Physical Activity and Executive Functioning in College Students

by

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ABSTRACT

PHYSICAL ACTIVITY AND EXECUTIVE FUNCTIONING IN COLLEGE STUDENTS

INTRODUCTION: Regular physical activity may increase neurological development, which has been shown to increase cognitive functioning in older adults and those with dementia. Studies have also shown physical activity and exercise may positively affect executive functioning in children. Little is known about the influence of physical activity on executive functioning in college students between the ages of 18-21 years, a population that is traditionally thought of as healthy. Therefore, the purpose of this study is to explore the association between physical activity and executive functioning in college-aged students. We hypothesize that regular physical activity is positively associated with executive functioning scores and that this association is independent of adiposity.

METHODS: Twenty males and 29 females (19.5 ± 0.1 yrs. old) participated in this study. Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ). Executive function was assessed by Stroop Color and Word Association Test (Stroop) and Trail Making Test A & B. A verbal ability test (analogies, synonyms, antonyms) was given in order to control for intelligence. Body composition was determined by a Tanita TBF-300 Body Composition Analyzer.

RESULTS: Partial correlations between physical activity/inactivity measures and measures of executive functioning were generally small (r-values ≤ 0.2) and not significant. However, there was a significant inverse correlation
between log moderate physical activity minutes per week and Stroop interference scores \((r=0.50, p=0.01)\). Also, a trend towards significance was noted for the correlation between sitting minutes per week and Stroop interference scores \((r=0.4, p=0.08)\).

CONCLUSION: These results suggest that in college students, moderate physical activity is inversely associated with executive functioning while sitting time may be positively associated with executive functioning. These findings are in contrast to previous studies in children and older adults, and may indicate a unique relationship between physical activity/inactivity and executive functioning in college students. Future studies to further examine this population in greater depth are warranted.
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# TABLE OF CONTENTS

| LIST OF TABLES | iv |

## CHAPTER

<table>
<thead>
<tr>
<th>#</th>
<th>INTRODUCTION</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Overview</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Physical Activity and Executive Functioning</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Obesity and Executive Functioning</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Physical Activity and Executive Functioning in Young Adults</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Purpose</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>REVIEW OF LITERATURE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Physical Activity</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Executive Functioning</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Physical Activity and Executive Functioning in Older Adults</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Physical Activity and Executive Functioning in Children, Adolescents and Young Adults</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Mechanism of Physical Activity and Increases Executive Functioning</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Type of Physical Activity</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Physiology</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Physical Fitness and Executive Functioning</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Physical inactivity and executive functioning</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Young Adults 18-21</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>METHODS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>
### RESULTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particpant Characteristics</td>
<td>28</td>
</tr>
<tr>
<td>Demographics</td>
<td>29</td>
</tr>
<tr>
<td>Physical Activity and Executive functioning Scores</td>
<td>32</td>
</tr>
<tr>
<td>Physical Activity and Executive Functioning Scores Independent of Body Composition</td>
<td>32</td>
</tr>
</tbody>
</table>
CHAPTER

5 DISCUSSION ............................................................................................................ 33
  Overview.................................................................................................................... 33
  Limitations............................................................................................................... 38
  Conclusions.............................................................................................................. 38

REFERENCES ........................................................................................................... 40

APPENDIX

A CONSENT FORM ...................................................................................................... 52
B MEDICAL SCREENER ............................................................................................ 55
C INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE ............................................. 60
D VERBAL ABILITY TESTS ........................................................................................ 63
E TRAIL MAKING TEST ............................................................................................. 71
F STROOP WORD AND COLOR TEST ........................................................................ 76
G SCRIPT .................................................................................................................... 81
<table>
<thead>
<tr>
<th>TABLE</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Participant Characteristics 28</td>
</tr>
<tr>
<td>2</td>
<td>Demographics 29</td>
</tr>
<tr>
<td>3</td>
<td>Physical Activity and Executive Functioning Scores 31</td>
</tr>
<tr>
<td>4</td>
<td>Physical Activity and Executive Functioning Scores Independent of Body Composition 31</td>
</tr>
<tr>
<td>5</td>
<td>Physical Activity and Executive Functioning Scores 32</td>
</tr>
</tbody>
</table>
Chapter 1

INTRODUCTION

Overview

The prevalence of obesity is increasing on a national scale and is reflected in the college population (Kattelmann, 2011). Increases in weight during an individual’s college years may lead to long-term health consequences such as cardiovascular disease, type 2 diabetes, hypertension, and dyslipidemia (Staples, 2008). Body mass index (BMI) in early adulthood has also been shown to be a predictor of BMI later in life, which suggests that obesity tracks throughout adulthood (Subramanian, 2007).

