EFFECTS OF ACUTE AEROBIC EXERCISE ON EXECUTIVE FUNCTION IN OLDER WOMEN

Roseann Perchinske

A Thesis
Submitted to the Graduate College of Bowling Green State University in partial fulfillment of the requirements for the degree of
MASTER OF EDUCATION

August 2013

Committee:
Dr. Lynn Darby, Advisor
Dr. Adam Fullenkamp
Dr. Amy Morgan
ABSTRACT

Dr. Lynn Darby, Advisor

In the older adult population, there is a high rate of decline in cognitive functioning. It has been reported that improving fitness levels exhibits a positive effect on cognition (Colcombe & Kramer, 2003; Colcombe et al., 2004). Older adult females 60-75 years of age who were moderately to highly fit performed better on working memory tasks after an acute bout of moderate or high-intensity aerobic exercise than before exercise. Participants included healthy females ($N = 11$) who were not on medications for cognitive impairment and who did not show signs of dementia or Alzheimer’s disease. A submaximal walking exercise test was administered to assess fitness levels, as well as modified flanker tasks and d2-tests, to measure executive functioning in the brain. Results indicated that older adults females, 60-75 years of age showed improved scores on the modified flanker task and d2-tests after a session of moderate or high-intensity aerobic exercise. These findings suggest that an acute bout of exercise, regardless of intensity, can improve tests of executive control.
ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Darby for all the help she has given me throughout the thesis process. Without her help and knowledge of statistics, I would not have been able to complete this project in a timely manner. I also want to thank my committee members, Dr. Morgan for all her knowledge and insight throughout this process, and Dr. Fullenkamp for designing the cognitive programs for my study. I would like to thank Yu Zhang, as well, for help in data collection. Lastly, I would like to thank my friends and family who have patiently supported me throughout higher education.
“Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it.” - Plato
TABLE OF CONTENTS

CHAPTER I. INTRODUCTION ................................................................. 1
   Limitations ................................................................................. 3
   Delimitations ............................................................................. 4
   Operational Definitions ............................................................. 4
   Purpose of the Study ................................................................. 6
   Significance of the Study ......................................................... 6
   Hypotheses of the Study ......................................................... 7

CHAPTER II. LITERATURE REVIEW .................................................. 8
   Introduction .............................................................................. 8
   Decreases in Executive Function ........................................... 8
   Aerobic Exercise Increases Cognition ..................................... 10
   Greater Fitness Levels Positively Effect Cognition ............... 12
   Mechanisms by Which Cardiovascular Exercise Improves Cognition ..................................................... 17
   Various Levels of Physical Activity May Enhance Cognition ................. 19
   Acute Effects of Cardiovascular Exercise on Cognition ............ 21
   Intensity and Duration of Exercise May Positively Affect Cognition ......... 28
   Summary ................................................................................. 30

CHAPTER III. METHODS ................................................................. 31
   Participants ............................................................................... 31
   Equipment ............................................................................... 31
   Procedure .............................................................................. 32


LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Descriptive Characteristics of Participants (N = 11)</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>Norms for Females, 60-69 Years of Age and 70-79 Years of Age</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>Correlation (r values) between VO\textsubscript{2}max and Dependent Variables at Pre-Ex, Imm-Ex 20-Minutes of Exercise, and Post-30 Minutes Exercise at Moderate and High Intensity</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>Means and Standard Deviations for Total Reaction Time (RT\textsubscript{T}), Incongruent Reaction Time (RT\textsubscript{I}), and Congruent Reaction Time (RT\textsubscript{C}) by Time and Exercise Intensity at Pre-Ex, Imm-Ex 20-Minutes of Exercise, and Post-30 Minutes of Exercise Regardless of Intensity</td>
<td>43</td>
</tr>
<tr>
<td>5</td>
<td>Means and Standard Deviations for Total Reaction Time (RT\textsubscript{T}), Incongruent Reaction Time (RT\textsubscript{I}), and Congruent Reaction Time (RT\textsubscript{C}) at Pre-Ex, Imm-Ex, and Post-30 Minutes of Exercise for Moderate (Mod) and High Intensity Exercise</td>
<td>44</td>
</tr>
<tr>
<td>6</td>
<td>Means and Standard Deviations for Error rate (normalized number of errors), GZ Value, and SKL Value at Pre-Ex, Imm-Ex, and Post-30</td>
<td>47</td>
</tr>
<tr>
<td>7</td>
<td>Time × Intensity Interaction Means and Standard Deviations for Error Rate, GZ Value, and SKL Values at Pre-Ex, Imm-Ex, and Post-30 at Moderate and High Intense Exercise</td>
<td>48</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Research Design: Time (3) × Intensity (2)</td>
<td>38</td>
</tr>
<tr>
<td>2</td>
<td>Total Reaction Time by Time and Exercise Intensity</td>
<td>43</td>
</tr>
<tr>
<td>3</td>
<td>Incongruent Reaction Time by Time and Exercise Intensity</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>Congruent Reaction Time by Time and Exercise Intensity</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>Error Rate Time and Intensity Levels</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>GZ value by Time and Exercise Intensity</td>
<td>49</td>
</tr>
<tr>
<td>7</td>
<td>SKL value by Time and Exercise Intensity</td>
<td>50</td>
</tr>
</tbody>
</table>
CHAPTER I: INTRODUCTION

There is a high prevalence of decreased cognition in the aging population (Chan et al., 2005). One of the typical characteristics of non-pathological brain aging includes some loss of cognitive function (Erickson & Kramer, 2008). However, there has been increasing evidence that regular physical activity can help prevent, or at least delay, the onset of cognitive loss (Colcombe & Kramer, 2003). Executive control (tasks demanding diligence, conscious control, and processing of new information), however, is the cognitive function most positively affected by cardiovascular exercise (Erickson & Kramer, 2008; Hillman, Snook, & Jerome, 2003). Participation in aerobic exercise and physical activity seem to have a strong shielding effect on brain function and anatomy, especially in older adults as well as those who are susceptible to the development of cognitive deterioration (Churchill et al., 2002; Colcombe & Kramer, 2003).

Cardiovascular exercise appears to considerably reduce the loss of brain tissue in regions controlling executive function, which will decrease the chance of developing cognitive impairment related to age (Colcombe & Kramer, 2003). Therefore, involvement in aerobic exercise during middle and older age is very important. During this time, the brain experiences many alterations in structure and function that may involve the development of specific diseases, including dementia (Stroth, Hille, Spitzer, & Reinhardt, 2009).

The frontal, prefrontal, and parietal portions of the brain are involved in executive control processes (Colcombe et al., 2004). Structural, physiological, and psychological changes in the frontal part of the brain are common in older adults (Colcombe et al., 2004). Aerobic exercise can help prevent these changes in the elderly (Colcombe et al., 2004). According to information obtained from animal and human neuroanatomical and behavioral archetype studies, what affects cortical performance in a positive manner as one ages is level of aerobic fitness (Colcombe et al.,
Effects of Acute Aerobic Exercise on Executive Function in Older Women

In terms of older adult brains, improvements in aerobic fitness can supply an amount of plasticity and resilience to neural substrates that is absent in the elderly who possess a low fitness status (Colcombe et al., 2004). It is believed that exercise helps increase oxygen-rich blood flow to the brain, which aids in normal physiological processes (Colcombe et al., 2004). When there is decreased blood flow due to physical inactivity, the brain does not function properly (Colcombe et al., 2004).

Effects from acute aerobic exercise may show similar cognitive benefits to those observed with chronic aerobic exercise participation, and there might be a relationship between acute and chronic aerobic exercise, as demonstrated in young adults (Kamjio et al., 2009). After a strenuous acute bout of exercise, cognition was increased in adolescents who also displayed comparable increased results in cognition from chronic aerobic exercise participation (Zervas, Danis, & Klissouras, 1991). Implications have been made that acute aerobic exercise helps increase cognitive processing speed among tasks demanding a substantial degree of executive control (Hillman et al., 2003; Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007). Chronic aerobic exercise greatly impacts executive functioning as well (Colcombe et al., 2006).

Colcombe et al. (2006) noted that the amount of gray and white matter, which is located primarily in the prefrontal cortex, increased after six months of cardiovascular fitness training. Executive control functions are located in the prefrontal cortex, and this area is thought to be very susceptible to age-related changes in executive function (Colcombe et al., 2004; Tisserand & Jolles, 2003). Therefore, the prefrontal cortex, which is vulnerable to age-related declines, is believed to be receptive to improvements in cognition from regular aerobic exercise (Kamijo et al., 2009).
Effects of Acute Aerobic Exercise on Executive Function in Older Women

However, not much research has been done in older adults involving acute aerobic exercise and cognition (Kamijo et al., 2009). Kamijo et al. (2009) revealed that in older adults 60-74 years of age, reaction time and response accuracy, elements of executive function were improved after an acute bout of light (30% of VO$_2$max) and moderate (50% of VO$_2$max) aerobic exercise (Kamijo et al., 2009). While Kamijo et al. (2009) found that executive function improved after light and moderate exercise, it is unclear whether cognition will be improved post-high-intensity exercise in older adults, especially if they are not chronic aerobic exercisers (Pesce, 2009). Kamijo et al. (2004) found that executive function decreased after an acute bout of high-intensity aerobic exercise in young adults.

Conversely, Budde et al. (2012) reported that in young adults, only those who exercised regularly displayed improvements in executive function after high-intensity aerobic exercise. Also, Hogervorst, Riedel, Jeukendrup, and Jolles (1996) and Winter et al. (2007) discovered that cognition can be increased after high-intensity exercise bouts. Cognition does not always decline after high-intensity exercise, such as sprinting (Winter et al., 2007). This study will investigate whether fitness and activity levels play a role in cognition increases or decreases after acute bouts of moderate and high-intensity exercise, and examine executive function immediately, and through 30 minutes after exercise in older adult females.

Limitations

Two limitations of the study that was completed are: 1) a small sample size, and 2) a cross-sectional study. Therefore, individuals who were once fit may have been unfit in this study, and vice versa, which may have a negative or positive impact on their cognition. In addition, more highly active participants may not necessarily have been highly fit. This study could be improved if it were to be done longitudinally so individuals and researchers can observe
how the number of years of being aerobically fit can impact executive functioning as opposed to just a single sample in time.

Delimitations

Delimitations are that only two types of cognitive tests were implemented. Also, only one element of executive function was tested, inhibitory control (sustained and selective attention, and reaction time). The dependent variables were reaction time and attention, elements of executive function (total reaction time, congruent reaction time, incongruent reaction time, error rate, the GZ value-working speed, and the SKL value-attention) while the two independent variables were Time (Pre-Ex, Imm-Ex, and Post-30) and Intensity (moderate and high).

Operational Definitions

Cognitive function - a term to describe many aspects of memory, including executive control, cognitive flexibility, working memory, and short-term memory (Miyake & Shah, 1999; Masley, Roetzheim, & Gualtieri, 2009).

Behavioral Inhibition- an aspect of executive function in which an individual is able to stop, or inhibit, a certain behavior or action (Miller & Cohen, 2001).

Short-term memory - includes a capacity of 1 to 60 seconds for retention and retrieval of verbal and visuospatial information (Foster, 2009). For example, short-term memory allows a person to retrieve and remember a phone number that was just given (Foster, 2009).

Working memory - a component of short-term memory, but should not be confused with short-term memory. Working memory allows an individual to process and manipulate information to recite the number backwards, or pick out a certain number within a seven number sequence (Foster, 2009). Working memory, or executive function, typically decreases with age (Bugg, DeLosh, & Clegg, 2006).
Executive control - a broad word used to define many cognitive functions, including working memory, cognitive flexibility, and inhibition (Kamijo et al., 2009; Chan, Shum, Toulopoulou, & Chen, 2008). Executive control, or function, manipulates, controls, and organizes other aspects of cognition (Bugg et al., 2006; Elliott, 2003). Executive functions include a wide variety of tasks, such as planning, attention, solving problems, initiation and directing actions, switching between tasks, reasoning, and multi-tasking, which also are all characteristic of working memory (Beilock & Carr, 2005; Bugg et al., 2006; Chan et al., 2008; Fukuda & Vogel, 2009; Miyake & Shah, 1999).

Cognitive flexibility - an element of executive function that includes multitasking, attentional shifting, and adaptation to changing environments (Ionescu, 2012).

Selective Attention - deciding to center attention on specific stimuli (Bates & Lemay, 2004). Selective attention is a measure of behavioral inhibition, which is an element of executive function (Miller & Cohen, 2001).

Sustained Attention - the capability to shift, search, and maintain attention (Bates & Lemay, 2004).

Reaction Time - reaction time is an element of executive control, and measures how quickly a participant responds to a stimulus presented (Hillman et al., 2003). In the modified flanker task to assess executive function, reaction time is the time needed between the identification of the direction of an arrow and the push of a button for the correct response (Hillman et al., 2003; Kamijo et al., 2007; Kamijo et al., 2009).

Modified Flanker Task - measures executive function by reaction time. The test measures total reaction time, congruent reaction time, and incongruent reaction time. In the congruent condition, arrows are displayed that point in the same direction as the middle arrow, the arrow of
reference, allowing quicker reaction time. In the incongruent condition, the arrow can point in the same or opposite direction as the arrow of reference, which can increase reaction time. This reaction time condition demands a larger extent of executive control, which is attributable to stimulation of the inaccurate answer before the assessment is finished (Kamijo et al., 2009).

**d2 Test of Attention** – This test assesses sustained and selective attention (Budde et al., 2012). Selective attention is an aspect of behavioral inhibition because one is choosing what stimuli they pay attention to, and is therefore an element of executive function (Miller & Cohen, 2001).

**Errors of the d2 test** - measures accuracy and attention to detail, and is the number of all errors of both confusion and elimination (Budde et al., 2012).

**GZ value of the d2 test** - measures the rate at which participants mark off each d2, and is the overall number of marked letters within the d2 test (Budde et al., 2012).

**SKL value of the d2 test** - measures attention, and is the standardized number of accurate answers minus confusion errors (Budde et al., 2012).

**Purpose of the Study**

To investigate whether physical fitness and activity levels are related to cognition before and after acute bouts of moderate and high intensity aerobic exercise for older adult females (≥ 60 years of age), and to determine if changes in cognition existed up to a half an hour after each exercise intensity.

**Significance of the Study**

The significance of the study is to determine whether physical fitness and activity level are positively related to cognition after acute bouts of moderate and high intensity exercise in older adult females. If a correlation is found, implications can be made regarding the cognitive functioning of this population immediately post-exercise.
Hypotheses of the Study

It was hypothesized that there was no relationship between estimated $VO_2\text{max}$ and cognitive function.

It was hypothesized that there was no significant difference in cognitive function (total reaction time, congruent reaction time, incongruent reaction time, error, GZ value, and SKL value) at different exercise intensities (i.e., moderate and high intensity exercise).

It was hypothesized that there was no significant difference in cognitive function (total reaction time, congruent reaction time, incongruent reaction time, error, GZ value, and SKL value) scores at different times (i.e., pre-exercise, immediately after exercise, and 30 min after exercise.)
CHAPTER II: LITERATURE REVIEW

Introduction

There are ways to train the brain to increase cognitive activity level. Greater aerobic fitness status is associated with improved executive function (Voss et al., 2010). In the part of the hippocampus that stores fresh information and memories, exercise encourages new neuron formation, including BDNF (brain-derived neurotrophin factor), gray matter in the prefrontal cortex, and brain signals transported via neurotransmitters (Erickson et al., 2010). BDNF, a protein in the brain, aids in keeping current neurons alive and increases the augmentation of neurons and synapses by acting on specific neurons of the peripheral and central nervous systems (Colcombe et al., 2004; Erickson et al., 2010). Cardiovascular exercise is found to generate these fresh synapses (Colcombe et al., 2004). Synapses are neuronal links that transfer information among neurons (Biederer, 2006). Voss et al. (2010) has shown that aerobically trained older adults increase the connectivity of these synapses to match those of individuals 30 years of age, which in turn, increases planning, memory, multitasking, and handling uncertainty. Cardiovascular exercise alters the components of cells and molecules that regulate numerous cognitive abilities (Colcombe & Kramer, 2003; Colcombe et al., 2004; Voss et al., 2010). Rather than just training memory or the process of making decisions via mental games, aerobic exercise offers a greater number of wide-spread advantages for improving cognition (Colcombe & Kramer, 2003; Colcombe et al., 2004; Voss et al., 2010).

