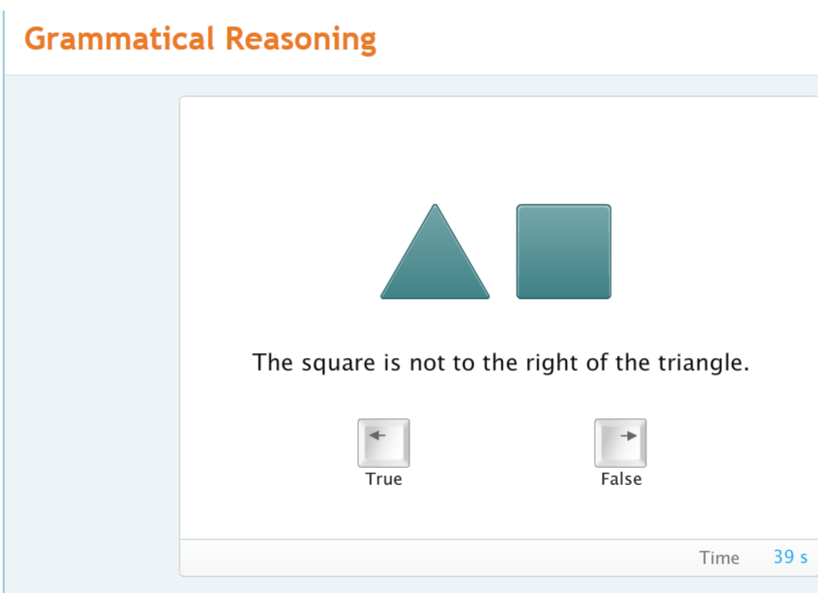

Figure 6. Grammatical reasoning assessment to evaluate mental flexibility.

Following these cognitive assessments, physical fitness assessments were completed in the following order, according to standards set by the American College of Sports Medicine (American College of Sports Medicine, 2010):

1) Anthropometric measurements: height, weight, waist circumference and hip circumference;
2) Body composition;
3) Cardiovascular endurance;
4) Muscular strength;
5) Muscular endurance;
6) Flexibility.

Fitness levels were assessed using industry standard field assessments. All assessments protocols followed standardized protocols that can be found in the American College of Sports Medicine's *Exercise Testing and Prescription Guidelines, 8th Edition* (American College of Sports Medicine, 2010). The methods of assessment selected were chosen for their ease of use, cost-effective nature in evaluating large groups of participants, and relative accuracy.

Anthropometric data was documented for all participants (height, weight, waist circumference, hip circumference and waist-to-hip ratio). Height was measured to the nearest tenth of a centimeter using a standard wall-mounted stadiometer (Medline Industries, Mundelein, IL). Weight was assessed using a standard platform scale (Medline Industries, Mundelein, IL) and recorded to the nearest 0.1 kg. Waist and hip circumferences were measured using standardized procedures (i.e. narrowest portion of the waist and the widest portion of the hips) utilizing a Gulick tape measure (Power Systems, Inc., Knoxville, TN) and were recorded to the nearest tenth centimeter. Body composition was evaluated using one of two methods. The preferred method was the three-site Jackson-Pollock skinfold assessment protocol as detailed in ACSM's Exercise Testing and Prescription Guidelines (American College of Sports Medicine, 2010). Measurement sites for male participants included the thigh, chest, and abdominal sites. Sites for female participants included the tricep, suprailliac, and thigh. Skinfold measurements were assessed using Lange skinfold calipers (Power Systems, Inc., Knoxville, TN) and were recorded to the nearest millimeter. The sum of the skinfolds was then used to calculate percent body fat to the nearest tenth percent. The secondary method that was utilized was Bioelectrical Impedance Analysis (BIA) (Omron, Shelton, CT). BIA was only used with participants whose body mass index (BMI) was measured in the obese category. Skinfold calipers are not considered to be an accurate assessment technique in obese individuals, nor is the assessment comfortable for these clients. BIA offered a relatively accurate, less invasive method of assessment.

Cardiovascular endurance was evaluated using the YMCA sub-maximal three-minute step test. This test involved participants stepping up and down, rhythmically on a 12-inch step platform to a cadence of 96 beats per minute for three minutes. A one-minute recovery heart rate was taken by palpitating the pulse at the radial artery at the end of the test and recorded in beats per minute. Muscular endurance of the trunk and core muscles was assessed using a timed one-minute abdominal partial curl-up test where participants were asked to complete as many curl-ups as they could in sixty seconds, ensuring that the trunk came off of the mat creating a 30-degree angle. The total number of correct and complete repetitions was recorded. Muscular endurance of the upper body was assessed using a maximal push-up test. Participants were asked to complete as many push-ups as they could at a self-determined, consistent cadence. There was no imposed time limit and the number of sequential, correct repetitions was counted until the participant either could no longer maintain their pace or was unable to continue. Muscular strength was evaluated using a back and leg dynamometer (Medco Athletics, Tonawanda, NY). Participants were asked to stand in a partial squat position with the handle at their knees. Using proper lifting technique, participants were asked to stand in a gradual, vertical direction creating maximal pull on the dynamometer. The highest measurement of two trials was recorded to the nearest half-pound.

Flexibility of the lower back and hamstrings was assessed using the modified sit-and-reach protocol with the Acuflex I Sit-and-Reach box (Power Systems, Inc., Knoxville, TN). The best of three attempts was recorded to the nearest half inch.

The exercise training sessions were led by the instructor of record in each of the designated courses. Participants were involved in 45-55 minutes of moderate to vigorous exercise. Participant attendance at the exercise sessions was obtained from the instructor's attendance book. Those attending fewer than 75% of the workout sessions were eliminated from final data analysis.

Role of the Researcher

I am a doctoral candidate at George Fox University in Newberg, OR. This research investigation will fulfill my dissertation requirement. I am also a full-time faculty member in the Health, Physical Education, and Athletics Department at the institution where the participants of this study were enrolled. As the principal researcher, I oversaw all recruitment, assessment, and evaluation in this study. My dual roles as both the researcher and a faculty member required me to consider many elements. In particular, it was critical that participants understand that their participation in this study was not a graded activity and was in no way required in order to be successful in their coursework.

Potential Contributions of the Research

Physical inactivity is a fast-growing public health problem and much attention has been paid to the impact regular exercise can have on a variety of chronic diseases. According to the American College of Sports Medicine (Sallis & Hutber, 2008), "exercise *is* medicine" and is a proven and effective treatment for heart disease, diabetes, hypertension, cancer, depression, anxiety, arthritis, osteoporosis and many other chronic diseases and conditions. Now research also supports the cognitive benefits of exercise throughout the lifespan. A current review of the literature seems to support that in addition to the numerous physical benefits of exercise there may also be substantial cognitive benefits. Research to date has clearly focused primarily on identifying these benefits in children and older adults. Both of these populations are of particular importance due to the significant cognitive stages that are associated with each of these points in the lifespan (cognitive development and cognitive maintenance/decline). These findings could serve as a convincing platform for public policy reform that would impact both our youngest and oldest generations. However, research addressing the relationship of exercise participation and cognition in the adult generation is underdeveloped. During adulthood, life and cognitive demands increase due to work, family, and personal responsibilities. It could be argued that the mental demands of life are at their greatest during this middle period of the lifespan. Research indicates that cognitive decline begins in our late 20' to early 30's (Salthouse, A.S., 2009; Tucker-Drob, E.M., 2011). While the rate of decline in cognitive abilities is relatively slow until older adulthood, attention, working memory (short term memory), long term memory, information processing speed, and cognitive control (ability to flexibly implement goals in the face of distraction) are still affected. According to Salthouse (2009):

> Many interventions currently target adults 60 years of age and older. However, if people start to decline when they are in their 20s and 30s, a large amount of change will likely have already occurred by the time they are in their 60s and 70s. This may affect the likelihood that interventions at that age will be successful because the changes might have accumulated to such an extent that they may be difficult to overcome. (p. 507)