Research indicates that obesity-related health may be moderated by physical fitness and/or physical activity (Church, 2004; Blair, 1999). Physically active overweight and obese individuals have a lower incidence of morbidity and mortality when compared to sedentary overweight and obese individuals (Church, 2004; Blair, 1999). Active obese and overweight individuals may also have a lower incidence of morbidity and mortality when compared to lean sedentary individuals. This evidence suggests that physical activity, independent of weight status, is protective against negative long-term health consequences (Church, 2004; Blair, 1999).

In recent years, there has been increasing evidence suggesting that living a long and healthy life is associated with regular physical activity (Goldman, 2005). Studies have shown that premature morbidity is reduced when individuals participate in moderate types of physical activity (Goldman, 2005).
Studies on physical activity and disease have found an inverse relationship between a physically active lifestyle and cardiovascular disease as well as evidence that physical activity may help prevent certain types of cancers like colon and breast cancer, type 2 diabetes by improving insulin sensitivity, reduce the risk and symptoms of osteoarthritis, and improve bone mineral density and strength to prevent osteoporosis (Kokkinos, Peter 2011; Diehl, 2008; Colbert, 2008).

Physical activity has also been shown to reduce cardiovascular disease morbidity and mortality independent of age (Diehl, 2008). In addition to these health outcomes, physical activity is also associated with a reduction in symptoms of depression and may be as effective as pharmacologic treatment in some populations (Clark, 2005).

The benefits of a physically active lifestyle extend beyond physical health to include cognitive outcomes. Several studies have examined these benefits in older populations and found that physical activity is protective against age-associated declines in memory, awareness, perception, and concentration (Allmer, 2005). However, recent evidence suggests that regular exercise in children and adolescents can also lead to beneficial adaptations in brain structure and function, which are associated with improvements in verbal and mathematic test scores and perceptual skills (Sibley, 2003). These recent findings suggest that exercise may be critical for brain development throughout life.
Physical Activity and Executive Functioning

Exercise has also been shown to be potential stimulus for neurological development and has been shown to increase cognitive functioning in older adults and adults with dementia (Scherder, 2010). Studies have further shown that exercise may increase cognitive functioning in individuals with traumatic brain injuries (Hovda, 2004) as well as increase cognitive functioning in otherwise healthy older adults (Scherder, 2010).

Decreases in physical activity coincide with cognitive declines (Scherder, 2010). This suggests that regular physical activity may reduce the risk of dementia in older adults and increase executive functioning such as attention, task switching, and planning in younger populations (Swaab, 2010).

This response to exercise may be explained through increases in brain-derived neurotropic factor (BDNF) levels. Exercise increases BDNF levels that can positively influence cognitive functioning. A study by Ferris et al. (2007), found that cognitive functioning improved following exercise in conjunction with increases in BDNF levels among adults (Ferris, 2007).

Another mechanism by which the association between improved cognitive functioning and regular exercise may be explained is a decrease in accumulation of oxidative modification. A study by Radak et al., in 2001, found that exercising rats improved cognitive functioning and decreased the accumulation of oxidative modifications of proteins when compared to sedentary rats (Radak, 2001). Oxidative modification of proteins is thought to contribute to cognitive impairment and diseases such as Alzheimer’s (Alafuzzoff, 2004).
Obesity and Executive Functioning

Lower scores on executive functioning tasks have been shown in obese individuals when compared to lean and overweight individuals (Davis, 2007). These tasks include, but are not limited to, planning, organizing, working memory, and management of time and space (Etnier, 2009). Studies have also shown a decrease in frontal lobe grey matter in obese adolescents (ages 14-21) when compared to their lean counterparts (Convit, 2011).