Decreases in Executive Function

The subject of cognitive functioning is a widely discussed topic in young and old individuals, however, this thesis will focus on executive function in the elderly. Typically, as one ages, cognitive functioning declines (Barnes, Yaffe, Satirano, & Tager, 2003). Several
studies have indicated that there are decreases in executive function related to age, including switching between tasks, working memory, planning, attention, and inhibitory control (Hasher & Zacks, 1994; Kramer, Hahn, & Gopher, 1999; Mayr & Kliegl, 1993). Decreases in executive control can lead to more serious problems. Cognition tends to decrease as an individual ages, which may result in an increased chance of developing impairments in cognition (Barnes et al., 2003). “Poor cognitive function has been associated with development of comorbid disease, increased risk of dementia, loss of independence, hospitalization, institutionalization, and death” (Barnes et al., 2003, p. 459). There are many elements of cognitive function that might be lost with aging, causing individuals to lose their ability to carry out basic tasks (Barnes et al., 2003; Bugg et al., 2006).

Barnes et al. (2003) conducted a 6-year longitudinal study in which different aspects of cognition were measured to examine whether aerobic fitness status had any impacts. Participants included 349 individuals 55 years of age and older (Barnes et al., 2003). During year one, baseline measures for fitness status and cognitive testing were collected (Barnes et al., 2003). A VO\textsubscript{2}max treadmill test tailored to older adults was used that included 11 two-minute stages that gradually increased in grade (0-18%) and speed (1.7-5.0 mph) (Barnes et al., 2003). The modified Mini-Mental State Examination (mMMSE) was administered for cognitive testing at baseline, but at year 6, the full MMSE was given. The scores from the two tests are strongly correlated (r = 0.92) in this study population (Barnes et al., 2003). The MMSE measures language and visuospatial capability, attention and calculation, capacity to follow instructions, orientation to time and place, and the identification and recollection of three words (Barnes et al., 2003).
At year 6, a subsample within the study was given additional cognitive tests, as well as the full MMSE (Barnes et al., 2003). These additional tests included measures of attention (an aspect of executive function), verbal memory, and verbal fluency, which are components of short-term memory (Barnes et al., 2003). Results indicated that higher levels of cardiovascular fitness were associated with better cognitive scores across all measures, and lower levels of fitness were linked with lower cognitive function (Barnes et al., 2003). However, the correlation among aerobic fitness level and cognition was greatest for executive control and attention, as well as results from the MMSE that measures global cognitive function (Barnes et al., 2003).

Aerobic Exercise Increases Cognition

Over time, the elderly who have shown indications of decreases in cognition or have signs of declining memory possess a greater chance of acquiring Alzheimer’s disease and different types of dementia (Berga, 2008). Being aerobically active on a regular basis can help reduce some of these age-related declines in cognition (Bugg et al., 2006). Numerous studies have shown that physical activity, particularly aerobic exercise, can help increase cognitive functioning in the elderly (Albert et al., 1995, Bugg et al., 2006, Colcombe et al., 2004, & Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001). Albert et al. (1995) conducted a longitudinal study over 2-2.5 years involving older adults ages 70-79 years who exercised vigorously, such as running or swimming, or who completed activities of daily living that included strenuous activities comparable to cutting the grass or raking leaves. The researchers found that this type of exercise was linked with less cognitive deterioration (Albert et al., 1995).

Bugg et al. (2006) wanted to discover if exercise affected time-of-day differences in how older adults performed on a measure of executive function. They recruited 35 healthy older adults without any history of head trauma such as loss of consciousness, psychiatric disease, or
Effects of Acute Aerobic Exercise on Executive Function in Older Women

dementia (Bugg et al., 2006). Executive function testing involved task switching. A physical activity questionnaire was given in order to assess the participants’ physical activity level (Bugg et al., 2006). The questionnaire was the Voorrips, Ravelli, Dongelmans, Deurenberg, and Staveren’s (1991) physical activity questionnaire that asks questions about activities of daily living such as washing clothes, scrubbing dishes, any leisure activities (walking, cycling), and sports (Bugg et al., 2006).

The executive control task involved reading directions on a computer screen that mentioned there would be different arrangements of large and small squares (Bugg et al., 2006). These squares showed up one at a time in the middle of the computer screen. The individuals in the study had to remember the number of small and large squares that were presented each time, and remember that number over a few times whenever a new square popped up on the screen (Bugg et al., 2006). Following each trial, correct answers were shown. Easier tasks included just one change in square arrangement, and more complex tasks incorporated more switches in the square sequence (Bugg et al., 2006). This type of executive control task involved attention switching and updating (Bugg et al., 2006).

Executive function was measured for the sedentary and active groups in the morning and again in the evening (Bugg et al., 2006). Results indicated that in sedentary older adults there was a significant decrease in executive function across the day, but the more active older adults did not show this decline from the morning to night session; their results were comparable at the two testing times and did not show any significant decrease in executive function (Bugg et al. 2006). This study suggests that physical activity level may play a role in preventing mental exhaustion throughout the day (Bugg et al. 2006). One limitation of this study was that the
investigators did not actually measure fitness level, only their activity level was self-reported, comparable to the Albert et al. (1995) study.

Greater Fitness Levels Positively Effect Cognition

Colcombe et al. (2004) conducted two studies to investigate the association between cardiovascular fitness and the aging brain. The first study consisted of 41 healthy, high-functioning older adults without any psychological illness or dementia. A test of aerobic fitness was administered, called the Rockport 1-mile walk test. Depending on level of ability, maximal \( \text{VO}_2 \) for older adults was estimated using this test. However, in those older adults who were able, a graded treadmill maximal \( \text{VO}_2 \) test was conducted. For the cognitive measures, reaction time and behavioral analysis were assessed with a flanker task, an adaptation of the Eriksen flanker paradigm (Colcombe et al., 2004). The Eriksen flanker task has been employed in many studies to explore how executive function is affected by one session of exercise (Eriksen & Eriksen, 1974; Hillman et al., 2003; Kamijo et al., 2007).

The flanker task includes two forms of stimuli (usually in the form of arrows) consisting of a congruent and incongruent condition, and depends on differing magnitudes of inhibitory control (Kamijo et al., 2009). In the incongruent situation (where an arrow may point in the opposite direction of the arrow of reference), a larger extent of executive control is used because of the stimulation of an inaccurate response before a decision is made (Kamijo et al., 2009). According to the frontal lobe hypothesis of aging, a prominent decrease in cognition is detected in executive control functions as humans’ age (West, 1996). As a result, it is thought that amid the Eriksen flanker task, the effect of interference (of the incongruent condition) may influence the elderly more than in young adults (Kamijo et al., 2009). Participants in the Colcombe et al. (2004) study had to respond to congruent arrows, which all faced either to the right or to the left,
or incongruent arrows, where one or two arrows may face a different direction than the arrow reference arrow. This test was comprised of 17 trials. The researchers were mainly interested in what went on in the participants’ cortical network during the response selection of an incongruent condition (Colcombe et al., 2004). During this cognitive test, researchers conducted an MRI on the participants in order to observe what was happening inside their brains (Colcombe et al., 2004).

In the second study, 29 different healthy older adults from 58 to 77 years of age took part in a longitudinal study. There were two randomly assigned groups. One group participated in cardiovascular fitness training (walking, jogging, or cycling), while the second group, the control group, was placed in a stretching and toning program. Study two participants were tested with the same cognitive measure and MRI assessment as in the first study; however, they were tested one week before the start of their program, and again a week after finishing their assigned exercise program (Colcombe et al., 2004).

Colcombe et al. (2004) found in their first study that the older adults who possessed a higher aerobic fitness level showed an increased activation level in many cortical parts of the brain linked with greater attention management. As for the reaction time task, both groups showed an extremely low error rate, but the high fitness group scored better when undertaking differing cues. Results from study 2 verified that participants from the cardiovascular exercise group greatly increased their aerobic fitness, and displayed a significantly higher degree of task-related functioning in the attention control area of the brain, an aspect of executive function (Colcombe et al., 2004). In addition, Colcombe et al. (2004) found that in both the cross-sectional and longitudinal groups of older adults, a higher level of cardiovascular fitness was connected with increased execution on measures of executive operations. Even when an
Effects of Acute Aerobic Exercise on Executive Function in Older Women

individual starts out from a low level of fitness and increases it to a higher level of fitness, the aging brain is positively affected by the increase in cardiovascular fitness level (Colcombe et al., 2004). Therefore, as individuals' age, it is imperative that they stay fit and participate in aerobic exercise in order to maintain a healthy brain (Masley et al., 2009).

An important relationship between cognitive health and physical fitness exists (Masley et al., 2009). Maintaining good physical fitness has a positive effect on preserving the mind. “Only a healthy body can produce or sustain a healthy mind. Today, this relationship receives much more attention as our aging population places a high priority on preserving cognitive acuity into our golden years” (Masley et al., 2009, p. 186). Masley et al. (2009) wanted to investigate whether cardiovascular exercise training increased cognitive functioning. They conducted a study in which they measured 91 healthy adults who belonged to a fitness center. During the 10 week study period, the control group exercised aerobically 0-2 days per week, and half of the intervention group exercised aerobically 3-4 days a week while the other half participated in cardiovascular exercise 5-7 days a week. It was decided that the treatment group would exercise aerobically at differing intensity levels (Masley et al., 2009). More participants were recruited, and measures of cognition were compared across the control, moderate, and intense exercise groups (Masley et al., 2009).

Participants in the Masley et al. (2009) study were both male and female, 18-70 years of age, who did not participate in cardiovascular exercise more than two days a week. Fifty-six individuals, stratified by BMI, were arbitrarily placed in three groups. Individuals who were assigned to the treatment group were given an exercise program that was led by certified fitness instructors from the American College of Sports Medicine. The Bruce Protocol was used to assess VO$_2$max. These participants were then advised to exercise aerobically for 30-45 minutes,
5-6 days out of the week for 10 weeks at 70-85% of their predicted maximum heart rate. These participants were also advised to decrease saturated fat while increasing fiber intake, as well as to find ways to better deal with stress (Masley et al., 2009).

In contrast, participants in the control group were told to maintain their current diet and activity or exercise level for the 10 week program. However, only about half of the exercise treatment group was able to exercise 5-6 times a week, while the other half reached 3-4 days a week. As a result, Masley et al. (2009) compared the effects of moderate aerobic exercise, high aerobic exercise, and low-aerobic exercise on cognition. Masley et al. (2009) reported that before the study started, there were not any significant variations between the treatment group and the control group for BMI, sex, age, years of education, and VO\textsubscript{2}max. Interestingly, VO\textsubscript{2}max improved by 6.5% in the control group (the 0-2 days of being active), 12% in the moderate exercise treatment group (3-4 days of exercise), and by 17.3% in the combined treatment group (either 3-4 days of exercise or 5-7 days of exercise), and 21.3% in the high exercise treatment group (5-7 days of exercise a week). Also, significant variations were reported with an increase in the frequency of exercise changing results for tests of cognitive flexibility, psychomotor speed, and attention across each group (Masley et al., 2009). There were greater improvements in these variables for the high exercise group when compared to the moderate exercise group, however, both groups increased these variables significantly from baseline (Masley et al., 2009).

On the contrary, when sex, years of education, and age were controlled statistically, only cognitive flexibility, an aspect of executive function, demonstrated significant differences among groups (Masley et al., 2009). The CNS Vital Signs test was used to assess cognition before and after the 10 week program. It contains tests of verbal and visual memory, finger tapping, symbol
digit coding, the Stroop test, shifting attention and continuous performance. The CNS Vital Signs test only takes 30 minutes for participants to complete. The test includes scores for mental speed, memory, attention, cognitive flexibility, and information processing time (Masley et al., 2009). Memory, psychomotor speed, and reaction time did not display significant improvements after increased cardiovascular fitness (Masley et al., 2009).

However, Masley et al. (2009) reported that cognitive flexibility was still significantly improved even after education, sex, age, and changes in psychomotor speed were controlled. Results from this observational study found that cardiovascular fitness level has a definite impact on brain functioning, and demonstrated an association of a dose-response with aerobic exercise for executive function (Masley et al., 2009). The shifting attention test and the Stroop test, which both examine executive function, were found to be the most sensitive to results of aerobic exercise. In the elderly, cognitive deterioration is reduced with cardiovascular exercise and increased cardiovascular fitness status (Masley et al., 2009). The results from this study also agree with studies from Barnes et al. (2003), Colcombe & Kramer (2003), and Churchill et al. (2002), who reported that as a result of heightened cardiovascular exercise and fitness, attention and cognitive flexibility in the frontal lobe displayed the largest advances in cognitive functioning (Masley et al., 2009).

Many other studies have shown that for tests on cognition, people who are physically fit achieve better scores and as they grow older, show a smaller amount of cognitive decline (Barnes et al., 2003; Hillman, Belopolsky, Snook, Framer, & McAuley, 2004; Roth, Goode, Clay, & Bill, 2003; Weuve et al., 2004). In the study conducted by Yaffe et al. (2001), cognitive functioning was found to have a protective benefit from low, moderate, or high physical activity levels in older adult females, while those who were sedentary were not protected from cognitive decline.
Colcombe et al. (2004) concluded that despite the type of cognitive task the participants were asked to complete, participants who took part in cardiovascular fitness training elicited a larger improvement in cognitive functioning than the control group (Colcombe et al., 2004).

Mechanisms by Which Cardiovascular Exercise Improves Cognition

It is important to understand why aerobic training helps increase cognitive function; this process has been studied more in animals than in humans (Colcombe et al., 2004). In adult animals, it has been found that cardiovascular exercise boosts the amount of neurochemicals, including BDNF. The increase in these neurochemicals then augments the development of synapses and new neurons, as well as neuronal survival and flexibility. This results in a more flexible, adaptive, and efficient brain, which leads to improved learning capabilities (Colcombe et al., 2004). Even though this information was originally discovered using animal models, these same findings have been shown in more recent studies in humans, and benefits on cognitive function from aerobic training have also been observed in older adults. These benefits include the development of new neurons, as well as increases in neurochemicals, neuron survival, synaptic development and flexibility (Colcombe et al., 2004).

As a result of aerobic fitness, the estimated course of decreases in the density of cortical tissue with aging was reduced dramatically as reported by Colcombe et al. (2004) for older adults 55-79 years of age. In the prefrontal, frontal, and parietal regions of the brain, cardiovascular exercise produced the most ample effects (Colcombe et al., 2004). The researchers also found that these areas of the brain were affected most by age-related deterioration (Colcombe et al., 2004). The prefrontal, frontal, and parietal areas of the brain may be where executive function takes place (Colcombe et al., 2004). In older adults, executive mechanisms display immense increases in behavior as a result of aerobic exercise (Colcombe et al., 2004).
Effects of Acute Aerobic Exercise on Executive Function in Older Women

Increases in an individual’s aerobic fitness status should have an even better protective benefit on the brain in terms of cognitive functioning (Colcombe et al., 2004). Aerobic exercise is shown to increase cognition in older adults through research from animals, as well as human neuroanatomical and behavioral studies (Colcombe et al., 2004). Neural substrates of the brains of aging humans are more flexible and resilient in those who have improved their aerobic fitness levels than in individuals with low fitness (Colcombe et al., 2004). How much physical activity is needed to prevent or decline diminishing levels of cognitive function needs to be identified.

A number of studies have displayed that the higher the fitness status of an individual, the better the protective effect for the brain in terms of loss of cognitive functioning (Berga, 2008; Colcombe & Kramer, 2003; Masley et al., 2009; Stroth et al., 2009). Improvements in cognition were linked with higher physical activity levels, and increased activity is related to a decreased chance of dementia, even when an individual does not start exercising until later in life (Berga, 2008). It is important for middle aged and older adults to start aerobic exercise training since this is the period where brain health may begin to deteriorate (Stroth et al., 2009). This might be why some individuals show losses of cognition even in middle age in their fifties and sixties, as opposed to an older age (Stroth et al., 2009).