Given that the human brain is a highly plastic organ, the potential to either improve cognitive performance, or at the very least delay age-related decline should be of particular importance during the adult years. Adding further support to the need to maintain or improve cognitive abilities in adults is the trend adults returning to higher education seeking job re-training or new degrees due to the economic downturn in the U.S. over the last four years. According to the National Center for Education Statistics (NCES) (2012) the percentage increase in the number of students age 25 and over has been larger than the percentage increase in the number of younger students, and this pattern is expected to continue. Between 2000 and 2010, enrollment of students 25 and over rose 42%, compared to a 34% increase in students under the age of 25. The NCES projects that between 2010 and 2020, there will be a 11% increase in enrollments of students under 25, and a 20% increase in students 25 and over; a trend that will quickly make non-traditional aged students the majority population in higher education (http://nces.ed.gov/programs/digest/d11/tables/dt11_200.asp). Regular exercise may prove to be a crucial lifestyle factor that could prevent cognitive decline, bolster cognitive performance, and potentially improve learning throughout the entire lifespan. As an exercise scientist, I have dedicated much of my career to educating people about the physical health benefits of regular exercise; the promise of exercise improving cognitive performance may be another benefit on the horizon. Higher education institutions have already begun to increase student recreation and physical education opportunities in order to improve the perceived value of the institutions and increase the number of healthy, social opportunities on campuses. Institutions may also find great value in knowing that by offering opportunities such as recreational sports, fitness classes, and physical education courses, they benefit students' cognitive well-being in addition to their physiological, sociological, and psychological health.

The aim of the present study was to examine the relationship between varying types of exercise on cognition in the adult population. These results add critical information to the ongoing scholarly discussion surrounding exercise and cognition, specifically in a population that currently lacks significant research.

CHAPTER 4

Results

Introduction

The purpose of this study was to examine the effects of physical exercise on cognitive and physical fitness abilities in adults. Specifically, the goal was to apply three different exercise treatments (cardiovascular training, strength training, and circuit training) and evaluate resultant changes in a variety of fitness and cognitive parameters after eight weeks of training. Thirty-seven adults enrolled at a northwest community college were recruited for this study. Participants were divided amongst three exercise treatment groups: cardiovascular training (CVT), strength training (ST), and mixed method training (MMT) and a control group (C) for the duration of the eight-week study (see Table 1). A comprehensive physical fitness evaluation was performed at the beginning and at the end of the eight week training session and included assessments of the following: 1) resting measurements: resting heart rate and resting blood pressure; 2) anthropometric measurements: weight, waist circumference and hip circumference; 3) body composition (percent body fat); 4) cardiovascular endurance (recovery heart rate post YMCA Step Test); 5) muscular strength (isometric maximal back and leg pull); 6) muscular endurance (push-up and abdominal partial curl-up test); and 7) flexibility (modified sit-and-reach). A cognitive evaluation of participants' "mental fitness" was also administered at the beginning of the study and at the end of the eight week training session, utilizing five assessments: 1) response speed and impulse control; 2) divided visual attention; 3) mathematical word equations; 4) memory span; and 5) grammatical reasoning.

This study sought to examine the relationship between exercise participation, resultant physical fitness changes, and cognitive fitness changes. In this study, the following research questions were investigated:

1) How do adults participating in cardiorespiratory, muscular fitness, and mixed method training (circuit training) regiments compare with one another and with the control group (no training) in terms of their overall cognitive changes after eight weeks of training?
2) Among those adults in the treatment groups who show improvements in physical fitness, are there any corresponding, common cognitive improvements?

I hypothesize that the following will occur:

H_1: Adults who participate in any of the three exercise treatments will experience greater improvements in cognitive fitness measures when compared to control group participants.

H_2: Adults who participate in any of the three exercise treatments will experience greater improvements in physical fitness when compared to control groups.

The mean and standard deviation were calculated for each group, for all variables, for both pre and post-test data. In addition, the percent change from pre to post-test was calculated. Paired t-tests were used to determine if significant changes occurred in fitness and cognitive variables over the eight-week study. A significance level of $p \leq 0.1$ was used to determine significance. This level was chosen due to the small sample used in this study. The coefficient of determination (r-squared) was calculated to determine the effect size of the resultant changes.

Results

Cardiovascular training group. Analysis of the fitness variables for the cardiovascular trained group indicated significant improvement in percent body fat ($p = 0.020$), abdominal muscular endurance as indicated by the partial curl-up test ($p = 0.064$), upper body muscular endurance as indicated by the push-up test ($p = 0.069$), and lower body flexibility as indicated by performance on the modified sit-and-reach test (p = 0.001) (see Table 2). On average, participants experienced a 7.1% decrease in body fat, a 19.4% increase in curl-up repetitions, a 32.0% increase in push-up repetitions, and a 16.1% increase in flexibility of low-back and hamstring flexibility. The magnitude of the effect size for improvements in both body composition and flexibility indicate a strong effect ($E.S._{\text{Body fat}} = 0.48$ and $E.S._{\text{Flexibility}} = 0.69$). The magnitude of the effect size for curl-ups and sit-ups was small, but was represented by a mean increase of 4 repetitions in curl-ups and 5 repetitions of push-ups. Surprisingly, the cardiovascular trained group did not show a statistically significant improvement in cardiovascular fitness (p = 0.437) as one might expect.

Table 2

Fitness Variable Changes After Eight Weeks of Cardiovascular Training (n = 10)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Resting Systolic Blood Pressure (mmHg)	111.33 (11.49)	108.67 (13.56)	0.72	0.492	0.05
Resting Diastolic Blood Pressure (mmHg)	71.78 (8.91)	74.22 (7.77)	0.99	0.351	0.10
Resting Heart Rate (bpm)	69.44 (10.61)	67.56 (8.57)	0.60	0.567	0.04
Weight (kg)	79.37 (15.69)	79.06 (14.91)	0.45	0.664	0.02
Waist Circumference (cm)	85.92 (13.12)	86.61 (12.16)	0.70	0.504	0.05
Hip Circumference (cm)	106.89 (10.30)	108.44 (13.29)	0.80	0.447	0.07
Body Fat (%)	31.09 (7.67)	28.79 (7.11)	2.91	**0.020**	0.48
YMCA Step Test Recovery Heart Rate (bpm)	101.67 (18.55)	97.22 (15.36)	0.82	0.437	0.07
Partial Curl-ups (reps)	37.11 (9.69)	43.89 (9.68)	2.15	**0.064**	0.34
Push-ups (reps)	18.56 (8.57)	23.78 (11.72)	2.10	**0.069**	0.33
Back and Leg Pull (lbs)	168.89 (70.97)	210.56 (65.12)	1.51	0.169	0.20
Sit-and-Reach (in.)	14.41 (3.61)	16.36 (2.76)	4.50	**0.001**	0.69

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

With regards to cognitive improvements, statistically significant changes were observed in the threshold time observed in the divided visual attention (p = 0.075), the number of items recalled in the memory span test (p= 0.081) (see Figure 7), and for the number of problems solved in 45 seconds in the problem solving test ($p = 0.079$) for the cardiovascular training group (see Table 3). All three of these variables had a large magnitude effect size (E.S. $_{\text{Divided Attention Time}}$ = 0.32, E.S. $_{\text{Memory Span}}$ = 0.31, E.S. $_{\text{Problem Solving}}$ = 0.031). The mean decrease in threshold time in the divided visual attention task was 23.6% indicating a faster response time. A 55.9% increase in the number of items recalled in the memory task was observed. The number of mathematical problems solved in 45 seconds increased by 25.1%. In summary, it can be said that participants were able to make decisions more quickly, recall more items, and solve equations more quickly after eight weeks of cardiovascular training.