Physical Activity and Executive Functioning in Young Adults

There is strong evidence that physical activity and obesity play a role in an individual’s morbidity and mortality (Waller, 2010) and can also impact cognitive functioning (Leos, 2005). With recent increases in the number of overweight and obese college students, obesity-related health risk factors such as high cholesterol, low HDL levels, and high LDL levels are observed in this population (Leos, 2005). Evidence shows that a substantial number of college students are physically inactive (National College Health Assessment, Reference Group Executive Summary, 2010). According to the 2010 National College Health Assessment, approximately 53% of college students do not meet the recommended physical activity guidelines set by the American College of Sports Medicine and the American Heart Association of moderate-intensity aerobic exercise for at least 30 minutes a day for five or more days a week or vigorous-intensity aerobic exercise for at least 30 minutes a day for three or more days a week (National College Health Assessment, Reference Group Executive Summary, 2010).
College students may be experiencing new changes in their lives that may impact their daily behaviors. Living away from home, moving to a new state or city, learning to manage money and time, may all be new experiences for students and may influence physical activity and eating habits. A recent study found that 65% of freshmen that lived on campus reported that their dietary habits were worse since starting college and 36% believed they gained weight since college began (Freedman, 2009). Although new college students may experience a newfound sense of freedom and independence, this may lead to unhealthy dietary decisions and a decrease in physical activity (Kattelmann, 2011). An individual’s college years have been shown to be extremely influential for lifestyle behaviors and habits that may contribute to obesity and related health risks later in life (Deusinger, 2005).

Increases in sedentary time and weight may have an impact on a student’s executive functioning. A student with impaired executive functioning may have difficulty paying attention during classes, which may impact academic performance. Students with poor academic performance may struggle to secure competitive internships and job opportunities. These lost opportunities may significantly impact overall success.

During adolescence, development of the pre-frontal cortex and hippocampus is more active than during adulthood (Zeigler, 2005). Evidence shows that physical activity impacts new capillaries and BDNF to develop in the hippocampus (Erickson, 2007). In animal studies, exercise has been shown to improve learning rates and tasks that are mediated by the hippocampus such as
spatial memory and visual recognition memory (Clark, 2004). For this reason, improving executive functioning in this population during this time period may be crucial and may have an effect on brain development and cognitive performance later in life.

To date, the majority of research examining the interactions of physical activity and obesity on cognitive functioning is focused on older populations. The literature is lacking research in younger populations, especially between the ages of 18-21 years, which has traditionally been thought of as a period of optimal health. With the growing obesity epidemic and the associated declines in physical activity, this age may be a critical period of life in terms of physical health as well as cognitive function. To this end, recent data suggest that this age group may have a higher rate of weight gain when compared to other ages (Wing, 2011). Given the potential for intervention in college students, this population represents a critical developmental period for understanding the interactions between physical activity, obesity, and cognitive functioning.

**Purpose**

The purpose of this cross-sectional observational study is to examine the association between physical activity and executive functioning in college-aged students. We hypothesize that regular physical activity will be positively associated with executive functioning scores. Our secondary aim is to explore whether the association between physical activity and executive functioning is independent of obesity.
Chapter 2

REVIEW OF LITERATURE

Impaired executive functioning may be associated with low physical activity and obesity. This review of literature focuses on the importance of physical activity to health, physical activity and executive functioning, physical inactivity and executive functioning, physical fitness and executive functioning, obesity and executive functioning, and the importance of studying college students ages 18-21 years, as a population. The primary objective of this cross-sectional observational study is to determine the association between physical activity and executive functioning in young adults during this critical life period.

Physical Activity

Physical activity is considered an important health marker and independent predictor of disease (Waller, 2010; Hurley, 2011). Research suggests that physical activity is thought to improve overall health status and quality of life by decreasing stress and anxiety and promoting higher self-esteem (Chomitz et al., 2009).

Recently, a focus on the cognitive benefits of physical activity has been studied in children and adolescents (Best, 2010). Regular physical activity is thought to facilitate development of executive functioning and/or enhance executive functioning in children and adolescents (Best, 2010). The development of executive functioning behaviors such as task switching and working memory are thought to continue to form from childhood into early adulthood (Tomporowski, 2011). In 2011, a review by Tomprorwski et al., stated that
physical activity interventions were needed for children in order to promote positive health behaviors and to encourage mental development (Tomporowski, 2011).

**Executive Functioning**

Executive functioning is a higher order cognitive ability that controls basic and purposeful cognitive functions and is associated with activity in the frontal lobe of the brain. Tasks of executive functioning include capability of response, task switching, and stopping. Executive functioning also includes behaviors related to planning, scheduling, inhibition, and working memory (Etnier, 2009). It is most often associated with the ability to focus on a given task (Tager, 2003). Executive function and frontal lobe functions are one sub-group of cognitive functioning (Salthouse, 2003).