Colcombe & Kramer (2003) found in their meta-analytic review of 18 intervention studies on sedentary, but healthy older adults that aerobic exercise improved cognition. As a result of increased cardiovascular fitness, the area of cognition that showed the greatest improvement was executive control processing. However, adults with excellent aerobic fitness showed the highest levels of spatial and controlled processing (Colcombe & Kramer, 2003). Several studies have come to the conclusions that a high fitness level has a superior effect on cognition as opposed to lower or even moderate fitness levels, and on tests of attention and
executive function, superior cardiovascular fitness levels seem to show a positive impact (Barnes et al., 2003; Churchill et al., 2002; Colcombe & Kramer, 2003; Colcombe et al., 2004).

Various Levels of Physical Activity May Enhance Cognition

Even though these studies have shown that a higher level of fitness helps protect against a decline in cognitive function, other studies have shown that just any activity level other than being sedentary will help attenuate this decline. Lautenschlager et al. (2008) demonstrated that regular walking, a moderate aerobic physical activity, can help increase cognition as well. As opposed to the 10-week study which showed that increasing aerobic fitness levels resulted in an increase in cognition (Masley et al., 2009), a study implemented for six months by Lautenschlager et al. (2008) added more physical activity in individuals primarily with walking. This study specifically controlled the quantity of exercise participated in, and it was concluded that while walking can promote an increase in cognitive function, other studies have found that the higher the level of fitness and activity, the greater the cognitive function (Lautenschlager et al., 2008).

Hillman et al. (2004) demonstrated that increased levels of physical activity improved executive function in older adults using the Eriksen flanker task (Eriksen & Eriksen, 1974). During the incongruent condition of the Eriksen flanker task (Eriksen & Eriksen, 1974), which measures inhibitory control functions (an aspect of executive control) and reaction time, cognition increased in moderate and highly active older adults. However, the low-active group in this study did not show much improvement in cognition (Hillman et al., 2004). Larson et al. (2006) executed a longitudinal study as well in 1740 older adults to examine if exercise, measured by an initial questionnaire, is related to a decreased risk for dementia. These adults, 65 years of age and older, were studied over a 6.2 year span. Interestingly, those who exercised
three or more times a week had a lesser chance of developing dementia (13 per 1,000 people),
while those who exercised fewer than three times a week had a greater chance in developing
dementia (19.7 per 1,000 people). There was a 32% decreased dementia risk for those who
exercised three or more times a week, indicating that this frequency of exercise is related to
slowing the development of dementia (Larson et al., 2006). However, more studies need to be
implemented to analyze how improvements in cognitive function are effected by exercise
intensity, frequency, and duration (Masley et al., 2009).

Many studies have shown positive correlations with regular aerobic exercise, particularly
higher levels, but some have not. It is not clear if there is a positive impact of physical activity
on memory and executive function (Tomporowski, 2003). Submaximal cardiovascular exercise
of 60 minutes or less in duration can improve information processing, but prolonged exercise
resulting in dehydration can hinder information processing and other executive functions
(Tomporowski, 2003). This may explain some of the confusion surrounding studies that do not
show improvements in cognition after exercise (Coles & Tomporowski, 2008). Coles and
Tomporowski (2008) did not find an increase in set-shifting, or selective attention, which is an
element of executive function, after an acute bout of cycling exercise. This is consistent with
findings from Kubesh et al. (2003), who also did not find improved executive function on the
set-shifting task after aerobic exercise.

Despite these studies, many others have shown that improved fitness levels help maintain
health in a variety of ways, and there are a number of ways that cognitive function in adults is
affected by aerobic fitness. Maintaining a high fitness level throughout life can decrease the
chance of developing heart disease, hypertension, diabetes, and cerebrovascular disease, which
are related to the degeneration of cognitive function with increasing age (National Institute of
Effects of Acute Aerobic Exercise on Executive Function in Older Women

Health, 2011; Spirduso, Poon, & Chodzko-Zajko, 2007). Also, possessing a high fitness status can be specifically linked with increased blood flow in the brain, as opposed to declining cognition in healthy older adults as well as individuals with Alzheimer’s disease who have been identified with decreases in brain blood flow (Barnes et al., 2003).

**Acute Effects of Cardiovascular Exercise on Cognition**

In older adults, there has not been much research done on the acute effects of cardiovascular exercise on cognition, compared with chronic exercise (Kamijo et al., 2009). The limited amount of research that has been conducted has shown contrasting evidence. One study investigated the effects of acute aerobic exercise and cognition in older adults as well as older patients with COPD and found that verbal processing increased after exercise only in the COPD patients (Emery, Honn, Frid, Lebowitz, & Diaz, 2001). In contrast, Molloy, Beerschoten, Borrie, Crilly, & Cape (1998) found that cognitive function was increased after an acute bout of cardiovascular exercise in older adults.

Kamijo et al. (2009) investigated acute aerobic exercise effects on older adults as compared with younger adults. They hypothesized that among older and younger adults, acute aerobic exercise effects on cognition would be comparable, and that the positive effects of acute exercise would be greater after a session of moderate exercise as opposed to light exercise. These researchers also believed that the effects might be greater in an incongruent flanker condition which uses a larger extent of executive control. The researchers conducted the investigation on 24 healthy males (12 older adults 60-74 years of age and 12 younger adults 19-25 years of age). A baseline session was conducted in order to measure ERPs (event related brain potentials), which are responses in behavior throughout a modified flanker task (Kamijo et al, 2009). Thirty-two practice trials were allowed, and 160 real trials were recorded. Also, the
Mini-Mental State Exam (MMSE), Beck Depression Inventory, as well as the International Physical Activity Questionnaire were given during this session. A graded exercise test (GXT) on a cycle ergometer was administered to obtain each participant’s VO$_2$max value. Each participant came in two other days at the same time of day as the baseline session so the researchers could conduct a light exercise intensity session (30% of VO$_2$max) as well as a moderate exercise intensity session (50% of VO$_2$max) of 20 minutes after a 5 minute warm up at half the intensity of the period of exercise. Kamijo et al. (2009) wanted to investigate if there were any differences in executive cognition between exercise conditions as well as age differences.

Before the bout of exercise, ERPs were set up to be assessed for after exercise, and 32 practice trials of the flanker task were allowed. Less than two minutes after the completion of the exercise bout, participants started the flanker task (Kamijo et al., 2009).

Following moderate exercise (50% VO$_2$max), Kamijo et al. (2009) found that both younger and older adults displayed a shorter reaction time as opposed to light exercise and baseline measures. In addition, after moderate and light exercise, both younger and older adults exhibited P3 latencies that were shorter than in the baseline measures. P3 latencies are thought to be either stimulus evaluation time or gauges of stimulus classification speed, as measured by ERPs (Kamijo et al., 2009). However, after moderate exercise, P3 amplitude (how much attention is contributed to a single task) was greater only in the younger adults than during baseline. This study advocates that moderate exercise may help stimulus evaluation mechanisms, which are different thought processes in identifying a stimulus (indicated by P3 latency), as well as response mechanisms. However, light exercise was shown to just increase stimulus evaluation mechanisms. Older adults displayed comparable effects of acute cardiovascular exercise on reaction time and P3 latency as younger adults, as Kamijo et al.
(2009) hypothesized, except for P3 amplitude. According to these results, Kamijo et al. (2009) reported that the effects of acute cardiovascular exercise are alike throughout lifetime. However, they reported that the means in which acute aerobic exercise impacts cognition might still depend on age (Kamjio et al., 2009).

Davranche, Hall, and McMorris (2009) conducted a study on a younger age group (average age was 30 years) and found similar results using the Eriksen flanker task regarding how moderate exercise diminishes reaction time. A GXT to determine VO$_2$max on a cycle ergometer was given to each participant in order to determine 50% of maximal aerobic power, a moderate exercise intensity. The flanker task was administered during the exercise session and during a period of rest. Participants were allowed 8 blocks of 64 trials each to practice before the actual study session. On different days, each participant took part in an exercise session, as well as a rest session, where they just sat on the cycle ergometer to take the flanker task. The exercise session consisted of a 5-minute warm up followed by 15 minutes of exercise at 50% of each individual’s maximal aerobic power (MAP). Researchers have confirmed that cognition is considerably enhanced by this length and intensity of aerobic exercise (Davranche, Burle, Audiffren, & Hasbroucq, 2005, 2006; Davranche & Audiffren, 2004). Also, in order to gather ample data without fatiguing, 15 minutes of exercise is adequate (Davranche et al., 2009). What was found was that on the Eriksen flanker task, moderate exercise helps decrease reaction time and it was equally advantageous for the congruent and incongruent situations.

McMorris et al. (2009) found that high intensity exercise at 80% of maximal aerobic power had a negative effect on reaction time when a flanker task was administered to participants during exercise. A baseline session of 8 blocks of 64 trials for the flanker task was allowed for each of the 24 male participants (average age was 24), followed by a VO$_2$max test to
determine what percentage of their VO\textsubscript{2max} they needed to be exercising at 50% (moderate intensity) and 80% (high intensity). During both exercise sessions, each participant warmed up for 5 minutes, then completed 15 minutes of exercise at either 50% or 80% (each participant completed both sessions) of their VO\textsubscript{2max}. The flanker task was administered to each participant during their 50% VO\textsubscript{2max} and 80% VO\textsubscript{2max} sessions during the third, eighth, and thirteenth minute of exercise. Results indicated that at 80% VO\textsubscript{2max}, reaction time during exercise on the flanker task was significantly slower than at 50% VO\textsubscript{2max} and during resting conditions. A slower reaction time was not seen until participants exercised at 80% of their VO\textsubscript{2max}. There were not performance decrements in executive function during moderate exercise (Davranche et al., 2005, 2006; Davranche et al., 2009; Kamjio et al., 2009), but there were once the intensity reached a higher level, particularly 80% of an individual’s VO\textsubscript{2max} (McMorris et al., 2009).

Previous literature has found that cognition increases after acute moderate intensity exercise, but it actually decreases during or following acute low- and high-intensity exercise (Budde et al., 2012). Research by Kamijo et al. (2004) also found that cognitive processing was improved after moderate exercise, but it declined after an acute session of vigorous exercise. Conversely, there have been studies that have not shown a negative affect following high-intensity exercise (McMorris & Graydon, 1996). In some of these studies, cognition was actually increased after acute strenuous exercise (Hogervorst et al., 1996; Winter et al., 2007). The different findings in these studies might be because individual traits of the participants were not taken into account during the examination of an acute bout of exercise on cognition (Budde et al., 2012). These may include activity and fitness level, and involvement in sport (Budde et al., 2012). It has been found that in young adults, trained athletes and aerobic exercisers are able
to improve cognition on tests of executive function during and after vigorous exercise at 80% of VO$_2$max or at anaerobic threshold as opposed to those who are less aerobically fit (Brisswalter, Arcelin, Audiffren, & Delignières, 1997; Budde et al., 2012; Zervas et al., 1991). “Physical activity level seems to be an important variable that may affect cognitive performance following intense acute exercise” (Budde et al., 2012, p. 126). However, the literature shows mixed findings on the intensity of exercise that needs to be prescribed based on the person’s level of fitness and the duration of the exercise bout (Tomporowski, 2003). Because of this, Budde et al. (2012) had participants (19-29 years of age) reach their maximum heart rate following an intermittent maximal exercise (IME) bout throughout a set time period. The exercise intensity was controlled during the IME to present an exercise intervention with comparable physiological effects apart from each participant’s fitness status (Budde et al., 2012).

The purpose of the Budde et al. (2012) study was to examine how executive function calling for specific and continual attention was affected by intermittent maximal exercise (IME). They also studied how the participant’s physical activity level could be impacted by the effect of IME on this cognitive function. They hypothesized that following IME, those participants with a higher physical activity level would show increased scores on a cognitive task as opposed to their lower fit counterparts (Budde et al., 2012). Their study included 51 college students, 19-29 years of age. Those with dyslexia, a BMI over 25 kg/m$^2$, mental or physical disabilities, and students who have taken psychoactive substances were excluded from this study (Budde et al., 2012). In young people, a high body fat percentage has shown to be associated with cognitive losses (Castelli, Hillman, Buck, & Erwin, 2007). One other exclusion criteria was not reaching a maximum heart rate of 220 bpm minus age during the actual exercise intercession to make sure that each participant achieved the same respective intensity during exercise (Budde et al., 2012).
Cognition was measured using a letter cancellation test, the paper and pencil version of the d2-test (Brickenkamp, 2002), which measures selective and sustained attention, an aspect of executive function (Budde et al., 2012). There are 14 lines of 47 arbitrarily assorted letters (“d” or “p”) with dashes above, below, or both above and below each letter (Budde et al., 2012). Participants have 20 seconds to mark off the letter “d” with only two dashes above, below, or both above and below each “d” (Budde et al., 2012). This test measures each participant’s capability to shift, search, maintain attention (elements of sustained attention), and to choose to center attention on specific stimuli, components of selective attention (Bates & Lemay, 2004). Selective attention is a measure of behavioral inhibition, which is an element of executive function (Miller & Cohen, 2001). The level of each participant’s physical activity was then measured using the German one-item questionnaire. Because the researchers assumed that those with a higher physical activity level would improve cognition after acute aerobic exercise based on their literature review, they divided students up into a low active and high active group (Budde et al., 2012). The low active group participated in physical activity less than three times a week, while the high active group was physically active on three or more days of the week, in adherence with the guidelines from the American College of Sports Medicine (Budde et al., 2012).

There was a control group and a treatment group. For the control group, participants were asked to remain stationary in a chair for the whole 8 minutes as compared to the treatment group who exercised. The treatment group consisted of three minute 20-meter sprints followed by a 2-minute rest period of standing, two times through. Each participant had to reach their HR max after 3 minutes. Every 15 seconds, the time was announced during each participant’s sprint. During the last 15 seconds, the time was announced every 5 seconds, and the participant was
encouraged to run at their maximum speed. In the week before the test, participants were instructed on how to sprint and reach their maximum heart rate progressively and exactly after 3 minutes. Each participant took part in both the exercise and control settings on separate days one week apart, but at the same time of day for each condition. The d2-tests were administered in a quiet room immediately following the bout of exercise or control situation. One week earlier, each participant was instructed on how to perform the d2-test and given time to practice to reduce effects of learning during the data collection (Budde et al., 2012).

Budde et al. (2012) found that there was not a significant effect of IME on executive function, but there was a correlation among chronic (as measured by the German one-item physical activity questionnaire) and acute exercise. Just the group that was highly active benefited in cognition from IME (Budde et al., 2012). Even though a few earlier studies had shown that cognition was negatively affected after intense exercise (Kamijo et al., 2004; Kamijo et al., 2007), Budde et al. (2012) demonstrated that this was not always true, and in some situations, cognition actually increased after intense exercise. Common factors that possibly displayed conflicting results include the duration and type of exercise as well as the types of cognitive tasks given in each study and how these were conducted (Budde et al., 2012). Also, previous studies did not consider that each participant differs in the intensity and duration of their chosen physical activity (Budde et al., 2012). Budde et al. (2012) also showed that there was no effect on cognition regarding physical activity levels in the control group (the resting situation), but when the researchers grouped participants within the study in a high or low physically active group, they found that just those who were highly physically active benefited from the exercise intervention, and following the IME bout, considerably improved their attention (Budde et al., 2012).
Budde et al. (2012) has shown that participants with a higher physical activity status increased selective and sustained attention following brief intermittent periods of maximal exercise, which supports the hypothesis that there is a relationship between acute and chronic exercise and cognition, and that acute bouts of exercise and increased cognition may depend on the status of aerobically trained individuals (Budde et al., 2012). These researchers went on to report that if other studies found comparable results in those with attention-related problems, such as older adults and those with ADHD, acute aerobic exercise may help improve cognition (Budde et al., 2012).