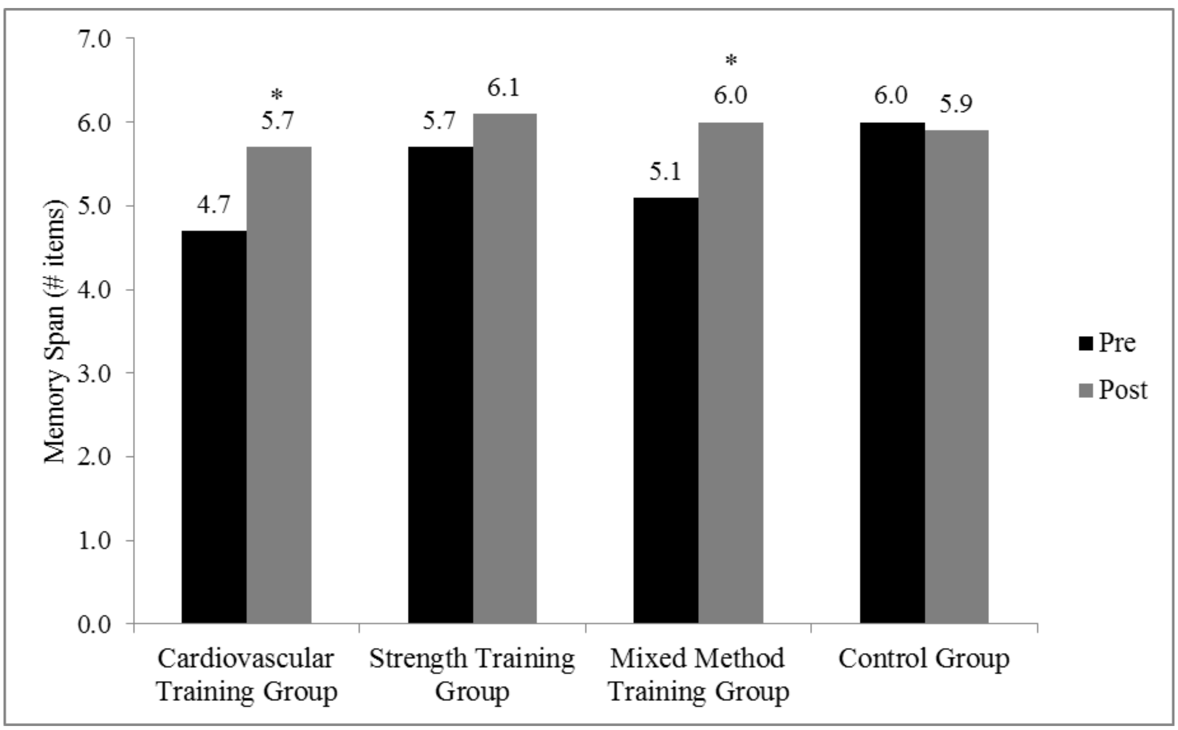

Figure 7. Memory span cognitive assessment results for all groups after eight weeks (*$p \leq 0.1$).

Table 3

Cognitive Changes After Eight Weeks of Cardiovascular Training (n = 10)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Response Speed (ms)	418.33 (59.72)	408.78 (66.45)	0.66	0.528	0.05
Divided Visual Attention - Correct Trials	8.44 (0.73)	8.33 (0.87)	0.36	0.729	0.01
Divided Visual Attention - Threshold Time (s)	0.32 (0.17)	0.20 (0.07)	2.04	**0.075**	0.32
Memory Span (# items)	4.67 (1.58)	5.67 (1.22)	2.00	**0.081**	0.31
Grammatical Reasoning & Cognitive Flexibility - Trials	10.00 (3.74)	10.22 (4.52)	0.18	0.859	0.00
Grammatical Reasoning & Cognitive Flexibility - Errors	1.22 (0.44)	0.89 (0.78)	0.89	0.397	0.08
Grammatical Reasoning & Cognitive Flexibility - Time (s)	3.93 (1.39)	3.92 (1.59)	0.02	0.984	0.00
Problem Solving (# correct)	11.00 (2.55)	13.44 (4.07)	2.01	**0.079**	0.31

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

Strength training group. After 8-weeks of strength training, participants experienced significant improvements in the number of partial curl-ups that could be completed in one minute (p = 0.014), the maximal number of consecutive push-ups completed (p = 0.001), and the maximal weight lifted in a single isometric back and leg pull (p = 0.027) (see Table 4). This was represented by a 40.3% increase in curl-up repetitions, a 37.4% increase in push-up repetitions, and a 23.3% increase in isometric strength. All three variables had a large magnitude effect size ($E.S._{Curl\text{-}ups} = 0.52$; $E.S._{Back/Leg} = 0.45$; $E.S._{Push\text{-}ups} = 0.83$). No other statistically significant improvements were observed in other fitness variables.

Table 4

Fitness Variable Changes After Eight Weeks of Strength Training (n = 10)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Resting Systolic Blood Pressure (mmHg)	113.11 (12.45)	112.00 (10.39)	0.63	0.547	0.04
Resting Diastolic Blood Pressure (mmHg)	77.56 (23.17)	75.56 (13.48)	0.35	0.736	0.01
Resting Heart Rate (bpm)	70.89 (12.09)	71.33 (11.53)	0.13	0.904	0.00
Weight (kg)	72.75 (25.72)	72.96 (26.91)	0.34	0.741	0.01
Waist Circumference (cm)	82.41 (19.21)	82.14 (20.65)	0.41	0.691	0.02
Hip Circumference (cm)	97.70 (14.17)	96.51 (13.30)	1.37	0.208	0.17
Body Fat (%)	17.07 (9.24)	17.57 (9.37)	1.05	0.326	0.11
YMCA Step Test Recovery Heart Rate (bpm)	95.44 (24.76)	95.56 (21.61)	0.02	0.988	0.00
Partial Curl-ups (reps)	35.56 (12.39)	47.22 (15.19)	3.12	**0.014**	0.52
Push-ups (reps)	28.44 (10.97)	37.44 (13.34)	6.60	**0.001**	0.83
Back and Leg Pull (lbs)	281.11 (103.95)	344.44 (138.19)	2.71	**0.027**	0.45
Sit-and-Reach (in.)	15.86 (4.31)	15.97 (4.67)	0.15	0.884	0.00

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

The strength training group was the only group to not show any statistically significant changes in any of the cognitive parameters after eight weeks of training (see Table 5). While cognitive fitness was not impacted negatively, the changes that were observed did not reach statistical significance.

Table 5

Cognitive Variable Changes After Eight Weeks of Strength Training (n = 10)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Response Speed (ms)	397.44 (61.50)	400.11 (98.34)	0.09	0.930	0.00
Divided Visual Attention - Correct Trials	8.22 (0.83)	7.78 (0.97)	1.18	0.272	0.13
Divided Visual Attention - Threshold Time (s)	0.37 (0.20)	0.37 (0.15)	0.13	0.903	0.00
Memory Span (# items)	5.67 (1.22)	6.11 (1.36)	1.51	0.169	0.20
Grammatical Reasoning & Cognitive Flexibility - Trials	8.22 (5.12)	8.44 (3.00)	0.10	0.922	0.00
Grammatical Reasoning & Cognitive Flexibility - Errors	2.00 (1.12)	2.00 (1.50)	0.00	1.000	0.00
Grammatical Reasoning & Cognitive Flexibility - Time (s)	3.73 (1.106)	3.233 (0.29)	1.77	0.114	0.26
Problem Solving (# correct)	10.78 (5.74)	12.56 (4.30)	1.61	0.146	0.22

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

Mixed method training group (circuit training). The mixed method training group experienced the greatest number of statistically significant changes in fitness variables. Specifically, participants experienced significant decreases in percent body fat (p = 0.014) and recovery heart rate after the YMCA step test (p = 0.001). Both of these variables had a large magnitude effect size (E.S. $_{\text{Body fat}}$ = 0.57; E.S. $_{\text{Step test}}$ = 0.68). In addition, statistically significant increases were seen with partial curl-up repetitions (p = 0.001), push-up repetitions (p = 0.001), maximal isometric strength as measured by the back and leg pull (p = .020), and lower body flexibility (p = 0.001) (see Table 6). The effect size calculations for each of these variables again indicated a large effect size (E.S. $_{\text{Curl-ups}}$ = 0.69; E.S. $_{\text{Back/Leg}}$ = 0.53; E.S. $_{\text{Push-ups}}$ = 0.84; E.S. $_{\text{Sit-Reach}}$ = 0.75). Overall, these results represented a mean decrease of 8.7% in body fat, an 18.3% in recovery heart rate, and an increase of 49.6% in curl-ups, 35.0% in push-ups, 24.2% in isometric strength, and 7.0 % in lower body flexibility. These physical improvements indicate improved fitness amongst several key parameters as a result of mixed method training.