**Physical Activity and Executive Functioning in Older Adults**

Research on physical activity and cognitive functioning has been largely studied in older adults. Evidence suggests that physical activity may help slow cognitive impairment associated with aging (Allmer, 2005). An increase in cerebral blood flow and energy metabolism as well as changes in the cerebral structure and neurotransmitter activity is thought to be responsible for improvements in cognitive capacities (Yael Netz, Dvolatzky Tzvi, Zinker Yael, Argov Esther, Agmon Ruth, 2011).

A study by Bixby et al., in 2007, aimed to determine if physical activity had a positive association with executive functioning in older adults age 65-92 years (Bixby, Spalding, Haufler, Deeny, Mahlow, Zimmerman, Hatfield, 2007).
Participants were asked to complete the Beck Depression Inventory and Mini-Mental Status Exam to exclude depression and dementia. Intelligence was also controlled for by using the Kaufman Intelligence Test. Participants were asked to report physical activity patterns during a period of three to five years prior to the study to assess if they had a stable physical activity. Participants were then asked to report their daily physical activity levels including exercise, recreation, and daily chores and activities. Executive function was assessed using the Stroop Color and Word Test. Overall, the study found that regular physical activity explained a significant proportion of variance in executive function and that a physically active lifestyle was associated with positive cognitive benefits. These benefits are increased with a higher intensity of physical activity (Bixby, Spalding, Haufler, Deeny, Mahlow, Zimmerman, Hatfield 2007). Another study examined whether increases in cognitive function were associated with physical activity in older adults at risk for Alzheimer’s disease. This study was a randomized controlled trial that included a 24-week physical activity intervention of 170 individuals. Each participant’s physical activity, cognitive function, depression, and quality of life were assessed at baseline and at 6, 12, and 18 months after. Participants in the experiment group received newsletters, telephone calls, and reminders to encourage physical activity and participated in three, 50-minute physical activity sessions, of their choice, per week. This study concluded that participants with slight memory impairment that participated in at least 142 minutes of exercise per week experienced significant cognitive improvements over controls (Sibley, 2003).
These studies provide evidence that leading an active lifestyle and participating in regular physical activity improves cognitive functioning in older adults although the duration, condition, intensity and frequency of exercise necessary for improvements in cognitive functioning remains to be determined (Rolland, Y., Abellan, G., and Vellas, B., 2010).

**Physical Activity and Executive Functioning in Children, Adolescents and Young Adults**

Recently, research has focused on the relationship between executive functioning and physical activity in younger populations. A study by Ruiz et al., in 2010, examined the relationship between participation in sports during leisure time and cognitive performance among 1,820 Spanish adolescents between the ages of 13-18 years. Participants’ cognitive abilities were assessed using the SRA Test of Educational Ability. Participants were also asked if they participated in sports outside of school times and the amount of screen time accumulated. A shuttle-run test was used to evaluate cardiorespiratory fitness. Participants were classified into two categories: meeting the fitness standards based on FITNESSGRAM standards or not meeting these standards. Muscular strength in the upper and lower body was also evaluated. The study concluded that individuals who spent time participating in sports during leisure time had significantly higher cognitive functioning compared to individuals who did not (Ruiz, 2010).

Another study by Kamijo and Takeda in 2009, examined the relationship between physical activity and executive functioning in young adults to determine
if regular physical activities improves executive control processes involved in working memory, mental flexibility, and inhibition. A total of 19 females and 21 males participated in this study. The average age of the participants was 21.4 ± 0.3 years. Participants were grouped in either an active or sedentary group using the IPAQ. Electroencephalograms (EEGs) were measured from nine electrode sites as participants were given two task-switching tests. The study found that young adults that participated in regular physical activity had improved executive control when presented with a task-switching test (Kamijo, 201).

A study by Roebroeck et al., published in 2005, explored the relationship between cognitive functioning and physical activity in patients with meningomyelocele (MMC). Individuals with MMC typically have difficulty in complex situations and may have difficulty explaining ideas clearly. Many adolescents with MMC are typically not involved in complex activities and sports because of this difficulty. Twenty-four subjects with an average age of 18 ± 4.0 years participated in the study and each individual’s verbal learning, memory, executive functioning, and reaction time were recorded. Subject physical activity was monitored by an activity monitor for two randomly selected weekdays. The results of the study showed that participants with poor performance scores of executive functioning were less active. This study concluded that certain cognitive impairments might be related to low physical activity (Roebroeck, 2006).

While research has yet to prove a direct link between habitual physical activity and increases in cognitive functioning in children, research has provided
evidence that exercise interventions have been successful in increasing cognitive functioning in children (Tomporowski, 2010) and have shown regular exercise also improves overall executive functioning in older adults (Rolland, Y., Abellán, G., and Vellas, B., 2010).