Intensity and Duration of Exercise May Positively Affect Cognition

Exercise intensity and duration may have an impact on cognitive functioning. Budde et al. (2010) conducted a study on school-aged children that measured the cognitive effects of executive function after a session of moderate (50-65% HR max) and high intensity (70-85% HR max) exercise (based on results of a shuttle run test used to determine target heart rate) compared to a sedentary control group. Children with a lower cognitive performance were able to increase this level after exercise, with either high or moderate intensity aerobic exercise (Budde et al., 2010). The exercise intervention consisted of students running around a track for 12 minutes while wearing a heart rate monitor that would beep if they were running too slowly or too fast. For the duration of the 12 minutes, the control group remained sedentary (Budde et al., 2010). Budde et al. (2010) used the Letter Digit Span test to assess the executive functioning of the children. After students finished their school lessons, a sample of their saliva was taken to measure hormones related to cognition that are affected by physical activity, and then were led to a silent room, where the Letter Digit Span test was administered. After the completion of this test, students were grouped into either a sedentary, moderate exercise, or high intensity exercise.
Effects of Acute Aerobic Exercise on Executive Function in Older Women

group. The sedentary group stayed in the classroom while the other two groups went outside to run around the track. After the completion of the 12 minutes, each group took the Letter Digit Span test again and their saliva was collected.

Results indicated that only the moderate intensity exercise group increased executive function significantly from the pre- and post-exercise intervention (Budde et al., 2010). Since the children were grouped into low and high cognitive performers, the results revealed that those who were low performers improved in cognition after moderate intensity exercise, and displayed a smaller significant increase after high intensity exercise. Students with a higher level of cognitive performance displayed no increase in cognition pre- and post- moderate or high intensity exercise (Budde et al., 2010). Consequently, improvements in executive function after any intensity of exercise may be of an advantage to those with low cognitive performance. The findings of this study show that high intensity exercise increases cognition in those with low performance, but not to the same extent as moderate exercise (Budde et al., 2010). Budde et al. (2010) declared previous research has found that exercise intensity is more important than exercise duration regarding the endocrine response to cognition. They were unsure if exercise duration might have changed the concentration of hormones enough to observe improvements in executive function (Budde et al., 2010). Interestingly, the saliva concentrations were dependent on the exercise intensity, with increased levels of hormones only after high intensity aerobic exercise, but not after the moderate intensity exercise and control groups. This was in agreement with adult saliva hormone concentration study results (Budde et al., 2010).

Kumar et al. (2012) found similar results of increased cognition in sedentary adults (18-30 years of age) through moderate exercise. For the intervention, participants had ERPs (event-related potentials) measured to assess central nervous system mechanisms before the exercise or
resting period. Participants were then split into an exercise group who cycled for 5 minutes at 60%-80% of maximum heart rate, or a control group that remained sedentary. For the exercise group, ERP was measured after 5 minutes, while the control group was measured again 15 minutes after their first assessment. Kumar et al. (2012) found that in those who are sedentary, acute moderate exercise of short duration increased cognition; however, there was no significant increase in P300 amplitude, most likely due to the short, 5-minute bout of exercise. Theories of P300 amplitude propose that it shows the distribution of attention and helps improve executive function (Kumar et al., 2012).

Summary

In conclusion, acute bouts of moderate aerobic exercise are shown to increase cognition, especially the aspect of cognition termed executive function. High-intensity aerobic exercise has been shown to increase cognition following exercise, however some research has shown that cognition is actually decreased after this level of exercise. The aerobic fitness status of an individual seems to play a major role in determining how much the individual will improve in executive function, especially following intense aerobic exercise. Minimal research has been done involving older adults and acute bouts of exercise, and how executive function is affected immediately, and up until 30-minutes post-exercise after exercise of differing intensities. The modified flanker task and d2-tests are reliable and valid measures of executive function (measures of cognitive processing speed, as well as sustained and selective attention) (Budde et al., 2012; Kamijo et al., 2007). If any significant differences are found in executive functioning following moderate and high-intensity exercise, implications may be made for this population.
CHAPTER III: METHODS

Participants

Women, 60-75 years of age (N = 11), were recruited from Bowling Green State University and the surrounding community to investigate whether there were differences in executive function after acute bouts of moderate and intense aerobic exercise based upon fitness and activity levels. Any participant who was taking medications for cognitive impairment was excluded, as well as individuals who were on blood pressure medications, antidepressants, or medications for mental illness. There were 10 individuals who were interested in participating, however, they were screened out of the study because they were on one or more of these medications. Therefore, about 50% of the respondents participated in the study.

High blood pressure in middle age is linked with the risk of cognitive deterioration in old age (Anstey & Christensen, 2000; Thorvaldsson et al., 2012). In older people, high blood pressure and a decrease in cognitive function is common (Anstey & Christensen, 2000; McGuinness, Todd, Passmore, & Bullock, 2008). High blood pressure can distinctly lead to vascular dementia, and possibly Alzheimer’s disease (McGuinness et al., 2008). Depression in late life has been negatively correlated with declines in cognition (Bierman, Comijs, Jonker, & Beekman, 2005; Tam & Lam, 2012). A physician’s consent form was obtained by each participant before being permitted to participate in the study. Participants gave their informed consent, and this study was approved by the Human Subjects Review Board at Bowling Green State University.

Equipment

A treadmill was used for a submaximal walking graded exercise test utilizing the Balke Protocol (American College of Sports Medicine, 2010). Vermed® electrodes were used to read
Effects of Acute Aerobic Exercise on Executive Function in Older Women

heart rate and rhythm by a 12-lead EKG during the Balke Protocol. The treadmill was also used for each exercise session, as well as a Polar™ heart rate monitor. A computer was used for the two cognitive tests, the modified flanker task and d2-test (Budde et al., 2012; Kamijo et al., 2009). The long version of the *International Physical Activity Questionnaire (IPAQ)* was administered in paper and pencil format to measure activity levels (Hagströmer, Oja, & Sjöström, 2006).

**Procedure**

Each participant came into the Exercise Physiology Lab in Eppler Complex three times at the same time of day, 4-7 days apart from each other. When arriving for the first visit, each participant was given an informed consent form that she needed to physically sign in front of the researcher. Before the participant signed the document, the participant was asked to carefully read the consent form. Then she had a chance to ask any questions, and the researcher thoroughly answered these questions. Each participant then completed a medical history questionnaire and the *International Physical Activity Questionnaire (IPAQ)* (Hagströmer, Oja, & Sjöström, 2006). The *IPAQ* is a popular physical activity questionnaire used internationally in research studies to assess physical activity level. There are two versions, the short and long version. The short version is used more for public health observation, while the longer version is employed frequently in research studies, offering more categories to average. The long version was used in this study. The validity of the *IPAQ* is suitable to be used in research studies involving physical activity level (Hagströmer, Oja, & Sjöström, 2005).

The *IPAQ* has three ratings. A 3 is devoted to those who are highly active and participate in 30 minutes of high-intensity exercise, or an hour or more of moderate-intensity exercise above the basal level of physical activity which equals about 5,000 steps a day (IPAQ, 2005).
Individuals who are highly active are also classified by taking 12,500 or more steps per day (IPAQ, 2005). Those who possess a moderate physical activity score of a 2 are active for 30 minutes on most days of the week at a moderate-intensity (IPAQ, 2005). Individuals who score a 1 are considered low active and do not meet any of the criteria for moderate or high active (IPAQ, 2005). The IPAQ also classifies individuals into a low, moderate, or high category by adding up MET-minutes/week (IPAQ, 2005). Those who are high active, or category 3, score at least 3000 MET-minutes/week from total physical activity levels (walking, moderate, or high-intensity exercise), or 1500 MET-minutes/week from high-intensity exercise (IPAQ, 2005). Individuals who are categorized as a 2, or are moderately active, attain at least 600 MET-minutes/week (IPAQ, 2005). Those who are categorized as a 1, or are low active, do not meet the criteria for categories 2 or 3 (IPAQ, 2005). Seven of the 11 women were highly active, while 4 were moderately active.

After these procedures, participants were informed of what measures would be taken and why. There were 9 participants who were in the 60-69 age group, and 2 in the 70-79 age group. Participants had their height and mass measured to determine body mass index (BMI). A BMI of 18.5 kg\(\text{m}^{-2}\) or less is considered to be underweight and increases the chance of developing cardiovascular disease, while a BMI of 25.0 to 29.5 kg\(\text{m}^{-2}\) is considered overweight, and a value of over 30.0 kg\(\text{m}^{-2}\) is considered obese (ACSM 2010). The risk of coronary disease, hypertension, and developing high cholesterol is greater for those who have a BMI value over 30.0 kg\(\text{m}^{-2}\) (ACSM 2010). Demographic data are shown in Table 1. Norms for women 60-69 and 70-79 years of age are shown in Table 2.

Following these measures, waist and hip circumferences (cm), measured with a Gulick tape, were used to determine distribution of body fat and health risk. The waist-to-hip ratio
(WHR) was calculated from these values. Waist measurements were taken around the smallest portion of the participant’s torso, while hip measurements were measured around the largest point of the trunk (ACSM, 2010). The waist-to-hip ratio (WHR) is a tool to measure the dispersion of body fat (ACSM, 2010). Those with more body fat dispersed in the waist area have a greater risk of developing metabolic syndrome, hypertension (which may negatively affect cognition), dyslipidemia, type 2 diabetes, coronary artery disease, and early death, than those with fat dispersed more around the hip and thigh area (ACSM, 2010). Researchers executing a study on WHR as a prediction of risk in older adults found that in a sample size of 659 women 70-79 years of age, a 28% increase in death was correlated with every 0.1 increase above either 0.8 or 0.9 (Srikanthan, Seeman, & Karlamanga, 2009).

Subsequently, a modified flanker task and d2-test were given to assess executive function before exercise. The modified flanker task measures reaction time and response accuracy which are aspects of inhibitory control and executive function (Kamijo et al., 2007; Kamijo et al., 2009). The test was administered on a computer screen, where 5 arrows were shown per situation. There were 80 situations, 40 congruent and 40 incongruent. In the congruent situation, arrows are displayed that point in the same direction as the middle arrow, the arrow of reference, allowing quicker reaction time. In the incongruent condition, the arrow can point in the same or opposite direction as the arrow of reference, which can increase reaction time. This reaction time condition demands a larger extent of executive control, which is attributable to stimulation of the inaccurate answer before the assessment is finished (Kamijo et al., 2009). The participant pressed either the right or left “control” button, depending on the direction the middle arrow was pointing. The modified flanker task takes about 8.5 minutes to complete (Kamjio et al., 2009).
The d2-test of sustained and selective attention, components of executive function (Bates & Lemay, 2004; Budde et al., 2012), includes 14 lines of 47 arbitrarily assorted letters (“p” or “d”) per line, where one line is shown at a time (Budde et al., 2012). There are one to four dashes over and under each letter. The participant only chooses the letter “d” with two dashes above or below the letter. With a click of a mouse, an “x” will be marked at the top of the chosen letter on a computer screen. Each line is shown for only 20 seconds before a new line is revealed. The total time allowed for the d2-test was approximately 5 minutes. The d2-test has been shown to be valid, and reliable in measuring some components of executive function, such as sustained and selective attention (Budde et al., 2012). There are three variables measured within the d2-test to assess attention. Each variable was normalized into a ratio according to the total number of d2’s within the test. The error rate measures precision and thoroughness, and is the number of all errors (marking off the wrong letter, a “d” with more or less than 2 dashes, or not marking off a d2 when there was one present). The GZ value measures working speed, and is the overall number of marked letters within the test. The SKL value is an indicator of attention span, and is the standardized number of accurate answers minus confusion errors (Budde et al., 2012).

In order to reduce the effects of learning (Davranche et al., 2009; Kamjio et al., 2009), 32 practice trials of the modified flanker task and 3 lines of the d2-test were permitted before the Balke Protocol and exercise trials, followed by 80 real trials of the modified flanker task, with 40 congruent and 40 incongruent situations. As soon as the modified flanker task was completed, participants started the d2-test.

After these cognitive tasks were completed, a measure of each participant’s current fitness level was assessed by having each participant complete a submaximal walking graded
exercise test (GXT) (i.e., the Balke Protocol). Heart rate and workload were used to estimate VO_{2\text{max}}, a measure of cardiorespiratory fitness. In females 60-69 years of age, a poor VO_{2\text{max}} value is $\leq 25 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, a fair value is 26-28 ml·kg⁻¹·min⁻¹, a good value is 29-31 ml·kg⁻¹·min⁻¹, an excellent value is 32-36 ml·kg⁻¹·min⁻¹, and a superior value is $\geq 37 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (Heyward, 2010). In older women 70-79 years of age, a poor VO_{2\text{max}} value is $\leq 23 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, a fair value is 24-26 ml·kg⁻¹·min⁻¹, a good value is 27-29 ml·kg⁻¹·min⁻¹, an excellent value is 30-36 ml·kg⁻¹·min⁻¹, and a superior value is $\geq 37 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (Heyward, 2010).

The participants were instructed on how to perform the Balke Protocol; participants walked on the treadmill until their heart rate reached 85% of their age-predicted maximum from the equation 206.9-(.67*age) (ACSM, 2010). The incline of the treadmill was increased every three minutes in accordance with the protocol (ACSM, 2010). The protocol includes a 3-minute warm-up period at 2.0 mph before the first stage (ACSM, 2010). The treadmill was increased in grade by 2.5% (ACSM, 2010). Each 3-minute stage increased in intensity, but the test was terminated once the heart rate reached 85% of each participant’s age-predicted maximum (ACSM, 2010). Blood pressure and heart rate were measured before the test, as well as during each stage of the GXT. During the protocol, participants were required to wear electrodes on the chest area to monitor the activity of the heart using an electrocardiograph (EKG) (ACSM, 2010).

Heart rate was monitored and taken each minute during the GXT. At the end of each 3-minute stage during the test, blood pressure was taken, and participants reported their RPE using the 15-point Borg (1973) scale. Participants chose a number from this scale, varying in numbers from 6 to 20 according to their perceived level of exertion (7 = very very light, 9 = very light, 11 = fairly light, 13 = somewhat hard, 15 = hard, 17 = very hard, 19 = very very hard) (Borg, 1973). Once the designated heart rate was achieved, the test was terminated (ACSM, 2010) and
participants cooled down with three minutes of slow walking until their heart rate was less than 100 bpm. During each three minute stage of exercise during submaximal test protocols, it is believed that heart rate reaches steady state (Heyward, 2010). Heyward (2010) also stated that there is a linear relationship among VO$_2$ and heart rate, between the ranges of 110 to 150 bpm. This relationship seems to be true for light and moderate intense exercise; however, this relationship becomes curvilinear at higher-intensity exercise. Submaximal exercise testing uses equations to determine an individual’s maximum heart rate. However, depending on the equation used, there may be variability among individuals and their HRmax, resulting in a ± 10% to 15% error in calculating the estimated VO$_2$max value, with HRmax differing as much as ± 11 bpm for any specific age (Heyward, 2010).

Less than two minutes after exercise, participants again completed 80 trials of the modified flanker task (Kamjio et al., 2009) followed by 14 lines of the d2-test. The modified flanker task and d2-test were taken once more 30 minutes post-exercise. During the waiting period, participants were given magazines to read, as well as water. The order of cognitive tasks were alternately assigned to participants; half took the d2-test first, while the other half took the modified flanker task first for each exercise session.

During the second and third sessions, the participants were alternately assigned to a moderate exercise session at 50% of their estimated VO$_2$max for 20 minutes, following a 5-minute warm-up period of walking, or a high-intensity exercise session at 75% of their estimated VO$_2$max for the same duration. The exercise intensity at a percentage of VO$_2$max was estimated from metabolic equations. Moderate intensity is defined as 40-59% of VO$_2$max, while high intensity is exercising at 60-84% of an individual’s VO$_2$max (ACSM, 2010). The speed was set at 3.0 mph while the grade was manipulated by the researcher to ensure each participant reached
the specified intensity after the warm-up period. Each participant completed both intensities of exercise on separate days. Heart rate, blood pressure, and RPE were recorded every 5 minutes during each exercise session (Kamjio et al., 2009). Before each session of exercise, participants were allowed 32 practice trials of the modified flanker task (Kamjio et al., 2009), and 3 lines of the d2-test, followed by 80 real trials of the modified flanker task and 14 lines of the d2-test (Kamjio et al., 2009; Budde et al., 2012). Each participant then started the modified flanker task or d2-test within 2 minutes after exercise (Kamjio et al., 2009). The modified flanker task and d2-test were taken again 30 minutes post-exercise. During the waiting period, participants were given magazines to read, as well as water.