Table 6

Fitness Variable Changes After Eight Weeks of Mixed Method Training (n = 9)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Resting Systolic Blood Pressure (mmHg)	118.50 (13.64)	116.25 (11.29)	0.53	0.612	0.03
Resting Diastolic Blood Pressure (mmHg)	74.75 (10.69)	73.25 (10.14)	0.69	0.510	0.06
Resting Heart Rate (bpm)	76.38 (5.97)	73.50 (10.86)	0.93	0.382	0.10
Weight (kg)	80.58 (21.49)	80.20 (21.41)	0.44	0.670	0.02
Waist Circumference (cm)	88.30 (18.89)	85.30 (18.48)	1.55	0.166	0.23
Hip Circumference (cm)	105.89 (10.14)	102.04 (8.30)	1.33	0.224	0.18
Body Fat (%)	26.53 (7.58)	24.60 (8.54)	3.28	**0.014**	0.57
YMCA Step Test Recovery Heart Rate (bpm)	120.13 (31.37)	96.00 (17.26)	4.14	**0.001**	0.68
Partial Curl-ups (reps)	36.25 (10.32)	51.38 (12.95)	4.23	**0.001**	0.69
Push-ups (reps)	23.00 (11.93)	29.38 (12.61)	6.50	**0.001**	0.84
Back and Leg Pull (lbs)	277.50 (107.94)	336.88 (129.48)	3.01	**0.020**	0.53
Sit-and-Reach (in.)	13.78 (1.77)	17.31 (1.95)	4.90	**0.001**	0.75

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

The mixed method training group experienced statistically significant increases in mathematical problem solving ability (p = 0.001) and in the number of items recalled in the memory span test (p = 0.088) (see Table 7). On average this represented a 48.8% increase in the number of problems solved when pre-test data and post-test data were compared and an 18.5% increase in memory span. The magnitude of the effect size for the changes in problem solving and memory were large ($E.S._{Problem\ Solving} = 0.79$; $E.S._{Memory} = 0.33$). No other cognitive parameters showed statistically significant improvements. It is interesting to note that the mixed method group was the only group to experience a large effect sizes in cognitive fitness and experienced the largest total number of improvements in the fitness categories (cardiovascular fitness, muscular endurance, muscular strength and flexibility) (see Figure 8).

Table 7

Cognitive Variable Changes After Eight Weeks of Mixed Method Training (n = 9)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Response Speed (ms)	393.13 (43.15)	368.13 (52.03)	1.12	0.302	0.13
Divided Visual Attention - Correct Trials	8.75 (0.71)	8.75 (1.04)	0.00	1.000	0.00
Divided Visual Attention - Threshold Time (s)	0.34 (0.12)	0.42 (0.14)	0.08	0.431	0.00
Memory Span (# items)	5.13 (0.64)	6.00 (1.07)	1.99	**0.088**	0.33
Grammatical Reasoning & Cognitive Flexibility - Trials	10.25 (4.80)	10.25 (2.12)	0.00	1.000	0.00
Grammatical Reasoning & Cognitive Flexibility - Errors	1.38 (0.74)	3.00 (3.42)	1.50	0.178	0.22
Grammatical Reasoning & Cognitive Flexibility - Time (s)	3.54 (1.06)	3.20 (0.54)	1.07	0.322	0.12
Problem Solving (# correct)	11.63 (4.47)	15.38 (3.38)	5.56	**0.001**	0.79

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

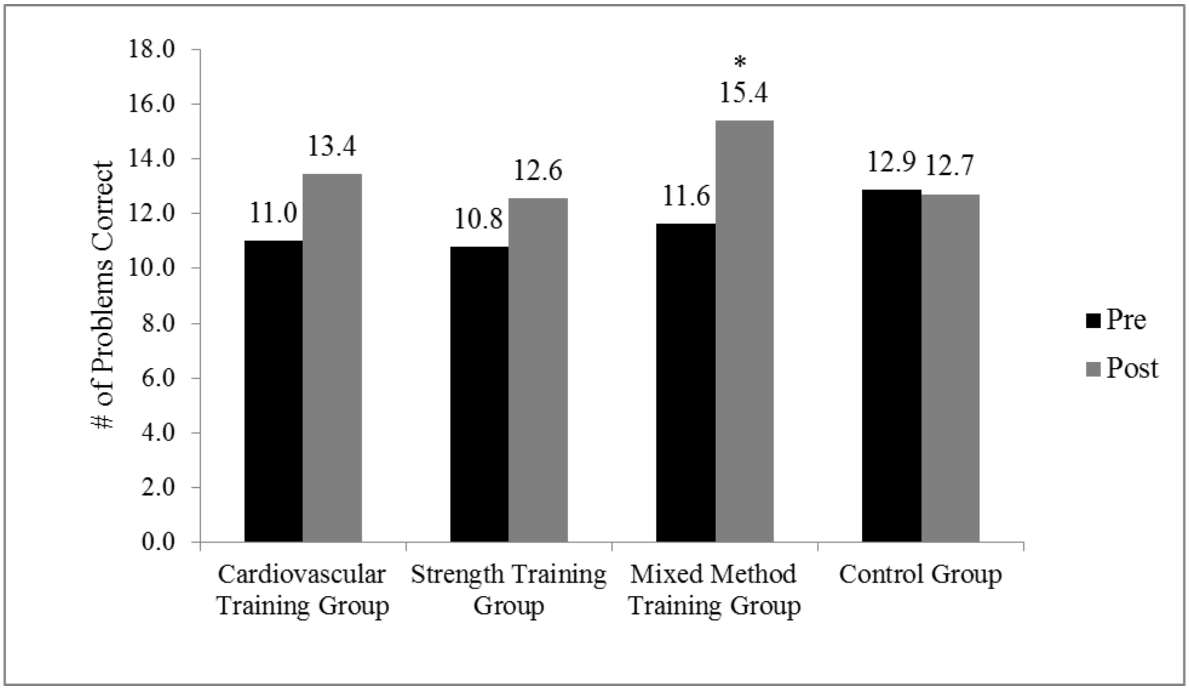

Figure 8. Number of mathematical equations solved in 45 seconds for all groups (*$p \leq 0.1$).

Control group. The control group did not experience any significant improvements in fitness over the course of the 8-week study, as was anticipated (see Table 8). However, the control group did show a surprising decline (negative impact on fitness) in three fitness parameters as indicated by increases in systolic blood pressure ($p = 0.027$), body weight ($p = 0.014$), and hip circumference ($p = 0.025$) (see Table 8). The control group's systolic blood pressure, body weight, and hip circumference increased from pre to post marking a significant shift towards lower levels of overall health. The increase in systolic blood pressure within this group is especially important to note as it represents a shift from a normal, healthy blood pressure (<120 mmHg), to a pre-hypertensive ($\geq$120 mmHg) blood pressure reading. The mean increase in body weight was 1.4kg (3.1 lbs.) during the eight-week period. All three variables showed a large magnitude effect size ($E.S._{Systolic\ BP} = 0.55$; $E.S._{Weight} = 0.63$; $E.S._{Hips} = 0.56$).