**Mechanism of Physical Activity and Increases in Executive Functioning**

Although a relationship between physical activity and executive functioning in children and older adults has been shown, the exact mechanisms that link the two together have not yet been determined. There are many thoughts surrounding this link but the literature is dominated by approximately two broad mechanisms: type of physical activity most engaged in and physiological changes in the brain (Best, 2010).

**Type of Physical Activity**

The increase in executive functioning after physical activity may be related to the type of physical activity performed. Evidence has shown that physical activity that involves working memory and task switching may facilitate increases in executive functioning overall. An example of such physical activity, would be playing basketball. A player will have to think quickly and will encounter contextual interference. Contextual interferences places demands on executive functioning and may require the player to perform a variety of movements in a rapid sequence such as passing a ball, moving in another direction, catching the ball, and shooting the ball. For these reasons, engaging in types of activity that include contextual interferences may increase executive functioning ability and could be thought of as executive functioning training.
These increases are likely related to the individual’s age and rate of cognitive development (Best, 2010).

**Physiology**

A study by Ferris et al., in 2007, studied the effect of acute exercise on serum brain-derived neurotrophic factors and cognitive function. Brain-derived neurotrophic factor (BDNF) is one of the neurotrophic factors that participates in plasticity, modulation, and transmission of neurons. Participants in the study consisted of 11 males and 4 females with an average age of approximately 25 years. The participants were given a graded exercise test and an endurance test on different days. Serum BDNF and cognitive function was assessed before and after the graded exercise test and endurance test. Blood was taken from the participants to determine serum BDNF levels. Cognitive function was assessed by the Stroop Color and Word Test before and after the exercise tests were given. The study results showed increased scores of cognitive function after all exercise and levels of BDNF were elevated after exercise, but the magnitude was dependent on the intensity of the exercise. The greater increase in levels of BDNF occurred after higher-intensity exercise was performed (Ferris, 2007).

A study by van Praag et al., found that neurogenesis of the hippocampus that resulted in cognitive improvements in memory and learning tasks after voluntary exercises in rats. Thirty-four mice were divided into two groups with one group given access to a running wheel. Both groups were trained on a Morris water maize and starting points were changed each day for six days. Mice were then anesthetized and brain hemispheres were analyzed separately. The results of
the study indicated the running group performed a faster path length than the control group when presented with a more challenging two-trial day. The results of the study indicated that physical activity can increase neurogenesis in the hippocampus resulting in synaptic plasticity (Van Praag H, Christie BR, Sejnowski TJ, Gage FH. 1999)

Finally, increased cerebral blood flow to the brain may link improved cognition and physical activity. Increases in cerebral blood volume have been discovered after chronic physical activity in both animal and human studies (Best, 2010).

**Physical Fitness and Executive Functioning**

Since research in the area of physical activity and executive functioning in young adults is continuing to grow in popularity, other studies have focused on the relationship between physical fitness and executive functioning.

Recently, research has also included physical fitness and executive functioning in children and older adults. A study by Davis et al., in 2007 looked at the effect of aerobic exercise on executive functioning in overweight children. This study had 94 participants with an age of 9 ± 0.84 years old and weight status averaged in the 85th percentile for BMI. Participants reported no engagement in regular physical activity. Participants were randomized into three groups: a control group with no exercise, a low-dose exercise group consisting of 20 minutes of aerobic exercise 5 times per week for 15 weeks, and a high-dose exercise group consisting of 40 minutes of aerobic exercise 5 times per week for 15 weeks. Body measurements, including height and weight, were taken at pre-
test and post-test. Fitness was also assessed during pre and post-testing using the Modified Balke Protocol for Poorly Fit Children. Executive function was measured at pre and post-testing using the Planning, Attention, Simultaneous, and Successive theory of cognitive function. At the conclusion of the study, results showed that the control group had a significantly lower post-test score of cognitive function than the high-dose exercise group. The control group and the low-dose group did not have a significant difference in scores suggesting that duration of physical activity may be crucial to a positive association between physical activity and executive functioning (Davis, C., Tomporowski, Phillip D. Tomporowski, P., Boyle, C., Waller, J., Miller, P., Nagileri, J., Gregoski, M, 2007).