Design

The research design was a pre-test/post-test experimental study with the treatment (exercise at a moderate or high intensity) given after pre-testing of the participants (Pre-Ex). After each type of exercise, the dependent variables were measured immediately after exercise (Imm-Ex) and at 30 minutes after exercise (Post-30).

<table>
<thead>
<tr>
<th>Intensity of Exercise</th>
<th>Mod</th>
<th>Pre-Ex</th>
<th>Exercise Treatment</th>
<th>Imm-Ex</th>
<th>Post-30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td>RTₜ, RTᵢ, RTₐ, Error rate, GZ, SKL</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Research Design: Time (3) × Intensity (2). Mod = moderate. RTₜ = Total reaction time. RTᵢ = Incongruent reaction time. RTₐ = Congruent reaction time. Error rate = the relative number of all errors of confusion and elimination. GZ value = measures the rate at which participants mark off each d2, and is the overall number of marked letters within the d2 test. The SKL value measures attention, and is the standardized number of accurate answers minus confusion errors.
Statistical Analysis

Means and standard deviations were reported for all variables. Correlations of VO$_2$max were calculated with each dependent variable. Appropriate two-way repeated measures ANOVAs were used to determine if there were significant differences between means for the various levels of the independent variables. Level of significance was set a priori $p \leq 0.05$. Appropriate post hoc tests were calculated to determine where the differences occurred, if applicable. ANCOVAs were calculated to control for the effects of age and VO$_2$max on the dependent variables. Sample size was determined using G* Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007), with power set at $(1 - \beta) = .80$ in order to detect a medium effect size ($f^2 > 0.1$).
CHAPTER IV: RESULTS

Demographic data for the participants who volunteered for the study are shown in Table 1. The mean estimated VO$_2$max value for participants in this study was 36.8 ml·kg$^{-1}$·min$^{-1}$.

Table 1

Descriptive Characteristics of Participants ($N = 11$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± S.D.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65.8 ± 3.8</td>
<td>60</td>
<td>72</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.7 ± 6.6</td>
<td>154.9</td>
<td>172.7</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>65.1 ± 8.0</td>
<td>50.5</td>
<td>77.7</td>
</tr>
<tr>
<td>BMI (kg·m$^{-2}$)</td>
<td>24.2 ± 2.3</td>
<td>19.7</td>
<td>25.7</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>74.8 ± 6.5</td>
<td>65</td>
<td>89.7</td>
</tr>
<tr>
<td>Hip (cm)</td>
<td>98.9 ± 5.4</td>
<td>88.6</td>
<td>109.5</td>
</tr>
<tr>
<td>WHR</td>
<td>0.75 ± 0.05</td>
<td>0.69</td>
<td>0.86</td>
</tr>
<tr>
<td>VO$_2$max (ml·kg$^{-1}$·min$^{-1}$)</td>
<td>36.8 ± 14.5</td>
<td>14.93</td>
<td>56.8</td>
</tr>
<tr>
<td>IPAQ Total Physical Activity Score (MET-minutes)</td>
<td>6857 ± 6298</td>
<td>657</td>
<td>22,947</td>
</tr>
<tr>
<td>IPAQ Rating</td>
<td>2.6 ± 0.51</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Note. VO$_2$max = maximal oxygen consumption in ml·kg$^{-1}$·min$^{-1}$; BMI = Body Mass Index in kg·m$^{-2}$; WHR = Waist-to-Hip Ratio; IPAQ = International Physical Activity Questionnaire; IPAQ rating: 1 = low active, 2 = moderately active, 3 = high active. Estimated VO$_2$max may vary ± 10-15% (Heyward, 2010).
Effects of Acute Aerobic Exercise on Executive Function in Older Women

Table 2

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Healthy BMI (kg m$^{-2}$)</th>
<th>Waist (cm)</th>
<th>WHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69 (Years of Age)</td>
<td>161.6</td>
<td>77.4</td>
<td>18.5-24.9</td>
<td>99.9, low risk = 70-89, high risk = 90-109 ≤ 0.90</td>
</tr>
<tr>
<td>70-79 (Years of Age)</td>
<td>159.1</td>
<td>74.8</td>
<td>18.5-24.9</td>
<td>99.8, low risk = 70-89, high risk = 90-109 ≤ 0.80</td>
</tr>
</tbody>
</table>


Relationship of VO$_{2max}$ to Cognitive Function

Correlations were calculated between VO$_{2max}$ and the dependent variables, and are shown in Table 3. VO$_{2max}$ was not correlated with any of the dependent variables. VO$_{2max}$ was not a significant covariate for any of the dependent variables. ANCOVAS were calculated to find significant differences between participant characteristics and the dependent variables. The ANCOVA for total reaction time with age used as a covariate was not significant. VO$_{2max}$ was not significantly correlated with any of the dependent variables for age. There were no significant differences for age, and there were no significant correlations for age with any of the dependent variables.

Because of the small sample size, the sample could not be divided into high and low fitness level groups. There were 4 participants who were categorized as moderately active according to the IPAQ, while 7 were categorized as highly active. Those who had the highest VO$_{2max}$ values in this study scored a 3 for high physical activity levels, while those who scored a 2 for moderate physical activity levels had lower VO$_{2max}$ values relative to the higher values. The average Total IPAQ Physical Activity Score for participants was 6857 MET-minutes, while their mean IPAQ rating was 2.6.
Table 3

Correlation (r values) between VO$_2$-max and Dependent Variables at Pre-Ex, Imm-Ex 20-Minutes of Exercise, and Post-30 Minutes Exercise at Moderate and High Intensity

<table>
<thead>
<tr>
<th></th>
<th>Moderate Intensity</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Ex</td>
<td>Imm-Ex</td>
<td>Post-30</td>
</tr>
<tr>
<td>RTT</td>
<td>0.633</td>
<td>0.523</td>
<td>0.618</td>
</tr>
<tr>
<td>RTI</td>
<td>0.608</td>
<td>0.572</td>
<td>0.611</td>
</tr>
<tr>
<td>RTC</td>
<td>0.626</td>
<td>0.474</td>
<td>0.642</td>
</tr>
<tr>
<td>Error</td>
<td>-0.164</td>
<td>-0.316</td>
<td>-0.474</td>
</tr>
<tr>
<td>GZ</td>
<td>0.183</td>
<td>0.299</td>
<td>0.462</td>
</tr>
<tr>
<td>SKL</td>
<td>0.173</td>
<td>0.318</td>
<td>0.396</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>High Intensity</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Ex</td>
<td>Imm-Ex</td>
<td>Post-30</td>
</tr>
<tr>
<td>RTT</td>
<td>0.585</td>
<td>0.483</td>
<td>0.651</td>
</tr>
<tr>
<td>RTI</td>
<td>0.622</td>
<td>0.478</td>
<td>0.626</td>
</tr>
<tr>
<td>RTC</td>
<td>0.496</td>
<td>0.464</td>
<td>0.485</td>
</tr>
<tr>
<td>Error</td>
<td>-0.324</td>
<td>-0.369</td>
<td>-0.055</td>
</tr>
<tr>
<td>GZ</td>
<td>0.395</td>
<td>0.539</td>
<td>0.122</td>
</tr>
<tr>
<td>SKL</td>
<td>0.411</td>
<td>0.468</td>
<td>0.098</td>
</tr>
</tbody>
</table>

Note. Pre-Ex = pre-exercise. Imm-Ex = immediately after exercise. Post-30 = post-exercise 30-minutes. *p ≤ 0.05. RT$_T$ = total reaction time. RT$_I$ = incongruent reaction time. RT$_C$ = congruent reaction time.

Reaction Time (Scores from the Modified Flanker Task) – Effects of Intensity and Time

Results of the two-way repeated measures ANOVA for total reaction time data indicated no significant difference due to exercise Intensity ($F = 0.138; df = 1; p = 0.719$). However, there was a main effect for Time ($F = 6.081; df = 2; p = 0.010; \eta^2_p = 0.403; 1-\beta = 0.825$); this is shown in Table 4 and Figure 2. There was no significant difference for the Time × Intensity interaction ($F = 0.639; df = 2; p = 0.540$). Means and standard deviations for Time and Intensity are shown in Table 5.
Table 4

*Means and Standard Deviations for Total Reaction Time (RT_T), Incongruent Reaction Time (RT_I), and Congruent Reaction Time (RT_C) by Time and Exercise Intensity at Pre-Ex, Imm-Ex 20-Minutes of Exercise, and Post-30 Minutes of Exercise Regardless of Intensity*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Ex</th>
<th>Imm-Ex</th>
<th>Post-30</th>
<th>p</th>
<th>η_p^2</th>
<th>1-β</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT_T</td>
<td>529.6 ± 109.8</td>
<td>494.8 ± 89.5</td>
<td>511.2 ± 100.3</td>
<td>0.010*</td>
<td>0.403</td>
<td>0.825</td>
</tr>
<tr>
<td>RT_I</td>
<td>566.3 ± 134.7</td>
<td>516.6 ± 88.8</td>
<td>526.8 ± 101.1</td>
<td>0.005*</td>
<td>0.447</td>
<td>0.890</td>
</tr>
<tr>
<td>RT_C</td>
<td>492.8 ± 91.4</td>
<td>473.0 ± 92.7</td>
<td>485.2 ± 97.9</td>
<td>0.035*</td>
<td>0.310</td>
<td>0.644</td>
</tr>
</tbody>
</table>


**Figure 2.** Total Reaction Time by Time and Exercise Intensity. (Pre-Ex = pre-exercise; Imm-Ex = immediately after exercise; Post-30 = post-exercise 30-minutes) (N = 10)
Table 5

Means and Standard Deviations for Total Reaction Time (RT_T), Incongruent Reaction Time (RT_I), and Congruent Reaction Time (RT_C) at Pre-Ex, Imm-Ex, and Post-30 Minutes of Exercise for Moderate (Mod) and High Intensity Exercise

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Time</th>
<th>Time × Intensity</th>
<th>p</th>
<th>( \eta_p^2 )</th>
<th>1-( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-Ex</td>
<td>Imm-Ex</td>
<td>Post-30</td>
<td>( p )</td>
<td>( \eta_p^2 )</td>
</tr>
<tr>
<td>Mod</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT_T</td>
<td>536.4 ± 144.7</td>
<td>499.2 ± 78.8</td>
<td>505.3 ± 92.6</td>
<td>0.540</td>
<td>0.066</td>
</tr>
<tr>
<td>RT_I</td>
<td>582.4 ± 187.2</td>
<td>521.6 ± 75.1</td>
<td>529.2 ± 104.1</td>
<td>0.683</td>
<td>0.042</td>
</tr>
<tr>
<td>RT_C</td>
<td>490.4 ± 111</td>
<td>476.9 ± 83.2</td>
<td>472.1 ± 90.4</td>
<td>0.196</td>
<td>0.166</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT_T</td>
<td>522.7 ± 93.9</td>
<td>490.3 ± 110.5</td>
<td>517.2 ± 110.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT_I</td>
<td>550.2 ± 110.4</td>
<td>511.5 ± 115.3</td>
<td>524.4 ± 104.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT_C</td>
<td>495.2 ± 83.3</td>
<td>469.1 ± 110.8</td>
<td>498.3 ± 114.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Pre-Ex = pre-exercise. Imm-Ex = immediately after exercise. Post-30 = post-exercise 30-minutes. Mod = moderate. * = significant main effect for Time. \( \eta_p^2 \) = partial eta², effect size. 1-\( \beta \) = power. \( N = 10 \).

Dependent, two-tailed post hoc t-tests for each combination of total reaction time means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Imm-Ex (\( t \) value = 3.053; \( df = 19 \); \( p = 0.007 \); Cohen’s \( d = 0.46 \); 1-\( \beta = 0.20 \)). The other means were not significantly different.

There was not a significant main effect for exercise Intensity (3 × 2 ANOVA) for the incongruent reaction time (\( F = 1.658; df = 1; p = 0.230 \)). However, there was a significant main effect for Time (\( F = 7.278; df = 2; p = 0.005 \); \( \eta_p^2 = 0.447 \); 1-\( \beta = 0.890 \)); this is shown in Table 4 and Figure 3. There was no significant Time × Intensity interaction (\( F = 0.390; df = 2; p = 0.683 \)). Means and standard deviations for Time by Intensity are shown in Table 5.
Dependent, two-tailed post hoc t-tests for each combination of incongruent reaction time means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Imm-Ex ($t$ value = 3.018; $df$ = 19; $p = 0.007$; Cohen’s $d = 0.56$; $1-\beta = 0.33$), and Pre-Ex to Post-30 ($t$ value = 2.217; $df$ = 19; $p = 0.039$; Cohen’s $d = 0.43$; $1-\beta = 0.40$). The other means were not significantly different.

There was not a significant main effect for exercise Intensity for the congruent reaction time ($F = 0.550$; $df = 1; p = 0.477$). However, there was a significant main effect for Time ($F = 4.044$; $df = 2; p = 0.035$; $\eta^2_p = 0.310$; $1-\beta = 0.644$); this is shown in Table 4 and Figure 4. There was no significant Time × Intensity interaction ($F = 1.789$; $df = 2; p = 0.196$). Means and standard deviations for Time and Intensity are shown in Table 5.
Dependent, two-tailed post hoc t-tests for each combination of congruent reaction time means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Imm-Ex ($t$ value = 2.297; $df$ = 19; $p = 0.033$; Cohen’s $d = 0.29$; $1-\beta = 0.18$). The other means were not significantly different.

Attention – Effects of Intensity and Time From the d2-Test

There was not a significant main effect for exercise Intensity for the error rate (relative number of errors) ($F = 1.067; df = 1; p = 0.326$). However, there was a significant main effect for Time ($F = 7.697; df = 2; p = 0.003$; $\eta^2_p = 0.435$; $1-\beta = 0.912$); this is shown in Table 6 and Figure 5. There was no significant Time $\times$ Intensity interaction ($F = 0.158; df = 2; p = 0.855$). Means and standard deviations for Time and Intensity are shown in Table 7.
Table 6

Means and Standard Deviations for Error rate (normalized number of errors), GZ Value, and SKL Value at Pre-Ex, Imm-Ex, and Post-30

<table>
<thead>
<tr>
<th></th>
<th>Pre-Ex</th>
<th>Imm-Ex</th>
<th>Post-30</th>
<th>p value</th>
<th>$\eta^2_\rho$</th>
<th>1-(\beta)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Rate</td>
<td>0.179 ± 0.840</td>
<td>0.165 ± 0.774</td>
<td>0.142 ± 0.666</td>
<td>0.003*</td>
<td>0.435</td>
<td>0.912</td>
</tr>
<tr>
<td>GZ Value</td>
<td>0.826 ± 0.192</td>
<td>0.848 ± 0.188</td>
<td>0.861 ± 0.159</td>
<td>0.005*</td>
<td>0.414</td>
<td>0.886</td>
</tr>
<tr>
<td>SKL Value</td>
<td>0.817 ± 0.188</td>
<td>0.835 ± 0.178</td>
<td>0.863 ± 0.164</td>
<td>0.001*</td>
<td>0.482</td>
<td>0.956</td>
</tr>
</tbody>
</table>

Note. * = significant main effect for Time. The error rate, GZ value, and SKL value were each normalized into a ratio divided by the total number of possible d2’s per line in each test. (Pre-Ex = pre-exercise; Imm-Ex = immediately after exercise; Post-30 = post-exercise 30-minutes) $\eta^2_\rho$ = partial eta$^2$, effect size; 1 – $\beta$ = Power. N = 11.