Table 8

Fitness Variable Changes in Control Group Participants After Eight Weeks (n = 8)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Resting Systolic Blood Pressure (mmHg)	115.43 (9.98)	122.00 (13.95)	2.91	**0.027**	0.55
Resting Diastolic Blood Pressure (mmHg)	74.57 (7.00)	78.57 (7.63)	1.57	0.167	0.26
Resting Heart Rate (bpm)	74.43 (16.30)	75.57 (11.30)	0.62	0.954	0.05
Weight (kg)	102.26 (60.45)	103.67 (60.88)	3.45	**0.014**	0.63
Waist Circumference (cm)	87.40 (12.40)	88.06 (12.72)	1.00	0.355	0.13
Hip Circumference (cm)	107.78 (11.10)	109.11 (12.09)	2.97	**0.025**	0.56
Body Fat (%)	24.04 (13.10)	24.54 (13.64)	1.61	0.160	0.27
YMCA Step Test Recovery Heart Rate (bpm)	118.00 (34.71)	122.29 (26.46)	0.64	0.545	0.06
Partial Curl-ups (reps)	45.71 (16.00)	46.86 (17.74)	0.53	0.615	0.04
Push-ups (reps)	34.43 (31.37)	35.57 (31.78)	1.00	0.356	0.13
Back and Leg Pull (lbs)	280.00 (207.71)	288.57 (227.43)	0.81	0.450	0.09
Sit-and-Reach (in.)	17.29 (3.41)	17.11 (3.43)	1.05	0.334	0.14

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

The control group data indicated a statistically significant increase in response speed (p = 0.045) demonstrating a slower response time to visual stimuli (see Table 9). The control group was the only group to perform significantly worse on any cognitive tests (see Figure 9). The effect size of this change was large in magnitude ($E.S._{\text{Response Speed}} = 0.48$). Potential reasons for this decline will be explored in Chapter 5.

Table 9

Cognitive Variable Changes in Control Group Participants After Eight Weeks (n = 8)

	Pre M (SD)	Post M (SD)	*t*	*p*	E.S.
Response Speed (ms)	402.71 (29.78)	474.57 (56.14)	2.53	**0.045**	0.48
Divided Visual Attention - Correct Trials	7.57 (1.27)	7.29 (1.11)	0.79	0.457	0.08
Divided Visual Attention - Threshold Time (s)	0.41 (0.14)	0.36 (0.13)	1.32	0.236	0.20
Memory Span (# items)	6.00 (0.58)	5.86 (0.90)	0.42	0.689	0.02
Grammatical Reasoning & Cognitive Flexibility - Trials	4.71 (2.36)	6.14 (2.67)	1.43	0.202	0.23
Grammatical Reasoning & Cognitive Flexibility - Errors	2.14 (1.35)	1.43 (0.53)	1.70	0.140	0.29
Grammatical Reasoning & Cognitive Flexibility - Time (s)	4.30 (0.40)	4.31 (0.71)	0.04	0.971	0.00
Problem Solving (# correct)	12.86 (1.57)	12.71 (1.70)	0.24	0.818	0.01

Note: Statistically significant values ($p \leq 0.1$) are shown in ***bold.***

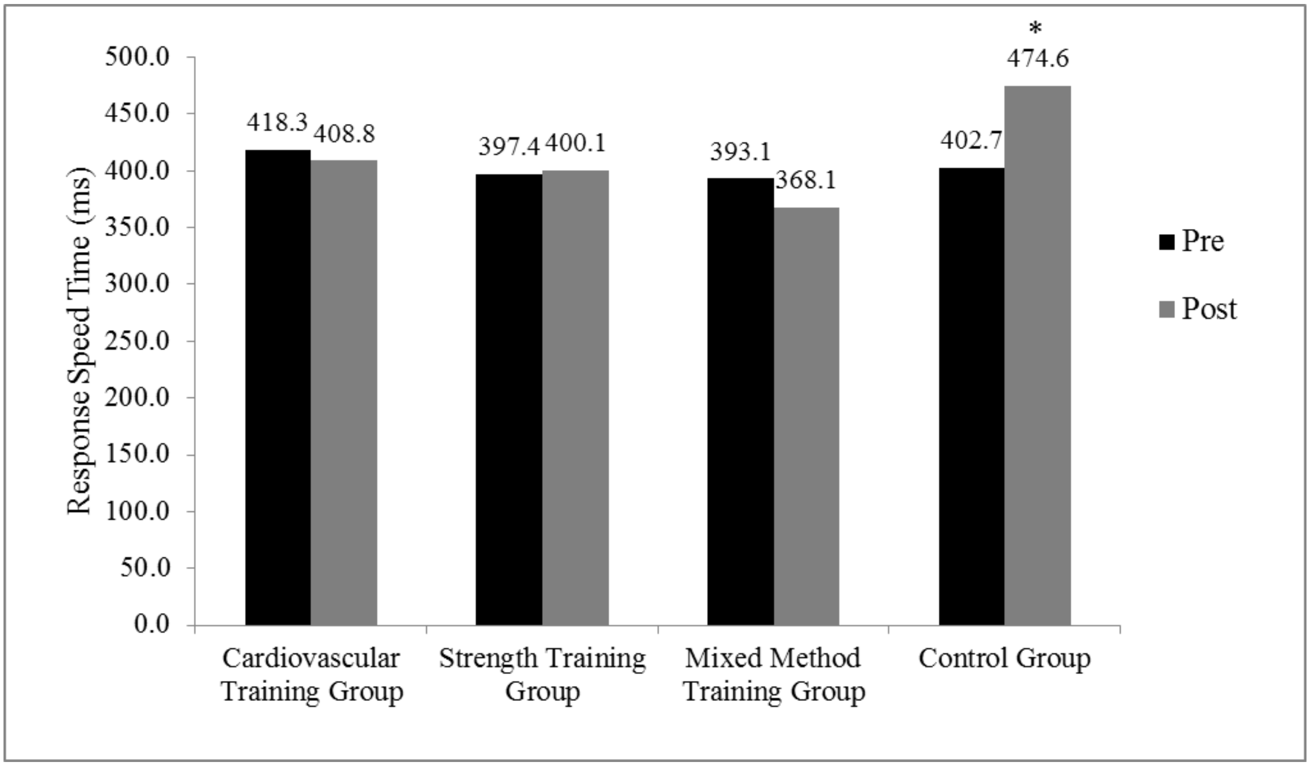

Figure 9. Response speed to visual stimuli for all groups ($p \leq 0.1$).

Summary

Only two exercise groups showed concurrent improvements in fitness and cognitive parameters. Both the cardiovascular trained group and the mixed method training (circuit training) group experienced statistically significant improvements in multiple fitness parameters and cognitive fitness parameters. Common improvements in fitness variables within these two groups included decreases in percent body fat, increases in muscular endurance (partial curl-ups and push-ups), and improvements in flexibility. Both groups also exhibited improvements in memory and problem solving abilities. Interestingly, the mixed method training group was the only group to improve their cardiovascular fitness *and* also to experience a decrease in threshold time of response for the divided attention test. While the strength training group experienced positive changes in partial curl-up and push-up scores, there were no statistically significant improvements in any of the cognitive variables.

One of the most surprising findings occurred in the control group. The control group not only experienced a statistically significant increase in systolic pressure, weight, and hip circumference, but also experienced a significant increase in response speed to visual stimuli. This was the only group whose fitness or cognitive parameters declined. It is also interesting to note that while all three exercise groups experienced improvements in muscular endurance (curl-ups and push-ups) and flexibility (modified sit-and-reach), not all three groups experienced cognitive changes.

It appears that the improvements in body fat percentage and cardiovascular endurance may be the two unique variables that were experienced in groups that showed both cognitive and fitness improvements. In contrast, declines in health scores with blood pressure, weight, and hip circumference were accompanied by decreased cognitive abilities. The results of this study offer new insight into the relationship between physical fitness and cognitive fitness. This relationship is discussed in depth in Chapter 5.

CHAPTER 5

Discussion

This study yielded mixed results in describing the relationship between physical fitness and cognitive fitness in adults. Changes were analyzed across multiple cognitive and fitness variables for 37 study participants divided amongst four groups: cardiovascular training (n = 10), strength training (n = 10), mixed method training (i.e. circuit training) (n = 9), and a control group (n = 8). Cognition was evaluated via five different assessments: 1) response speed and impulse control; 2) divided visual attention (correct number of trials completed and threshold time for response); 3) mathematical word equations (total number answered correctly in 45-seconds); 4) memory span; and 5) grammatical reasoning (correct number of trials, number of errors, and time for response).