A study by Castelli et al., in 2007, explored the relationship between physical fitness and academic achievement in third and fifth grade students. A total of 259 children participated in this study. Participants were given the FITNESSGRAM test to assess physical fitness and the Illinois Standard Achievement Test. Height and weight measurements were also taken. The results of the study showed that a higher academic performance was related to a high physical fitness score. Strength and flexibility were unrelated to academic performance (Castelli, 2006).

A similar study by Chomitz et al., in 2009, looked at the relationship between physical fitness and academic achievement in urban public school children. A total of 1,103 fourth, sixth, and eighth grade students were assessed in mathematics using the Massachusetts Comprehensive Assessment System.
English was assessed in 744 fourth and seventh grade students. Similar to the study by Castelli, physical fitness was assessed during physical education class using 5 domains of cardiovascular endurance, agility, abdominal strength, flexibility, and upper-body strength were assessed using adaptions from Amateur Athletic Union and FITNESSGRAM. Height and weight measures were also taken. The findings of this study indicated that there is a significant relationship between academic achievement and physical fitness. Physical fitness scores had a stronger association with math academic performance than English academic performance (Chomitz, 2009).

Another study by Netz et al., in 2010, looked at the relationship between physical fitness and cognitive function in older adults. In this study, there were a total of 83 participants ages 65 to 85 years. Physical activity was assessed using the Habitual Physical Activity Questionnaire and aerobic fitness levels were assessed using a graded exercise test of the Blake protocol that included electrocardiogram, heart rate, blood pressure, and rating of perceived exertion. Participants’ cognitive function was assessed by the Mindstreams computerized test that comprises of a variety of cognitive tests. Overall, the study found that participants who had an improved aerobic fitness were associated with higher cognitive functioning even in subjects with advanced age (Yael Netz, Dwolatzky Tzvi, Zinker Yael, Argov Esther, Agmon Ruth, 2011).

**Obesity and Executive Functioning**

Obesity is defined as having an excess amount of body fat and body weight. Body mass index is used to define overweight and obese individuals
(American College of Sports Medicine, 2010). An adult with a BMI of 25 or
greater is defined as overweight and an adult with a BMI of 30 or greater is
defined as obese. BMI is calculated as body weight in kilograms divided by
height in meters squared (American College of Sports Medicine, 2010).

Research has shown that obesity can predispose an individual to an
increase in glucose levels, blood pressure, and blood lipids that can lead to type 2
diabetes, hypertension, dyslipidemia, and cardiovascular disease. Although
obesity is associated with negative health outcomes, research suggests that
physical activity may be a more important variable to consider for overall health
outcomes (Blair, 1999; Church, 2004).

Recently, research has examined the relationship between obesity and
executive functioning. Although the literature suggests that overweight and
obesity may be related to decreases in cognition, there is much more evidence and
research that has resulted in findings suggesting that physical activity and
physical fitness may result in higher cognitive functioning and higher academic
achievement (Burkhalter, 2011).

**Physical Inactivity and Executive Functioning**

As evidence for the association between physical activity and executive
functioning increases, data supporting physical inactivity and executive
functioning impairment also continues to grow. Evidence shows that chronic
inactivity may decrease mental functioning in children (Booth, 2000).
One study by Harade et al., suggested cognitive gains from regular exercise would be lost when regular exercised ceased (Okagawa, 2004). Another study by Hansen et al., in 2004, found that adults participating in regular aerobic exercise had an improvement in cognitive functioning as they continued to train. The individuals who stopped participating in regular aerobic exercise did not have improvements in cognitive functions (Thayer, 2004). A review by Scherder et al., in 2010, concluded that a restriction of movement by restraints in individuals that have been institutionalized in order to reduce activity may produce stress that damages regions of the brain that may impact cognition that has already been affected by dementia. This provides evidence that these individuals need to be treated with physical activity and not be physically restrained. Scherder also concluded that animal studies that do not allow subjects to engage in physical activity show decreases in executive functioning (Swaab, 2010).