Figure 5. Error Rate Time and Intensity Levels. (Pre-Ex = pre-exercise; Imm-Ex = immediately after exercise; Post-30 = post-exercise 30-minutes) (N = 11)
Table 7

*Time × Intensity Interaction Means and Standard Deviations for Error Rate, GZ Value, and SKL Values at Pre-Ex, Imm-Ex, and Post-30 at Moderate and High Intense Exercise*

<table>
<thead>
<tr>
<th></th>
<th>Pre-Ex to Imm-Ex</th>
<th>Pre-Ex to Post-30</th>
<th>Imm-Ex to Post-30</th>
<th>p value</th>
<th>( \eta^2 )</th>
<th>1-( \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Mod</td>
<td>0.185 ± 0.146</td>
<td>0.171 ± 0.192</td>
<td>0.155 ± 0.174</td>
<td>0.855</td>
<td>0.016</td>
<td>0.071</td>
</tr>
<tr>
<td>Error High</td>
<td>0.174 ± 0.202</td>
<td>0.159 ± 0.192</td>
<td>0.129 ± 0.159</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GZ Mod.</td>
<td>0.818 ± 0.206</td>
<td>0.832 ± 0.188</td>
<td>0.847 ± 0.174</td>
<td>0.825</td>
<td>0.019</td>
<td>0.076</td>
</tr>
<tr>
<td>GZ High</td>
<td>0.833 ± 0.192</td>
<td>0.863 ± 0.206</td>
<td>0.875 ± 0.155</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKL Mod.</td>
<td>0.816 ± 0.206</td>
<td>0.819 ± 0.183</td>
<td>0.855 ± 0.183</td>
<td>0.558</td>
<td>0.057</td>
<td>0.136</td>
</tr>
<tr>
<td>SKL High</td>
<td>0.818 ± 0.192</td>
<td>0.852 ± 0.192</td>
<td>0.870 ± 0.155</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. The error rate, GZ value, and SKL value were each normalized into a ratio divided by the total number of possible d2’s per line in each test. Mod = before and after moderate exercise. High = before and after high-intensity exercise. Pre-Ex = pre-exercise. Imm-Ex = immediately after exercise. Post-30 = post-exercise 30-minutes. * = significant main effect for Time. \( \eta^2 \) = partial eta\(^2\), effect size. 1-\( \beta \) = Power. N = 11.

Dependent, two-tailed *post hoc t-tests* for each combination of error rate means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Post-30 (\( t \) value = 2.795; \( df \) = 21; \( p \) = 0.011; Cohen’s \( d \) = 0.29; 1-\( \beta \) = 0.10). The other means were not significantly different.

Results of the two-way ANOVA for the GZ value indicated no significant difference due to exercise Intensity (\( F \) = 3.686; \( df \) = 1; \( p \) = 0.084). However, there was a significant main effect for Time (\( F \) = 7.068; \( df \) = 2; \( p \) = 0.005; \( \eta^2 \) = 0.414; 1-\( \beta \) = 0.886); this is shown in Table 6 and Figure 6. There was no significant difference for the Time × Intensity interaction (\( F \) = 0.194; \( df \) = 2; \( p \) = 0.825). Means and standard deviations for Time and Intensity are shown in Table 7.
Figure 6. GZ value by Time and Exercise Intensity. (Pre-Ex = pre-exercise; Imm-Ex = immediately after exercise; Post-30 = post-exercise 30-minutes) (N = 11)

Dependent, two-tailed post hoc t-tests for each combination of GZ value means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Imm-Ex (t value = -2.373; df = 21; p = 0.027; Cohen’s d = -0.16; 1-β = 0.70), and Pre-Ex to Post-30 (t value = -2.864; df = 21; p = 0.009; Cohen’s d = -0.28; 1-β = 0.08). The other means were not significantly different.

There was not a significant main effect for exercise Intensity for the SKL value (F = 1.002; df = 1; p = 0.340). However, there was a significant main effect for Time (F = 9.294; df = 2; p = 0.001; ηp² = 0.482; 1-β = 0.956); this is shown in Table 6 and Figure 7. There was no Time × Intensity interaction (F = 0.601; df = 2; p = 0.558). Means and standard deviations for Time and Intensity are shown in Table 7.
Dependent, two-tailed *post hoc t-tests* for each combination of SKL value means (i.e., Pre-Ex to Imm-Ex, Pre-Ex to Post-30, and Imm-Ex to Post-30) were calculated. There was a significant difference from Pre-Ex to Post-30 ($t$ value $= -3.271$; $df = 21$; $p = 0.004$; Cohen’s $d = -0.35$; $1-\beta = 0.08$), and Imm-Ex to Post-30 ($t$ value $= -2.176$; $df = 21$; $p = 0.041$; Cohen’s $d = -0.22$; $1-\beta = 0.15$). The other means were not significantly different.
CHAPTER V: DISCUSSION

The aim of this study was to investigate the acute effects of moderate (50% of VO$_2$max) and intense (75% of VO$_2$max) aerobic exercise for older adult females (60-75 years of age), and to determine whether these individuals showed improvements in cognition, as measured by executive control (reaction time and attention) tasks, immediately after exercise and post-exercise 30-minutes. There were significant Time effects for each dependent variable of the cognitive tasks.

Acute Effects of Exercise on Reaction Time

Reaction time results from the modified flanker task (i.e., total reaction time, reaction time for the incongruent condition, and reaction time for the congruent condition) improved after exercise (i.e., Imm-Ex, and/or Post-30) regardless of exercise intensity (i.e., moderate-intensity and high-intensity). Total and congruent reaction time decreased immediately after exercise and leveled off 30-minutes post-exercise. However, incongruent reaction time continued to improve from before exercise to post-30 minutes of exercise.

These results are comparable to the findings by Kamijo et al. (2009), who discovered that reaction time is improved immediately after moderate-intense exercise. They had participants complete a modified flanker task before and less than 2 minutes after both a light (30% VO$_2$max) and moderate (50% VO$_2$max) cycling session of 20 minutes in younger (19-25 years) and older adults (60-74 years). After exercising at 50% VO$_2$max, reaction time significantly decreased for both age groups. However, the exercise session at 30% VO$_2$max and at baseline resulted in no significant decrease in reaction time. The older age group displayed comparable cognitive benefits after a session of cardiovascular exercise as compared to the younger age group, therefore, for this mature age group, the benefits of acute cardiovascular exercise are similar to
the results from the present study (Kamijo et al., 2009). Immediately after aerobic exercise at both moderate and high intensities (50% $\text{VO}_2\text{max}$ and 75% $\text{VO}_2\text{max}$) in this study, older adult females (60-75 years) significantly decreased their reaction time as well. While improvements in reaction time were not affected by Exercise Intensity, reaction time was decreased (i.e., improved) after both intensities, indicating that reaction time decreases after an acute bout of moderate or high-intensity aerobic exercise.

Davaranche et al. (2009) also used a modified version of the Eriksen flanker task, which measures executive function, and found that during 20 minutes of cycling at a moderate intensity of 50% of maximal aerobic power, reaction time was improved in university students and staff compared to baseline. Davaranche et al. (2009) found that moderate exercise decreases reaction time for both congruent and incongruent conditions as well, which is supported by the results of this study.

The larger reaction time effect of the incongruent condition in this study, however, may be due to the fact that it uses a larger portion of executive control processing (Hillman et al., 2003; Kamijo et al., 2007) than the congruent condition. The incongruent arrows cause a slower reaction time from the stimulation of an inaccurate answer before the task is finished (Hillman et al., 2003). This is because the surrounding arrows point in opposite directions as the middle arrow, the arrow participants are expected to react to (Kamijo et al., 2009). The accurate answer brought out by the target stimulus is challenged by the incongruent condition (Hillman et al., 2003; Kamijo et al., 2009). Therefore, executive function will be challenged during the incongruent condition of the flanker task.

Executive control mechanisms are thought to be the most stimulated by aerobic exercise as opposed to any other cognitive processes. It is believed that executive function is most
Effects of Acute Aerobic Exercise on Executive Function in Older Women

affected by age; older adults use a larger extent of executive control during the incongruent
condition of the flanker task because of the stimulation of an inaccurate answer (Kamijo et al.,
2009). These mechanisms of executive control require greater concentration and awareness,
such as during reaction time and attention tasks (Hillman et al., 2003). Exercise improved
concentration and awareness for participants in the present study. Older adult females displayed
a greater reaction time effect of the incongruent condition from Pre-Ex to Imm-Ex, as well as
Pre-Ex to Post-30 for both intensities, as opposed to the congruent condition, which just showed
improvement from Pre-Ex to Imm-Ex.

The findings from this study of the reaction time effect for the incongruent condition is
important because acute aerobic exercise of moderate and high-intensity can improve executive
control processes in older women who possess a high level of fitness (i.e., mean VO\textsubscript{2} max in this
study was 36.8 ml`kg\textsuperscript{-1}`min\textsuperscript{-1}). The VO\textsubscript{2} max of the participants in this study is considered
superior for those 60-79 years of age (ACSM, 2010), and is between the 90-95 percentiles. This
supports the results of Colcombe et al. (2004), who assessed fitness levels with a submaximal
exercise test to estimate VO\textsubscript{2} max using the Rockport 1-mile walk test. They reported that older
adults with higher fitness levels displayed a greater reduction in reaction time during the
incongruent condition of a flanker task. This is important because it is possible that the positive
cognitive benefits after acute aerobic exercise are the same regardless of intensity in individuals
who exercise regularly (Kamijo, 2009; Zervas et al., 1991).

In older adults, executive function may be responsible for controlling how they walk,
particularly during more difficult predicaments such as walking up stairs or walking outside in
icy conditions (Mirelman et al., 2012). Because of this, the risk of a fall might be due to
declining executive functioning (i.e., reaction time and attention). At rest, individuals of a high

Effects of Acute Aerobic Exercise on Executive Function in Older Women

and low fitness possess similar reaction time scores, however, those who are of a higher fitness level display a greater reduction in the incongruent condition of a flanker task, which requires a larger extent of executive control than the congruent condition (Colcombe et al., 2004). If executive function can be improved through increases in aerobic fitness, then many older adults may want to participate in regular aerobic exercise to also improve reaction time.

Acute Effects of Exercise on Attention

For the d2-test of selective and sustained attention, each dependent variable of the d2-test was normalized into a ratio because the total number of d2’s in each test was not the same. The number of d2’s in each test was randomized because if the total number of d2’s were identical in each test, participants might start to see a pattern. Each variable that was measured demonstrated a significant improvement after exercise, and continued to improve up until post-30 minutes of exercise, regardless of Intensity. The number of total errors (both errors of elimination and confusion), measures accuracy and attention to detail, and significantly decreased from Pre-Ex to Post-30. This means that aerobic exercise reduces error up until 30-minutes post-exercise. The GZ value is the overall number of marked letters (“d” or “p”), whether the marked letter is right or wrong, within the d2-test (Budde et al., 2012). This value corresponds to working speed (how fast one responds in marking off a letter), and significantly increased from Pre-Ex to Imm-Ex, as well as from Pre-Ex to Post-30, meaning that working speed increased after exercise, and persisted 30-minutes post-exercise. The SKL value measures attention span, and is the standardized number of accurate answers minus confusion errors. The SKL value significantly improved from Pre-Ex to Post-30, and from Imm-Ex to Post-30. This means that almost all marked letters were accurately marked as d2’s therefore, attention span increased across time.
Changes in Executive Function After Moderate Vs. High-Intensity Aerobic Exercise

McMorris et al. (2009) revealed that in young adults who participated in recreational sports, reaction time is improved after 50% of maximum aerobic power, but not after 80% aerobic power. Even though these researchers did not observe a decrease in reaction time after high-intensity exercise, Budde et al. (2012) stated that increases in cognition occur following acute exercise of high-intensity in those individuals who participate in a high level of physical activity and possess a higher fitness status than individuals who are not as fit. In this study, many of the participants were of a high cardiovascular fitness level (mean VO$_2$max was 36.8 ± 14.5 ml·kg$^{-1}$·min$^{-1}$), and participated regularly in physical exercise. These women significantly decreased their total, incongruent, and congruent reaction time after both moderate and high-intense aerobic exercise. There was not a significant difference in the amount of decreased reaction time after moderate or high intensity exercise. This study would have needed 7-8 more people to have significant power to detect a medium effect size due to Intensity level. It was difficult to recruit women of 60-75 years of age for this study who were not on medications for high blood pressure, mental illness, cognitive impairment, depression, or high blood cholesterol.

In addition, Albert et al. (1995) suggested that in adults 70-79 years of age, those who regularly incorporate high-intensity exercise show less of a decline in cognition. In older adults, Tsujii, Komatsu, & Sakatani (2013) assessed executive function after a control session and a moderate aerobic exercise session, and found that executive control improved after acute moderate exercise. In the present study, cognition was increased following both moderate and
Effects of Acute Aerobic Exercise on Executive Function in Older Women

More research needs to be done in older adults to determine increases in cognition after exercise, at what intensities, and why.

**Aerobic Capacity (VO₂max) Determines Performance on Executive Function Tests**

Recent evidence proposes that increases in aerobic fitness through regular physical activity are essential to sustain cognition (Hötting & Röder, 2013). In this study, reaction time was significantly lower following both a moderate and high-intensity exercise session for older adult females 60-75 years of age who possessed a mean VO₂max of 36.8 ± 14.5 ml·kg⁻¹·min⁻¹. This supports results from previous studies in that the mean fitness level of participants in this study was high. In the Barnes et al. (2003) study, higher fitness levels of older adults resulted in improved cognition, as well. The average age of the participants in the Barnes et al. (2003) study was 68.7 years, and the mean VO₂max for the highest fit women was 22.8 to 36.1 ml·kg⁻¹·min⁻¹ compared to women with lower fitness levels in the study (12.3 to 22.7 ml·kg⁻¹·min⁻¹). Barnes et al. (2003) concluded that those who possessed a higher fitness level displayed higher levels of cognition which correlates with this study. However, in the current study, older adult females with a lower VO₂max value were not compared because the sample size was too small.

In older adults, Bugg et al. (2006) assessed physical activity levels using the Voorrips et al. (1991) physical activity questionnaire and found that in those who were more active, executive function did not decline when measured in the evening compared with morning cognitive testing. However, in those who were sedentary, executive function diminished throughout the day. This suggests that in older adults, those who are more active possess higher levels of cognitive functioning. Since the mean fitness level of participants in the current study was high (mean VO₂max of 36.8 ± 14.5 ml·kg⁻¹·min⁻¹), and their physical activity level was moderately high (mean IPAQ rating was 2.6 ± 0.51), this could indicate that in those who are...
highly fit and active, cognitive function is higher after moderate and intense acute aerobic exercise.

In this study, participants were tested at the same time of day, 4-7 days apart from each other. Most participants were tested in the morning or early afternoon. However, it may be beneficial to test each participant at different times of day, such as in the Bugg et al. (2006) study, but after a moderate and high intense exercise session to determine if there are any time of day effects on cognition, and how the intensity of the exercise bout affects cognition.

Colcombe et al. (2004) reported that individuals with a higher level of fitness show greater improvements in attention and reaction time, which is similar to the results of this study. Colcombe et al, (2004) conducted a cross sectional study in which they tested fitness levels, and found that those who possessed a higher level of cardiovascular fitness displayed higher levels of attention and faster reaction times. Because of the small sample size and difficulty recruiting, we were unable to complete a similar comparison.

After an acute bout of moderate or high-intensity exercise, attention was improved in healthy older adult females, as shown in this study by the results of the d2-test. Since the population for this study was highly fit and active older adult females, it is logical that attention improved following exercise. However, if the participants were not fit, there may have been no impact on attention due to exercise (Budde et al., 2012). Stroth et al. (2009) reported that in younger adults who participated in a running program for 6 weeks, attention only improved due to repetition of the d2-test, but not from the running intervention. However, Chodzko-Zajko, Schuler, Solomon, Heinl, and Ellis (1992) reported that in cognitive tasks that require greater concentration, the tasks would be more sensitive to differences in fitness level than tasks that may become automatic. Stroth et al. (2009) believed that the d2-test of attention requires less
concentration, can become automatic, and may not be a reliable task to use in assessing the effects of exercise on attention.

However, in this study, participants practiced the d2-test during their baseline session, where fitness status was assessed. They first had a chance to practice 3 lines of the d2-test, and then real trials (14 lines) were taken before their submaximal exercise test. Immediately after the exercise test, real trials (14 lines) were taken of the d2-test, and 30 minutes post-exercise, 14 lines of the d2-test were taken again, just like in the treatment protocol. When participants arrived for their second and third sessions to assess the effects of acute aerobic exercise of moderate and high-intensity on executive function (i.e., attention and reaction time), they had a chance to practice 3 lines of the d2-test, and then took the real trials, 14 lines of the test Pre-Ex, Imm-Ex, and Post-30. Because participants had many chances to practice, this study was still able to show an improvement in the d2-test of attention following aerobic exercise of moderate and high-intensity. It is unlikely participants’ scores changed due to a practice effect, because the number of d2’s in each test was randomized. If the total number of d2’s were identical in each test, participants may have improved attention due to practice.