Changes in cognition. After eight-weeks of exercise training, improvements in response threshold time in the divided visual attention assessment only improved significantly within the cardiovascular training group. There were no statistically significant cognitive changes in the number of correct trials achieved in the divided visual attention assessment for any of the groups. From these results, it appears that cardiovascular exercise improves the ability to respond correctly to specific cues while filtering out unnecessary information, even when cues begin to appear more quickly. Given that our day to day lives are becoming increasingly filled with competing stimuli (e.g., cell phones, computers, television, e-mail, text messaging, face-to-face conversations, etc.), the ability to respond to important cues while filtering out unnecessary and potentially distracting information is critically important to functioning in the workplace, at home, and in social situations. These results support previous findings in the literature showing that cardiovascular exercise improves information processing abilities and attentional processes in adults (Colcombe & Kramer, 2003; Spirduso et al., 2008).

In addition to improvements in divided visual attention threshold time, the cardiovascular trained group also experienced significant improvements in memory span and in mathematical problem solving abilities. The mixed method training group also significantly improved in these two cognitive areas. Improvements in memory span were manifested by the ability to reproduce visual patterns of increasing length. This is a new finding in this field of study and has not been identified in the current body of literature. Short-term memory has not been shown to improve after either acute bouts of exercise or after exercise training (Coles & Tomporowski, 2007; Tomporowski & Ganio, 2006). While some studies have shown general increases in cognition, none have specifically identified improvements in short-term memory in adults, nor in children or older adults. The lack of research studies completed to date on the long-term effects of exercise on cognition in adults and the inconsistency of how cognition as defined in studies may be a primary reason for the lack of findings in this area. It is important to note that the frontal lobe of the brain, which is responsible for short-term memory and numerous other cognitive functions, has been shown to be positively impacted by aerobic exercise via increased brain volume, blood flow, and vascularization (Kramer et al., 2006; Lista & Sorrentino, 2010; Ploughman, 2008). The unique findings of this study may be related to improvements in one or more of the factors listed above.

The cardiovascular training group and the mixed method training group also experienced statistically significant improvements in mathematical problem solving performance. Similar findings specific to math performance have been shown in children (Castelli et al., 2007; Catherine L. Davis et al., 2011; Hollar et al., 2010) and in young adults (Tomporowski, 2003), although the research in young adults was limited to only the acute effects of exercise and did not explore long-term impacts. This specific improvement in mathematical problem solving ability in adults has not been investigated in previous studies. This finding offers a novel addition to the current body of literature and direction for future research, especially as the number of adult-learners continues to increase in higher education.

The only group to experience statistically significant changes in response was the control group, and the change was not favorable. Over the eight-weeks of this study, control groups saw a significant increase in response time to visual stimuli (i.e. slower to respond). This change in cognition was accompanied by significant increases in blood pressure and weight gain, both of which are well recognized as critical health risks. However, the change in response time to visual stimuli can in and of itself pose a risk. Response time to visual stimuli is critical in numerous aspects of day to day life. Whether responding to a sudden change in a traffic light, or to a quickly approaching vehicle as one steps off the curb to cross the street, or even to the sudden trip and fall of a small child, our ability to respond to visual stimuli as quickly as possible can represent the difference between potential injury and safety for ourselves and others. The ability to respond to visual stimuli with a direct motor response is controlled primarily by the motor cortex of the brain which is located in the posterior aspect of the frontal lobe. The role of physical exercise training is thought to impact this area of the brain because learning new or novel exercises, as one might do in circuit training, and cardiovascular endurance improvements are associated with increases in the size of the motor cortex and neurogenesis in this brain region (Adkins, Boychuk, Remple, & Kleim, 2006). While it should not be assumed that the lack of exercise in the control group of this study was the direct or only cause of the increase in response time to visual stimuli, this new evidence points to an area for possible future research. Future studies that are able to map not only changes in physical fitness and cognition, but actual structural and hemodynamic changes in the brain are needed to better understand this interesting phenomenon.

Only two cognitive measures appeared to be unaffected by the exercise or control treatments. Specifically, the number of correct trials (out of twelve) in the divided visual attention task and the grammatical reasoning task showed no significant changes over the eight-week study. As stated previously, the threshold time for the divided visual attention task did show significant improvements in the cardiovascular trained group. The lack of change in the number of correct trials that were completed by participants could be due to a lack of sensitivity with the test selected or the relative brevity of the study (eight weeks). The relationship between exercise and grammatical reasoning has not yet been investigated in the current body of research, so it is difficult to provide an explanation as to why this variable would be entirely unaffected by physical activity (or inactivity), although there is no evidence to suggest that it should be affected , either.

The strength training group was the only group to show no statistically significant changes (positively or negatively) in any of the cognitive variables. The findings of this study are somewhat in contrast to findings from one previous study that specified that acute resistance training in middle-aged adults result in positive cognitive adaptations (Chang & Etnier, 2009). The findings by Chang and Etnier showed improvements in executive function and processing speed, as indicated by improvements in scores on the Stroop Test and Trail Making Test, immediately following a bout of strength training exercises. One potential reason for the difference in results of this study from Chang and Etnier’s work is that this study did not look at the acute effects, but rather the long term effects of exercise training. As described previously, the acute hemodynamic response to exercise is thought to be highly influential in cognitive abilities. What is not well understood is how long that response lasts. Improvements in cognitive abilities in older adults, after regular participation in strength training exercise, has been demonstrated (Cassilhas et al., 2007; Ozkaya et al., 2005). However, to date, no other studies were found that examined the impact of consistent strength training in the adult population and their correlative effects on cognition.

Overall, the cardiovascular trained group and the mixed method group were the only two groups to experience positive changes in cognitive variables (see Figure 10). Both of these groups also experienced numerous changes in physical fitness which will be discussed in the next section.

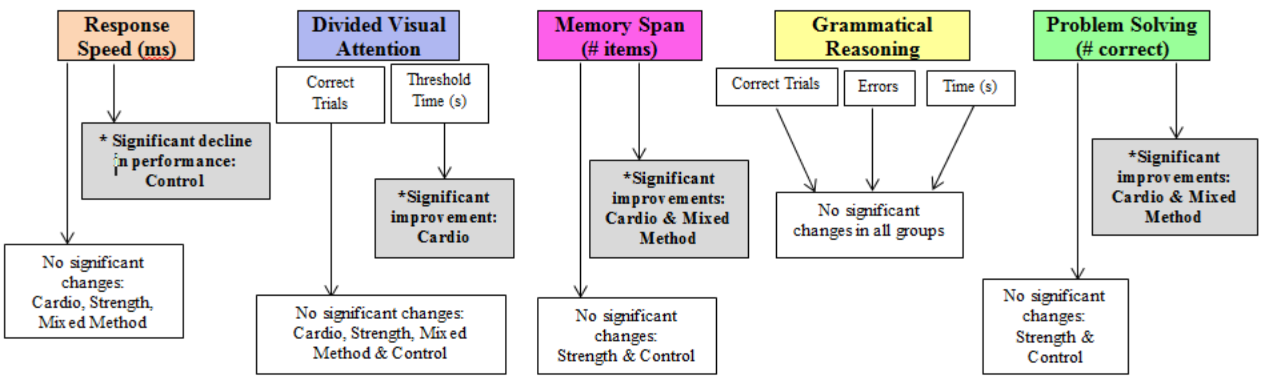

Figure 10. Resultant cognitive variable changes after eight-weeks for all groups (cardiovascular, strength, mixed method and control).

Changes in physical fitness. In order to begin to determine if there were any patterns in fitness improvements and cognitive improvements, it is necessary to examine the fitness changes that occurred only when cognitive improvements were experienced. All three exercise groups showed improvement in muscular endurance measures (push-ups and partial curl-ups), but all did not show improvements in cognition. Similarly, muscular strength improvements were seen in both the strength training group and the mixed method group, but the strength training group saw no improvements in cognition. With the goal of narrowing the examination of variables, muscular endurance and muscular strength improvements cannot be confidently said to be a commonly experienced variable when cognitive improvements occur.