**Young Adults 18-21 Years of Age**

Individuals between the ages of 18-21 are considered to be at the upper end of the pediatric scale. Research suggests that physical activity may have a greater influence on cognitive functioning in children and may be necessary for healthy neural development. Also, evidence suggests there are crucial points throughout childhood where exercise may promote optimal neural development and be associated with health benefits (Tomporowski, 2011). These benefits may be lost with inactivity, providing evidence that physical activity is crucial throughout the entirety of childhood and upwards into young adulthood. During the ages of 18-21, young adults are at a pivotal time in their lives. Many are living
independently in different cities and states for the first time in their lives. Others may be working full-time for the first time and are beginning to find their place in society and the workplace. These young adults will be the next generation of business executives, politicians, decision-makers, and leaders. If the number of inactive young adults continues to grow in this population, the future of this generation’s health, productivity, cognitive function and overall contribution to society may be impacted significantly by lack of physical activity.
Chapter 3

METHODS

Participants

Forty-nine (20 males / 29 females) between the ages 18-21 years were recruited for this study. Participants were recruited through a variety of methods including, flyers, mass e-mail, direct contact, and class recruitment. Recruitment was facilitated by the use of incentives such as free body fat testing and a chance to earn a $50 gift card. Participants were screened for physiological disorders, medical conditions, and brain injuries that may influence executive functioning using a brief medical history questionnaire (See Appendix A). The study was reviewed and approved by the Arizona State University Institutional Review Board (IRB). Participants were administered informed consent prior to any procedures.

Inclusion Criteria

English-speaking college students between the ages of 18-21 years from Arizona State University.

Exclusion Criteria

Participants diagnosed with psychological conditions such as severe depression, anxiety, and ADHD as well as those on anti-convulsion medications, medications that may influence cognitive ability, and those who have suffered a traumatic brain injury were excluded from this study. Additionally, those with metabolic abnormalities such as type 1 diabetes, or with physical conditions that limit exercise ability were excluded.
Procedures:

Participants were invited to ASU for consent and testing. Participants were asked to achieve a minimum of six hours of sleep the night before testing since sleep depravation is associated with a decrease in cognitive function and most college students average six hours of sleep per night (Zhang, 2008). Participants were asked to refrain from illicit drug use for 48 hours prior to the study visit since substance use is associated with impulsiveness and is thought to decrease executive function (Tucha, 2009). Participants were asked to refrain from alcohol use for at least 24 hours before participating in the study since excessive alcohol consumption has been shown to increase cell death and may inhibit neurogenesis in the hippocampus (Taffe, 2010; National Institute On Alcohol Abuse and Alcoholism 2004). Participants were also be asked to refrain from physical activity the day of testing due to acute physical activity affecting cognitive performance (Collardeau, 2002). They were also asked to refrain from eating a meal at least two hours before testing since food consumption may also influence cognitive performance (Smith, 1993) but no more than 4 hours since skipping meals may influence memory (Hoyland, 2009).

Measures

Participants were given a questionnaire that contained medical history, socioeconomic, stress, education level, and demographic questions.

Physical Activity Assessment
Physical Activity was assessed using the International Physical Activity Questionnaire (IPAQ) short form (See Appendix B). The IPAQ assesses physical activity of the participant in the last seven days and asks how many days they engaged in moderate and vigorous activity, walking, and sitting. The IPAQ short form has been previously validated in college students (r=0.71-0.89; Han, 2006).

**Anthropometry**

Standing height was assessed without shoes using a wall-mounted Seca 240 stadiometer (Stadiometer, North Bend WA, USA), and BMI was calculated as body weight in kilograms divided by height in meters squared.

**Body Composition.** Body composition was assessed using a Tanita TBF-300 Body Composition Analyzer (Tanita) (Arlington Heights, IL, USA). The Tanita measures body composition using bio-electrical impedance (BIA). Subjects are asked to stand barefoot on a metal sole plate where surface electrodes are located. Weight is recorded automatically when the participant steps on the machine, and height is entered manually. The electrical signal is applied and travels through water in the body. Lean tissue has more water than fat tissue and allows the signal to pass with less resistance than fat. The Tanita uses an equation to calculate body fat and fat free mass and has been shown to have a standard error of estimate of approximately 3.5% (Heymsfield, 1996) when compared to Dual Energy X-ray Absorptiometry (DEXA).

Prediction equation for body density (BD):

Male BD = 1.1008-.1129 WR/Ht$^2$ + 0.000178R

Female BD = 1.0907-0.1120 WR/Ht$^2$ + 0.000134R
W-Weight

R- Resistance

BD is then applied to the following formula to calculate percent fat:

% Fat ={(4.57/BD)=4.142} x 100

(Tsui, 1998)

**Cognitive Measures**

Upon completion of anthropometry and body composition, cognitive functioning tests were administered in random order and included the Stroop Test, Trail Making Test (TMT), and the verbal fluency test.