Budde et al. (2012) studied active and inactive young adults (19-29 years of age) and had them participate in both an intermittent maximal exercise session and a seated control session. The d2-test of attention was taken directly after both the exercise and control conditions. Those who were more active were able to improve their attention on the d2-test after the exercise condition, while those who were inactive did not benefit from the exercise session. This finding is similar to results in this study, because older adult females 60-75 years of age who possessed a higher level of aerobic fitness and physical activity participation were able to improve their
Effects of Acute Aerobic Exercise on Executive Function in Older Women

attention on the d2 test following an acute bout of moderate and high-intensity aerobic exercise, however, there was no comparison to a less active group due to the small sample size.

Since older adults of a high fitness level participated in this study, this could have significant implications because if older adult women could exercise before they start their day, they might be better able to pay attention to surrounding stimuli, such as during driving. However, according to Kamijo et al. (2007), individuals should first increase their fitness level to gain cognitive benefits. It is believed that decreased blood flow to the frontal lobe in the brain is due to a reduced ability to maintain attention during challenging endeavors in older adults (Mahoney, Verghese, Goldin, Lipton, & Holtzer, 2010). Because the act of driving a car, planning out business meetings, or balancing a checkbook requires executive function, if a decline in this type of cognition occurs in older adults, they are going to have a more difficult time carrying out these tasks. Since aerobic exercise is known to increase blood flow to the brain (Colcombe et al., 2004), it is important that older adults increase the amount of time they spend participating in aerobic exercise to enhance their fitness so that they can maintain good levels of executive functioning.

Effects of Recovery Time on Cognition

Post hoc t-tests were also calculated in order to determine at which point after exercise cognition was improved, either immediately after, post-30-minutes, or both. Pontifex, Hillman, Fernhall, Thompson, and Valentini (2009) tested 21 younger adults (Means: 20.2 years, VO$_{2\text{max}}$ = 54.6 ml•kg$^{-1}$•min$^{-1}$) to determine whether acute aerobic exercise, resistance exercise, or both affected cognition after exercise. Participants completed a modified Sternberg task (Sternberg, 1996) which assessed reaction time and response accuracy (i.e., executive function) by displaying a series of letter sequences involving uppercase consonants or lowercase
Effects of Acute Aerobic Exercise on Executive Function in Older Women

Participants had to press a key with their right or left thumbs, depending on which sequence was present. Participants completed the Sternberg task before, immediately after, and 30-minutes following 30 minutes of aerobic exercise on a treadmill at 60-70% of VO$_2$max, 30 minutes of strength training, or a rest condition of 30 minutes. Reaction time only decreased immediately after exercise and 30-minutes post-exercise for the aerobic exercise condition (Pontifex et al., 2009). Hogervorst et al. (1996) found that in trained individuals (18-42 years of age), reaction time and working speed was improved immediately after a bout of cycling at 70% of their VO$_2$max, a workload that mimicked what they would cycle at for a one hour all-out effort. Lambourne, Audiffren, and Tomporowski (2006) found that in young adults (average age was 21.1 ± 1.7 years, and mean VO$_2$max was 37.33 ± 5.15 ml·kg$^{-1}$·min$^{-1}$) who cycled for 40 minutes at a moderate intensity, cognition returned to baseline measurements 30-minutes post-exercise.

If attention is elevated after exercise, this may help an individual identify a stimulus, and then react. For example, if attention and reaction time are improved after exercise, this may make the individual more alert during driving. Individuals can pay more attention to the road, and if a deer suddenly crosses the road in front of the car, they can immediately react and step on the brakes. Executive function, especially selective attention, is very important in driving. Deterioration in selective attention results in an increased risk for crashes and decreases in driving ability (Adrian, Postal, Moessinger, Rascle, & Charles, 2011). More research is needed to determine the difference between moderate and high-intensity exercise on cognition 30-minutes post-exercise in older adults.
Future Research

Future research might directly measure VO$_2$max to delineate moderate and high-intensity aerobic exercise. Many of the studies in this paper indicated that higher levels of fitness correlate with higher levels of cognition, however, some researchers used physical activity questionnaires instead of a direct measure of fitness, such as a VO$_2$max test. VO$_2$max was estimated in this study, and there may be some error, therefore, in the estimation of the moderate and high-intensity exercise prescriptions (Heyward, 2010). Therefore, the moderate (50% of VO$_2$max) and high (75% of VO$_2$max) intensities used in this study may not have been different enough. Future research should compare older adult females with high and low directly measured VO$_2$max values (with a physician present) and how their cognition is affected after a session of low, moderate, and high-intensity aerobic exercise to see if there is a difference after the intensity of exercise, and if fitness level matters. Furthermore, further research can assess the effects of recovery time on cognition after each of these intensities (i.e., 15, 30, 60, or 120 minutes) in older adults to compare the results from this study. Based on the results of this study from Imm-Ex to Post-30, further research should strive to investigate whether or not reaction time and attention is improved or returns to baseline 30-minutes post-exercise of low, moderate, or high-intensity. However, cognition may never return to baseline measures if there is a training effect.

Also, it was a challenge to recruit females between the 60-75 year old age ranges who were not on medications for high blood pressure, mental illness, cognitive impairment, depression, high blood cholesterol, or who had a metabolic condition, such as diabetes. Future research may include individuals on medications, except those on cardiovascular medications, to determine if there are any positive effects on cognition from aerobic exercise in these...
Effects of Acute Aerobic Exercise on Executive Function in Older Women

individuals. Because this study was done on older adult females, it is important to note that females may be at the greatest risk of developing cognitive decline because their estrogen levels drop after menopause (Spirduso et al., 2007). It is believed that estrogen may have a protective benefit on cognitive function in women, although, taking supplemental estrogen may impose health risks; not enough information is known about taking extra estrogen (Asthana, 2004).

In a study conducted by Erickson et al. (2007), females 58-80 years of age were studied to find a difference between fitness level, executive function, and number of years on hormone replacement therapy. Those who were on hormone replacement therapy less than 10 years scored higher on executive control tasks and displayed a smaller loss of brain tissue, measured by an MRI, as opposed to females who were on hormone replacement therapy for 11 or more years. However, the females who possessed a higher cardiovascular fitness level did not lose as much brain tissue even if they took hormone replacement therapy for 11 or more years, when compared with those possessing a low fitness status. Females with a high level of fitness who did not take hormone replacement therapy were safeguarded from age-related losses in brain tissue, as well (Erickson et al., 2007).

All of the participants in this study were post-menopausal, but were moderately to highly active and had, on average, a high aerobic capacity. Because aerobic exercise is known to increase cognition in both young and older adults, it is important that females stay regularly active, or start an exercise program if they have not already. Further research needs to be done on older adult females regarding aerobic exercise to determine what other beneficial effects in cognition are sustained after exercise, how exercise can positively impact cognition, and determine mechanisms for positive changes.
Further research may also want to compare the effects of aerobic vs. resistance exercise on cognition in older adults. Colcombe et al. (2004) administered a longitudinal study in which they studied two groups, one was designed to improve cardiovascular fitness through walking for 6 months, beginning at 40-50% of HR reserve for 10-15 minutes and increased to 60-70% of HR reserve for 40-45 minutes three times a week. They compared this group with a stretching and strengthening control group. Individuals who were more fit at the beginning of the study, and who improved their cardiovascular fitness throughout 6 months also increased cognition at the end of the study. The control group (who participated in stretching and strengthening) did not significantly improve cognition. Even when an older adult increases his or her fitness level from sedentary or minimal activity, a positive effect on cognition is observed (Berga, 2008; Colcombe & Kramer, 2003; Colcombe et al., 2004; Masley et al., 2009; Stroth et al., 2009). In this study, older women were able to improve their cognition after aerobic exercise, as well, but resistance exercise and stretching were not compared. More research needs to be done on whether fitness, activity level, and type of exercise result in an increase in cognition.

Summary

Following acute aerobic exercise of moderate and high-intensities, older adult females (60-75 years of age) significantly reduced their reaction time and improved their attention. Reaction time and attention are aspects of executive function. Executive function is typically part of age-related cognitive decline, and if older adults are able to increase executive function after aerobic exercise, this could improve older adults completion of tasks requiring immediate attention and reaction (e.g., stopping a car when the traffic light turns from green to red).

Also, it may be important for older adult females to increase their fitness levels by participating in aerobic exercise more often and for longer periods of time in order to gain the
most in terms of cognition. Additional studies need to be completed on older adults, especially females, to further investigate the acute effects of exercise as well as exercise training on cognition. However, in this study, executive function was improved following an acute bout of moderate and high intensity aerobic exercise in older women who had high aerobic capacities and activity levels. Therefore, continuing to participate in aerobic activities may help these women throughout each day on tasks requiring cognitive abilities. The research evidence supports that maintaining aerobic fitness and activity levels may help to sustain cognitive abilities.
REFERENCES


Effects of Acute Aerobic Exercise on Executive Function in Older Women


Effects of Acute Aerobic Exercise on Executive Function in Older Women

from


Thorvaldsson, V., Skoog, I., Hofer, S. M., Börjesson-Hanson, H., Östling, S., Sacuiu,


Effects of Acute Aerobic Exercise on Executive Function in Older Women


APPENDIX A: INFORMED CONSENT

Informed Consent

Investigator: Roseann Perchinske  Phone: (440)-382-6787

Project Title: Influence of Fitness Levels on Reaction Time and Attention in Older Women

Purpose: You are being asked to participate in a research study to find out whether physical fitness is related to reaction time and attention after short periods of moderate and high-intensity aerobic exercise. Reaction time (the time needed between the identification of the direction of an arrow and the push of a button for the correct response) and attention (identifying letters and figures in a certain time period) will be measured after 20 minutes of exercise for adult women over 60 years of age. As part of my work on my graduate level studies in Kinesiology at Bowling Green State University, I am interested in testing adult females, 60-75 years of age for my research study. I am interested in the results of this study because cognitive function may decrease as a result of aging. My advisor is Lynn Darby, Ph.D., who is a professor of Exercise Science, and she will be supervising my research project.

If you participate, you will be asked to complete three (3) exercise sessions of 20 minutes each. Each time you come to the laboratory you will spend about 1-1.5 hours completing exercise and the tests. All of your testing will be completed at the same time of day over the course of 2-3 weeks. Each session will involve reaction time (the time needed between the identification of the direction of an arrow and the push of a button for the correct response) and attention (identifying letters and figures in a certain time period) tasks taken before and immediately after, and 30 minutes after exercise. You are welcome and encouraged to ask any questions about the study at any time.

Procedures: To be allowed to participate, you will need to have your physician sign an approval form that I give you. If your physician cannot fax the form, or sign it without an appointment first, then you are responsible for any costs.

Session 1: As a volunteer in this research project you will be asked to come to the BGSU Exercise Physiology Lab in Eppler South Room 124 to fill out some forms about your current health status and physical activity level to make sure it is safe for you to participate. After your paperwork is done, we will measure your blood pressure, height, body weight, and waist and hip circumferences taken on your skin at the waist and over your underwear at the hip. You will have a chance to practice two cognitive tasks (i.e., reaction time, which is the time needed between the recognition of the direction of an arrow and the push of a button for the correct response, as well as attention, which is the identification of letters and figures in a certain time period) that are a part of this study. After the practice session is complete, real trials of the cognitive tasks will be taken. You will complete 80 trials of the reaction time and 14 trials of the attention tasks. Next, we will have you walk on a treadmill to estimate how aerobically fit you are.

Submaximal Exercise Test. You will complete a 3-minute warm-up walking period at 2.0 mph before the first stage of the treadmill test. After the warm-up the speed of the treadmill will...
Effects of Acute Aerobic Exercise on Executive Function in Older Women

increase to 3mph (i.e., faster walking) and every 3 minutes thereafter, the treadmill will increase in grade (incline) by 2.5 percent. The test will be stopped once your heart rate reaches 85% of its age-predicted maximum. This will feel like you are breathing a little fast and walking briskly. Blood pressure and heart rate will be measured before and during this test. The test will take 10-20 minutes, depending on your level of fitness. During this test you will need to wear electrodes on the chest area in order for the researchers to watch the activity of the heart. If any irregular rates or rhythms are found at rest or during exercise, the test will be stopped immediately, and you will be referred to your physician for follow-up.

Sessions 2 and 3: You will arrive at the lab at the same time of day 4-7 days after session 1, and take trials of cognitive tasks, exercise at either a moderate or high intensity (i.e., 50% or 75% of your maximal capacity determined from session 1) for 20 minutes (after a 5-minute warm-up period), and then complete the two cognitive tasks immediately and 30-minutes after walking on the treadmill. During the third session you will arrive at the lab at the same time of day 4-7 days after session 2, take the cognitive task trials, exercise at the exercise intensity you did not do during session 2, and then complete the two cognitive tasks immediately and 30-minutes after walking on the treadmill. During the second and third sessions, you will be wearing a heart rate monitor around your chest under your shirt. The heart rate monitor will not hurt you in any way, and will not stick to your skin.

Exclusion Criteria: Any participant who is taking medications for cognitive impairment, depression, mental illness, blood pressure, high blood pressure, or high cholesterol will not be allowed to participate in this study. Also, if you have been clinically diagnosed with depression in the past 3 years, or have any other orthopedic or metabolic condition (e.g., diabetes) that could increase your health risk, you will be unable to participate. The target population is females 60-75 years of age, so if you are a male, or under the age of 60 yrs. or over 75 yrs., you will not be needed for this study.

Risks: If an accidental injury occurs, appropriate emergency measures will be taken. The risks that you may experience by participating in this study are no greater than what you would experience in your daily life if exercising on your own. However, certain risks to your health and well-being are always possible such as: 1) cardiovascular injury (i.e., stroke, heart attack, and even death), 2) acute fatigue and/or light muscle soreness lasting 1-4 days after the fitness test, moderate exercise bout and high-intensity exercise bout, depending on your fitness level, 3) nausea, lightheadedness, and dizziness sometimes associated with intense exercise, and 4) all other potential risks associated with intense exercise. The likelihood of experiencing a stroke, heart attack, or other health risk is potential but not very likely. According to the American College of Sports Medicine (2010) “Several studies have looked at the risks of exercise testing...in a mixed population, the risk of exercise testing is low, with approximately six cardiac events per 10,000 tests. In addition, the majority of these studies used symptom-limited exercise tests. Therefore, it would be expected that the risk of submaximal testing in a similar population would be lower.”

If you do experience any of these side effects, these will almost certainly stop, unless you have a cardiovascular issue. If you experience fatigue, stomach discomfort, or dizziness, it will probably occur as soon as exercise is stopped, and will come to an end within 10-15 minutes. If you do develop any of these side effects, the researcher will ask you to stay in the lab so she can monitor you until the side effects subside. If these are severe or continue appropriate emergency measures will be taken.
Benefits: By participating in this study, you will receive information about your current fitness level (e.g., aerobic capacity, body mass index, waist to hip ratio) and executive function (e.g., reaction time, attention, etc.). Conclusions can be made about women 60-75 years of age immediately after the study if a relationship is shown between executive function and fitness or activity level. Fitness professionals could be made aware of this when working with older women and design exercise programs that target this population.

Confidentiality: Your identity and information you provide will remain confidential. After data collection for each exercise session, your data file (associated with an ID number) will be stored in a locked room, in which only the researcher and other personnel working on this study will be allowed to see this information. For the cognitive tasks, your ID number will be saved on a password protected computer. Your name will not be associated with any of your data.

Voluntary Participation: Your participation is completely voluntary. You are free to withdraw at any time. You may decide to skip questions (or not do a particular task) or discontinue participation at any time without penalty. Deciding to participate or not will not affect your relationship with Bowling Green State University.