Improvements in body composition (i.e. decreases in percent body fat) were observed in both the cardiovascular trained group and the mixed method trained group. These two groups were also the only two groups to both show improvements in memory span and problem solving. The cardio group showed one additional improvement in the area of threshold time in the divided visual attention assessment. There is research evidence that suggests that obesity negatively impacts cognitive processes (M. F. Elias, Elias, Sullivan, Wolf, & D'Agostino, 2003). While there currently are no other studies that have shown the reverse to be true (i.e. improvements in body composition elicit improvements in cognition) the findings of this study could be significant in beginning research in that area. While the exact mechanism by which obesity impacts cognition is not known, findings in animal research suggests that concomitant obesity related health factors such as increases in triglycerides and hyperglycemia negatively impact cognition (Farr et al., 2008). Again, this points to an interesting area for future research.

In addition to the negative impacts obesity can have on cognition, hypertension (high blood pressure) has also been associated with decreases in cognitive performance (M. F. Elias et al., 2003; M.F. Elias et al., 1993). It is interesting to note that the control group was the only group to see a statistically significant increase in systolic blood pressure over the eight-weeks of the study and was also the only group to experience a significant decline in response speed to visual stimuli. In addition to the increased systolic blood pressure, control group participants also gained a statistically significant amount of body weight and an increase in their average hip circumference. After only eight-weeks, these worsening health scores are worth note and concern. The mechanism behind the impact of hypertension or increasing body weight on cognition is not well understood and is an interesting area for future research.

Significant improvements in lower body flexibility were also observed in the cardiovascular training group and the mixed method training group. As indicated above, these two groups were the only ones to also experience improvements in cognition. Improved flexibility has not been noted as a potential influencing factor on cognition. Two studies using an older adult population found no improvement in cognition following a regular stretching routine or participation in a yoga class (Oken et al., 2006). It is unlikely that improved flexibility could potentially influence cognition, as many of the positive changes in cognition are proposed to be related to hemodynamic and biochemical changes that occur after exercise training (Etnier, 2008). Stretching is not associated with improved resting heart rate, blood pressure, improved cardiorespiratory fitness or muscular strength. The improvements in flexibility are strongly related to the training protocols these two groups participated in. Future studies would benefit from eliminating any flexibility work, even minimally focused, from exercise groups in order to more carefully narrow the scope of cognitive improvements associated with exercise.

In Perspective

One value of this study was the inclusion of three different training groups. More specifically, research has been very limited in looking at the potential benefits on cognition of mixed method (circuit) training in humans. To date, the only studies that have examined this mode of training and resultant changes in the brain have utilized animals (rats). These studies have shown significantly larger increases in brain development when comparing rats that performed simple cardiovascular exercise (wheel running) to rats that gained cardiorespiratory exercise through novel activities (maze running). In a study by Anderson, Eckburg, and Relucio

(2002), a group of rats that learned motor skills on an obstacle course that increased in difficulty over training and required balance and coordination showed significantly greater increases in the thickness of the motor cortex in the brain when compared to a second group that ran voluntarily in exercise wheels but had little opportunity for skill learning. While both exercise groups showed improvements over controls, the impact of novel exercise training was significant. I think that this area of study offers particularly fascinating potential for future studies.

Another value of this study was the comprehensive nature of the fitness assessments that were completed. Many studies have limited their evaluations to cardiorespiratory and muscular fitness (Åberg et al., 2009; Chang & Etnier, 2009; Tomporowski, 2003). While this presented challenges in data analysis due to the large volume of data, it does provide a richer context from which to draw conclusions.

A limiting component of this study was the small, non-randomized sample. While statistically significant findings were observed, a larger sample size would certainly add to the validity of the results. It is also important to point out that the cardiovascular training group did not include any male participants. While there is no evidence to suggest that there are gender differences in how men and women experience cognitive changes as a result of exercise training, this should be noted as a limiting aspect of this data. Examining the correlation between fitness variables and cognitive changes in future studies with larger sample sizes would offer additional valuable information in this area of study. An additional limiting factor was the population that was observed was from a single college, participating in exercise courses in a specific department. Results from a broader population and the inclusion of self-directed, not instructor directed, exercise could be influential in resultant changes. It is possible that resultant changes in cognition were influenced by the overall academic learning that occurred during the physical education classes. However, students in the control group were also enrolled in college-level courses and showed no improvements in cognition. It is also important to note that those participating in the exercise interventions were taught by a variety of instructors. Instruction from a single instructor, in all exercise groups would also help to eliminate the possibility, although unlikely, of cognitive improvements being associated with a specific instructional style.

An additional limiting component of this study is that all exercise sessions took place in a group setting. It is well accepted that new social contacts, novel experiences, and other environmental enrichment factors are influential in cognitive development (Anderson et al., 2002; Curley, Jensen, Mashoodh, & Champagne, 2011). While the control group was also immersed in the same academic culture and did not experience cognitive improvements, it is still important to note that studies in non-academic settings might result in different conclusions. Caution should be used in comparing the results of this present study with cognitive changes in those that participate in exercise in less stimulating environments. The results of this study could be further expanded by controlling for environmental enrichment factors in future study designs.

One of the limitations of the current literature is that cognitive measures vary widely from study to study, as do the constructs of cognition. Most studies limit cognitive testing to a single aspect (i.e., memory, or processing speed, or problem solving) and rarely address the multi-dimensional nature of cognition. In addition, a wide variety of cognitive assessments are used throughout the research with very little consistency in selection from study to study. The cognitive assessment tool utilized in this study was selected for its cost-effectiveness, ease of access, and the variety of dimensions of cognition it assessed. However, this tool has not been used in similar studies in the field. This represents a challenge in that specific performance data cannot be compared with other studies, but it also offers an opportunity for future studies to utilize this same tool and begin to assess cognition in a more multi-faceted manner.

Key Recommendations

Based upon all of the implications for future research study discussed, below are three key recommendations for future research:

1) Future research needs to continue to examine the interaction between changes in specific health and fitness variables (i.e. blood pressure, body composition) and cognition in adults. Specifically, researchers need to identify which biochemical and hemodynamic changes as a result of long-term exercise participation are most influential in eliciting cognitive changes.
2) Exercise prescriptions as an academic intervention tool for adult-learners may offer another fascinating pathway for future research. From the results of this study, it appears that adults experience cognitive benefits as a result of participation in regular exercise. Specifically, mathematical problem solving and memory span seem to be highly influenced. Currently, academic intervention models for struggling students typically involve recommendations for tutoring, increased contact time with instructors, and modifications to the student's learning environment. Future academic intervention models could include a regular cardiovascular and/or circuit training program that will not only benefit the student's health, but also could offer promising benefits to the student's cognitive abilities.
3) Cardiovascular exercise and mixed method training appear to be the most influential forms of exercise on cognition in adults when considering the results of this study. Future studies are needed to continue this research and to further clarify the benefits

of these training models. Larger sample sizes, longer study durations, and detailed monitoring of exercise intensity, duration, and mode will enhance our knowledge of these interesting and important findings.

Conclusions

The aim of this study was to gain insight into the complex relationship that exists between physical fitness and cognitive fitness. Specifically, research in the adult population is limited and has previously focused solely on either academic performance in young college students or on correlations with future IQ measures. This study provided new evidence to suggest that cardiorespiratory exercise training and mixed method circuit training appear to be highly influential on some aspects of cognition (memory span and problem solving ability). Cardiovascular training also offered an additional benefit in the area of divided visual attention response time. Both the cardiovascular training and mixed method training groups showed common statistically significant improvements in body composition. These two groups were the only groups to experience these concurrent changes in body composition and cognition. This finding offers a rich future of research possibilities and is increasingly important in our nation as we experience the highest rates of obesity in our history. Exercise may not only offer an opportunity to improve physical fitness, manage body weight and reduce the risk of chronic disease, but it may also offer an opportunity to improve our mental fitness, as well.

The results of the control group are significant and worth considering. This was the only group to experience a decrease in cognitive ability (response speed) and concurrently experience a shift in blood pressure from a normal range at the beginning of the eight weeks and to a pre-hypertensive range eight weeks later. This finding, in addition to the statistically significant weight gain within this group, potentially points to yet another reason why exercise is crucial to total health.

Of particular interest to me, is research in the area of how the physical health of adult students impacts their ability to learn and perform in the academic environment. Regular exercise could offer an additional “prescription option” in the presence of learning difficulties and/or disabilities. Given the numerous physical health benefits of regular exercise that are widely understood and accepted, the findings of this study and future studies will only enrich this perspective.