Contact Information: If you have any questions or comments about this study, you can contact Roseann Perchinske at 440-382-6787 or rperchhi@bgsu.edu, or Dr. Lynn Darby, professor of Exercise Science at Bowling Green State University, this student’s advisor, at 419-372-6903, or ldarby@bgsu.edu. You may also contact the Chair, Human Subjects Review Board, Bowling Green State University, at 419-372-7716 or hrsrb@bgsu.edu, if you have any questions about your rights as a participant in this research study. Thank you for your time in reading this document.

Authorization: I have read this document and the study has been explained to me. I have had all of my questions answered. I volunteer to participate in this study.

I know that I will receive a copy of this letter, and a copy of my results if I so request, after completion of the study.

_____________________________  ______________________________
Participant Signature               Date

BGSU HRR # 271781
EFFECTIVE 07/06/2013
EXPRES 12/31/2013
APPENDIX B: PHYSICIAN CLEARANCE FORM

January 15, 2013

Dear Dr. ______________,

Your patient, ______________, would like to participate in a research study regarding the influences of physical fitness on executive function (i.e., reaction time and attention) in older women (60-75 years of age). This research study is part of a master’s thesis at Bowling Green State University. The purpose of this study is to determine whether physical fitness is related to executive function after short bouts of moderate and high-intensity aerobic exercise. Based on the study description, we would appreciate your medical opinion concerning if your patient, ______________, is able to participate. Further details of the study are shown on the attached Physician's Approval Form.

Could you please take a moment and complete the enclosed Physician Approval Form? This form will assist us in determining your patient’s eligibility for participation in the research study. Please provide us with any specific concerns or conditions that we should be aware before she engages in physical exercise. Also, please indicate if you agree to the participation of this individual in the research study.

Thank you for your assistance. Could you please provide the requested information on the following pages?

Please return this form to:

Roseann Perchinske
4915 New England Lane Apt. 204
Sylvania, OH 43560
(419)-372-6903
mphch@bgsu.edu

If you have questions, you may contact me. You may also contact my advisor, Professor Lynn Darby, Ph.D. at (419)-372-6903 or ldarby@bgsu.edu. Thank you again for your time and assistance.

Sincerely,

Roseann Perchinske
Master's Student, School of HEMSLS
Bowling Green State University
PHYSICIAN APPROVAL FORM – RESEARCH STUDY FOR THE INFLUENCE OF AEROBIC EXERCISE ON COGNITION IN OLDER WOMEN

Description of Study

I will be studying the influence of physical fitness on executive function in older women. The purpose of this research study is to determine whether physical fitness is related to executive function (i.e., reaction time and attention) after short bouts of moderate and high-intense aerobic exercise.

Description of Assessment

Session 1:
- Blood pressure, height, body weight, and waist and hip circumferences will be measured.
- Trials of cognitive tasks will be administered, and after a practice session, your patient will complete 80 trials of the reaction time and 14 trials of the attention tasks.
- Next, she will walk on a treadmill to estimate fitness level. Heart rate and EKG will be monitored using a 12-lead EKG.
- As soon as the heart rate reaches 85% of its maximum, the test will be stopped, and cognitive tasks will be completed immediately afterwards and 30 minutes later.

Submaximal Exercise Test:
- A 3-minute warm-up period at 2.0 mph will be administered before the first stage of the Balke walking treadmill protocol.
- The speed will then increase to 3mph (i.e., faster walking) and every 3 minutes thereafter, the grade will increase by 2.5 percent. The test will be stopped once heart rate reaches 85% of its age-predicted maximum.
- Blood pressure and heart rate will be measured before this test, as well as during each stage.
- The test will take 10-20 minutes, depending on your patient’s level of fitness.
- If any abnormal rates or rhythms are detected at rest or during exercise, the test will be stopped immediately, and your patient will be referred for follow-up.

Sessions 2 and 3:
- Your patient will arrive at the lab at the same time of day 4-7 days after session 1.
- She will take trials of the cognitive tasks, walk at either a moderate or high intensity (i.e., 50% or 75% of her maximal capacity determined from session 1) for 20 minutes (after a 5-minute warm-up period), and then complete the two cognitive tasks immediately and 30-minutes post-exercise.
- During the third session she will arrive at the lab and do everything she did in session 2 but will walk at the exercise intensity not completed previously.

Subjects will be instructed to call or e-mail either myself or Dr. Darby (my advisor) with any questions during the study.

1) Are there specific concerns or conditions we should be aware of before this individual engages in exercise/activity? ____________ YES ____________ NO

If yes, please specify:

Continued on next page...
2) Please provide the following information so that we may contact you if we have any further questions:

_______ I AGREE to the participation of this individual in engaging in aerobic exercise to determine whether it influences cognition.

_______ I DO NOT AGREE to the participation of this individual in engaging in aerobic exercise to determine whether it influences cognition.

________________________________________________________
Physician’s Name

________________________________________________________
Physician’s Signature

________________________________________________________
Address

________________________________________________________
Telephone: __________________

________________________________________________________
Fax: __________________

Thank you for your help.

RELEASE OF INFORMATION

I, ____________________, hereby authorize the above-named physician to release the information included in this form to Roseann Perchinske.

________________________________________________________
Participant’s Signature ________________________________ Date
APPENDIX C: MEDICAL HISTORY QUESTIONNAIRE

EXERCISE PHYSIOLOGY LABORATORY
124 EPLLER SOUTH, SCHOOL OF HUMANS
BOWLING GREEN STATE UNIVERSITY

MEDICAL HISTORY QUESTIONNAIRE

All information given is personal and confidential. It will enable us to better understand you and your health and fitness habits. In addition, we will use this information to classify your health status according to the American College of Sport Medicine (ACSM) recommendations for risk stratification (ACSM, 2009). Please let us know if and when you have changed your medication (dose & type), diet, exercise or sleeping habits within the past 24 or 48 hours. It is very important for you to provide us with this information.

NAME ___________________ AGE ___________ DATE ___________

OCCUPATION ____________________________

1. **FAMILY HISTORY**

Check each as it applies to a blood relative:

- **Heart Attack**
  - yes
  - no
  - unsure
  - If yes, age at onset (ys): relation to you ____________________________

- **Sudden Death**
  - yes
  - no
  - unsure
  - If yes, age at onset (ys): relation to you ____________________________

- **Coronary Revascularization**
  - yes
  - no
  - unsure
  - If yes, age at onset (ys): relation to you ____________________________

  Father’s Age ___________ Deceased: Age at death ___________
  (*Before 55 yr. in father or first-degree male relative)

  Mother’s Age ___________ Deceased: Age at death ___________
  (*Before 65 yr. in mother or first-degree female relative)

2. **PERSONAL HISTORY**

- **Current Cigarette Smoking**
  - yes
  - no
  - unsure

- **Sedentary Lifestyle**
  - yes
  - no
  - unsure
  - Persons not participating in at least 30 min of moderate intensity physical activity on at least 3 days/week for at least 3 months.

- **Obesity**
  - BMI >30 kg/m²
  - yes
  - no
  - unsure
  - If yes, give value (kg/m²): ______________________________________
  - Waist circum. >40” men: 35” women: yes
  - no

- **High Blood Pressure**
  - yes
  - no
  - unsure
  - Systolic Blood Pressure >140 mmHg or diastolic >90 mmHg
  - If yes, give value __________________________ mmHg

- **Dyslipidemia**
  - yes
  - no
  - unsure
  - Total S mm Cholesterol >200 mg/dl; value: __________ mg/dl
  - LDL-C >130 mg/dl; value: __________ mg/dl
  - HDL-C >40 mg/dl; value: __________ mg/dl
  - On lipid lowering medication: yes
  - no

- **Diabetes**
  - yes
  - no
  - unsure
  - If yes, age of onset (ys): relation to you ____________________________
  - years
  - Impaired fasting glucose ≥ 100 mg/dl; value: __________ mg/dl
  - Impaired glucose tolerance test: yes
  - no
  - (Note: values confirmed by measures on two separate occasions)

- **Negative Risk Factor**
  - yes
  - no
  - unsure
  - HDL ≥ 60 mg/dl; value: __________ mg/dl

For Office Use Only:
  - __________ Sum of positive and negative "CVD risk factors" (according to Table 2-3 ACSM (2009))

NOTE: All risk factors are explained verbally to each person completing the questionnaire.

Classification according to ACSM (2009) (check one): ______ Low risk; ______ Moderate risk; ______ High risk
3. MEDICAL HISTORY

Name of your physician

Date of your most recent physical examination

What did the physical examination include?

Have you ever had an exercise EKG? Yes____ No_____

Are you presently taking any medications? Yes____ No_____
(Including over-the-counter medications and/or herbs)

List name and dosage

Have you ever taken:

- Digitalis
  yes____ no____ unsure____
- Nitroglycerin
  yes____ no____ unsure____
- High Blood Pressure Medication
  yes____ no____ unsure____
- Sedatives
  yes____ no____ unsure____
- Inderal
  yes____ no____ unsure____
- Insulin
  yes____ no____ unsure____
- Froneystyl
  yes____ no____ unsure____
- Vasodilators
  yes____ no____ unsure____
- Other
  yes____ no____ unsure____

If yes, list medications:

4. EXERCISE HISTORY

Do you exercise? Yes____ No____ What activity

How long have you been exercising?

How many days do you exercise? How many minutes per day?

What kinds of shoes do you work out in?

Where do you usually exercise?

Do you monitor your pulse during your workout?
5. **HEALTH HISTORY**

<table>
<thead>
<tr>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you use Health Foods? Yes ___ No ___ List __________________________

Do you take Vitamin pills? Yes ___ No ___ List __________________________

Approximate your daily intake: Coffee ______ tea ______ coke ______ beer ______ wine ______ liquor ______

Do you smoke or use tobacco products? Yes ___ No ___

If yes, approximate daily usage: Cigarettes ______ Cigars ______ Pipes ______ Chewing Tobacco ______

Did you ever smoke? Yes ___ No ___ How many years? ______ Age when you quit ______

Approximate number of hours you work per week? ______ Vacations weeks per year ______

Home Status: Very happy ______ Pleasant ______ Difficult ______ Problem ______

Work Status: Very happy ______ Pleasant ______ Difficult ______ Problem ______

Do you feel you are stressed? Yes ___ No ___ Unsure ______

Are you worried about your health? Yes ___ No ___ Unsure ______

6. **APPROXIMATE A TYPICAL 24 HOUR DAY FOR YOU**

Number of hours:

<table>
<thead>
<tr>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relaxation/Leisure activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Driving/Riding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

Additional information from client interview to further assess health/coronary risk status:

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

Signature of Tester __________________________ Date 08/30/09
A study being conducted at Bowling Green State University is in need of volunteers to be evaluated in a research study. The study will be conducted over the next 3 months and will take 3, 1-1.5 hour sessions involving 20 minutes of exercise. Volunteers will also be asked to complete reaction time and attention tests during these sessions.

To qualify for the study:

1. You must be a female between 60-75 years of age
2. You DO NOT have to currently be physically active
3. You must not be on medications for:
   a. High Blood Pressure
   b. Mental Illness
   c. Cognitive Impairment
   d. Depression
   e. High Blood Cholesterol
4. You must not have:
   a. An orthopedic condition
   b. A metabolic condition (e.g., diabetes)
   c. Been clinically diagnosed with depression in the last 3 years.

By participating in this study, you will gain knowledge about your current fitness status (e.g., aerobic capacity, body mass index, waist to hip ratio) and memory (e.g. reaction time and attention) free of charge!

If you are interested in learning more about this opportunity please contact:

Roseann Perchinske  
Phone: 440-382-6787  
Email: rperchi@bgsu.edu

Bowling Green State University
INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous and moderate activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?
   - [ ] Yes
   - [ ] No  ➡️ Skip to PART 2: TRANSPORTATION

The next questions are about all the physical activity you did in the last 7 days as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing stairs as part of your work? Think about only those physical activities that you did for at least 10 minutes at a time.

   _______ days per week
   - [ ] No vigorous job-related physical activity  ➡️ Skip to question 4

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?

   _______ hours per day
   _______ minutes per day

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking.

   _______ days per week
   - [ ] No moderate job-related physical activity  ➡️ Skip to question 6

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.
5. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?

___ hours per day
___ minutes per day

6. During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work? Please do not count any walking you did to travel to or from work.

___ days per week
☐ No job-related walking → Skip to PART 2: TRANSPORTATION

7. How much time did you usually spend on one of those days walking as part of your work?

___ hours per day
___ minutes per day

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the last 7 days, on how many days did you travel in a motor vehicle like a train, bus, car, or tram?

___ days per week
☐ No traveling in a motor vehicle → Skip to question 10

9. How much time did you usually spend on one of those days traveling in a train, bus, car, tram, or other kind of motor vehicle?

___ hours per day
___ minutes per day

Now think only about the bicycling and walking you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place?

___ days per week
☐ No bicycling from place to place → Skip to question 12

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.
11. How much time did you usually spend on one of those days to bicycle from place to place?
   
   _____ hours per day  
   _____ minutes per day

12. During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?
   
   _____ days per week
   
   □ No walking from place to place  
   
   → Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

13. How much time did you usually spend on one of those days walking from place to place?
   
   _____ hours per day  
   _____ minutes per day

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, chopping wood, shoveling snow, or digging in the garden or yard?
   
   _____ days per week
   
   □ No vigorous activity in garden or yard  
   
   → Skip to question 16

15. How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?
   
   _____ hours per day  
   _____ minutes per day

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?
   
   _____ days per week
   
   □ No moderate activity in garden or yard  
   
   → Skip to question 18

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.
17. How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?
   ___ hours per day
   ___ minutes per day

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?
   ___ days per week
   □ No moderate activity inside home  →  Skip to PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

19. How much time did you usually spend on one of those days doing moderate physical activities inside your home?
   ___ hours per day
   ___ minutes per day

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?
   ___ days per week
   □ No walking in leisure time  →  Skip to question 22

21. How much time did you usually spend on one of those days walking in your leisure time?
   ___ hours per day
   ___ minutes per day

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like aerobics, running, fast bicycling, or fast swimming in your leisure time?
   ___ days per week
   □ No vigorous activity in leisure time  →  Skip to question 24

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.
23. How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?
   _____ hours per day
   _____ minutes per day

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time?
   _____ days per week
   ☐ No moderate activity in leisure time ➔ Skip to PART 5: TIME SPENT SITTING

25. How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?
   _____ hours per day
   _____ minutes per day

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the last 7 days, how much time did you usually spend sitting on a weekday?
   _____ hours per day
   _____ minutes per day

27. During the last 7 days, how much time did you usually spend sitting on a weekend day?
   _____ hours per day
   _____ minutes per day

This is the end of the questionnaire, thank you for participating.
APPENDIX F: HUMAN SUBJECTS REVIEW BOARD APPROVAL LETTER

DATE: February 8, 2013
TO: Roseann Perchinske
FROM: Bowling Green State University Human Subjects Review Board
PROJECT TITLE: [371791-2] Influence of Fitness Levels on Executive Function in Older Women
SUBMISSION TYPE: Revision
ACTION: APPROVED
APPROVAL DATE: February 6, 2013
EXPIRATION DATE: December 11, 2013
REVIEW TYPE: Expedited Review
REVIEW CATEGORY: Full Board review category

Thank you for your submission of Revision materials for this project. The Bowling Green State University Human Subjects Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

The final approved version of the consent document(s) is available as a published Board Document in the Review Details page. You must use the approved version of the consent document when obtaining consent from participants. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require that each participant receives a copy of the consent document.

Please note that you are responsible to conduct the study as approved by the HSRB. If you seek to make any changes in your project activities or procedures, those modifications must be approved by this committee prior to initiation. Please use the modification request form for this procedure.

You have been approved to enroll 30 participants. If you wish to enroll additional participants you must seek approval from the HSRB.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must also be reported promptly to this office.

This approval expires on December 11, 2013. You will receive a continuing review notice before your project expires. If you wish to continue your work after the expiration date, your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date.

Good luck with your work. If you have any questions, please contact the Office of Research Compliance at 419-372-7716 or hsrb@bgsu.edu. Please include your project title and reference number in all correspondence regarding this project.
This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Bowling Green State University Human Subjects Review Board's records.