The Greek philosopher Thales states: *Mens sana in corpore sano*. Translated this means “a healthy mind in a healthy body”. What was once widely accepted in ancient society as a priority has somehow slipped in importance in the modern world. The contributions of this study, if read in ancient Greek times, may have offered little novelty. However, in the current health crisis our nation is experiencing, these findings may bolster the idea that exercise *is* medicine and is a crucial, not optional, aspect of our lives. It is my hope that this research continues to expedite a movement towards health in our nation and the recognition that exercise offers many more benefits than simply strong muscles.

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APPENDICES

Appendix A. Physical activity readiness questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire (PAR-Q)*

NAME OF PARTICIPANT ____________________

DATE ____________________

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (✓) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1 Has your doctor ever said you have heart trouble?
☐	☐	2 Do you frequently have pains in your heart and chest?
☐	☐	3 Do you often feel faint or have spells of severe dizziness?
☐	☐	4 Has a doctor ever said your blood pressure was too high?
☐	☐	5 Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6 Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7 Are you over the age of 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness appraisal. Tell your physician what questions you answered YES to on PAR-Q or present your PAR-Q copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:
- unrestricted physical activity starting off easily and progressing gradually.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:
- A GRADUATED EXERCISE PROGRAM – a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- A FITNESS APPRAISAL – the Canadian Standardized Test of Fitness (CSTF)

postpone

If you have a temporary minor illness, such as a common cold.

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE).
  Reference PAR-Q Validation Report, British Columbia Ministry of Health, May, 1978.
* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

Appendix B. Exercise Treatment Group Descriptions

	Cardiovascular Training Group	Strength Training Group	Mixed Method Training Group
	Note: All exercise groups completed three hours per week of the specified training modality.		
Activity Description	Emphasis on improving cardiorespiratory conditioning. Sustained, rhythmic activities utilizing the large muscle groups of the body at a moderate to vigorous intensity were selected.	Emphasis on progressive resistance training using a variety of exercise modalities including barbells, dumbbells, resistance bands, and machines. Workouts were designed to develop strength, muscular size, muscle definition, toning, and improve general physical condition.	Emphasis on the combination of both strength training and cardiovascular exercises performed in varying intervals to improve overall physical conditioning. Exercises were performed at varying work and rest intervals emphasizing total body work in each session.
Intensity	60-85% of Target Heart Rate	3-5 sets of 8-10 exercises performed at 70-80% of 1 repetition maximum	Cardio: 60-95% of Target Heart Rate Strength: 15 or more repetitions at 30-50% of 1 repetition maximum.
Sample Exercises	Walking, jogging, elliptical machines, cardio kickboxing, indoor cycling, etc.	Squats, lunges, bench press, overhead press, bicep curls, tricep extension, etc.	Combination of strength and cardiovascular exercises in alternating sequences. For example: jump rope, squats, high knee run, bicep curls, etc.

Appendix C. George Fox University IRB Approval

GEORGE FOX UNIVERSITY

School of Education
414 N. Meridian St., V124, Newberg, OR 97132
503.538.8383 | Fax 503.554.2868 | soe.georgefox.edu

Sept. 18, 2012

Ms. Marisa Hastie
Ed.D. Student
Department of Educational Foundations & Leadership
George Fox University

Dear Ms. Hastie:

This letter is to inform you that as a representative of the GFU Institutional Review Board I have reviewed your proposal for research investigation entitled "Effects of Exercise Participation on Cognition in Young Adults." The proposal is approved.

Best wishes as you complete your research investigation.

Sincerely,

Terry Huffman, Ph.D.
Professor of Education
Human Subjects Research Committee
George Fox University
(503) 554-2856

Appendix D. Research Site IRB Approval

[redacted] IRB
Expedited Review Form
Page 1

EXPEDITED REVIEW FORM

[redacted]titutional Review Board

09 /13 /2012	[redacted]	
Date Submitted	**Institutional Review Board**	**File Number**

Effects of Exercise Participation on Cognition in Young Adults
Title of Research Project

Marisa Hastie	Health, Physical Education & Athletics	x. 5552	hastiem@[redacted]edu
Principal Investigator/Project Director	**Department**	**Phone Extension**	**Email address**
N/A			
Co-investigator/Student Investigator	**Department**	**Phone Extension**	**Email address**
N/A			
Co-investigator/Student Investigator	**Department**	**Phone Extension**	**Email address**

Anticipated Funding Source: none

Projected Duration of Research: 3 **months** **Projected Starting Date:** 10/1/2012

Other organizations and/or agencies, if any, involved in the study: George Fox University

Expedited Review Category (see categories on page 1–check one) 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5 ☐ 6 ☐ 7 ☐

SUMMARY ABSTRACT

Please supply the following information on a separate page: BRIEF description of the participants, the location(s) of the project, the procedures to be used for data collection, whether data will be confidential or anonymous, disposition of the data, who will have access to the data.

ADDITIONAL ATTACHMENTS

- Any brochures, advertisements or recruitment material given to subjects.
- A completed copy of the Consent Form Checklist.
- A copy of the Consent form that will be provided to the participants.

RESPONSIBILITIES OF THE PRINCIPAL INVESTIGATOR:

- Any additions or changes in procedures in the protocol will be submitted to the IRB for written approval prior to these changes being implemented
- Any problems connected with the use of human subjects once the project has begun must be communicated to the IRB Chair
- The principal investigator is responsible for retaining informed consent documents for a period of three years after the project.
- If IRB requires modifications in project prior to approval, IRB will notify the PI who can then make changes and resubmit application for final approval.

Marisa L. Hastie	09/13/12		/ /
Investigator/Project Director Signature		Co-Investigator/Student Signature (if appropriate)	

Signature of IRB Committee Chair:			**Date:** 9/21/12
IRB Chair: Check 1 box:	xx☒ Approved	☐ **Approved with Conditions**	☐ **Refer to Full Committee Review**

Appendix E. Informed Consent Document

Letter of Consent
Exercise and Cognition Research Study

Dear Student:

My name is Marisa Hastie and I am a full-time faculty member at Lane Community College in the Health, Physical Education, and Athletics Department and a Doctoral student at George Fox University in the Educational Foundations and Leadership Program (Newberg, OR). I am conducting a research study to explore the relationship between exercise participation and cognition. As an enrolled student in a physical education course, you are invited to participate in this study which will involve participation in two fitness and cognitive evaluations over a ten week academic term. Each evaluation will take approximately 90 minutes of your time and will include a cognitive assessment followed by a comprehensive fitness evaluation (resting measurements, body composition, cardiovascular fitness, muscular fitness and flexibility). Your continuous enrollment and attendance in your physical education course is also a required aspect for inclusion in this research study.

The findings of this study promise to add valuable information to the existing body of research. Findings will provide insight into the complex relationship between cognition and exercise.

The risks associated with participation are minimal. However, as with any form of physical activity there are inherent risks of injury. You will be asked to complete the Physical Activity Readiness Questionnaire (PAR-Q) honestly and consult a physician prior to making significant changes to your exercise status. Every effort will be made to ensure your safety. It is your responsibility to inform the researcher of any potential health concerns or limitations you might have. Participation is completely voluntary and you may withdraw from the study at any point.

The results of this study will be used for research purposes only and may be used for presentations at professional conferences/ meetings or publications in peer-reviewed professional journals. All data will be kept confidential. I affirm to keep personal identities and information confidential.

All research data will be kept in a password protected file on a secure computer that only I have access to. All data will be destroyed at the end of a three year period by me.

I appreciate your interest and time considering participating in this project. If you have any concerns or questions at any time, you may contact me at hastiem@lanecc.edu or 541-463-5552. You may also contact: Lane Community College's Director of Institutional Research, Assessment and Planning, Craig Taylor, at taylorc@lanecc.edu or 541-463-5364; or the chair of my dissertation committee, Gary Tiffin, at gtiffin@georgefox.edu or 503-554-2874.

If you understand the use of this research and agree to participate, please sign below.

Signature___________________________ Date ______ DOB______*Must be 18 years or older*