**The Stroop Test.** The Stroop is an instrument commonly used to assess executive functioning and impulse control, attention, and concentration (Dempsey, 2011). The Stroop test has been shown to have acceptable reliability with reliability scores of between .84 and .86 (Siegrist, 1997). It has been previously used in a variety of populations including young adults (Baroun, 2006; McCabe, 2005). The test consists of 3 pages where the first page has the words “RED”, “GREEN”, and “BLUE” printed in black ink in a random order so that no word repeats itself immediately. Participants were asked to read the words on page 1 as fast as possible for a total of 45 seconds. Page 2 consists of the letters XXX printed in blue, green, or red ink in an order so that no color repeats itself immediately. Participants were asked to name the color of the items on the pages as fast as possible for 45 seconds. Page 3 consists of the words “RED”, “GREEN” and “BLUE” printed in red, green, and blue ink but no words are printed in the color they represent. Participants were asked to name the color of ink that each
word is written as fast as possible, for 45 seconds. The total time for test administration was four minutes. An interference score (Dempsey, 2011) is calculated using the following formula:

\[ C \times \frac{W}{C + W} \]

\( C = \) number of correct colors named on page 3
\( W = \) number of words read correctly on page 1

**The Trail Making Test.** The Trail Making Test (TMT) is a commonly used instrument in assessing cognitive functioning (See Appendix C; Ryan, 2008). The TMT measures visual scanning, visual searching, set-shifting abilities, and visuospatial sequencing (Wagner, 2011). There are two parts to the test, Trails A and Trails B. The participant was asked to connect 25 numbers in their sequential order for Trails A without lifting the pencil from the paper. The participants were timed and if an error was made, the examiner pointed out the mistake and the participant was allowed to correct it. If the participant did not finish the test in five minutes, they were asked to stop the test and a score of five minutes was recorded. A score of 29 seconds is recorded as average and anything greater than 78 seconds is recorded as deficient. A higher score indicates greater impairment. Immediately following completion of Trails A, participants were asked to connect 25 numbers or letters in sequential order for the Trails B portion of the test without lifting pencil from paper (Gaudino, 1995). The participants were timed and if an error was made, the examiner pointed out the mistake and the participant was allowed to correct it. If the participant did not finish the test in five minutes,
they were asked to stop the test and a score of five minutes was recorded. A score of 75 seconds is recorded as average and anything greater than 273 seconds is recorded as deficient (Gaudino, 1995) (Ryan, 2008). The TMT is used in a variety of populations with acceptable reliability (Part A r=.76-.89, Part B r=.86-.94) and has been successfully used to assess cognitive function in numerous studies including college students (Wagner, 2011).

*The verbal fluency test.* Intelligence was measured as a controlling variable when examining executive functioning scores. Verbal ability tests are commonly used as a measure of intelligence and have previously been used in executive functioning studies (Ardila, 2000). An antonym and synonym vocabulary test, and an analogy test were given to all participants. The antonym test contains 10 questions. For each question, a word is given in all capital letters followed by four answer choices. The instructions state that the participants must select an answer that is opposite in meaning to the word given (Hambrick, 1999). Participants were given two minutes to answer all items correctly. The participant’s score was calculated as the total number of items solved correctly. The synonym test also contains 10 questions and the given word is also written in all capital letters, followed by four answer choices (Brewer, 2010). The instructions state that the participant must select an answer that has the same meaning as the word given (Hambrick, 1999). Participants were given two minutes to answer all items correctly (Brewer, 2010). The participant’s score was the total number of items solved correctly. These tests have a reliability score of 0.88 and 0.89, respectively.
The Armed Forces Qualification Test (AFQT) analogy test will also be given (Berger, 1988). This analogy test has been shown to have a reliability score of 0.83 and validity score of 0.09. Participants were given five minutes to complete this portion. The test consists of 18 questions each with four answer choices. Participants were asked to select the answer that best fits the given analogy. The participant’s score was the number of correct answers in five minutes (Berger, 1988; See Appendix D).

Subject Sample Size

Given the limited data available on executive function and physical activity in college students, data from a study examining physical activity and overall cognitive performance in adolescents was examined (Ruiz-Martín-Matillas, 2010). Martin-Matillas observed significantly higher overall cognitive performance among adolescents who participated in physical sport participation (54.7 ± 13.0 score on cognitive performance test) compared to those that did not (50.1 ± 13.5, P<0.001). The authors calculated an effect size (Cohen, 1998) of 0.32 for the relationship between physical activity and cognitive performance. Using a one sided estimate for a bivariate normal model of correlation rho H1 = 0.31, correlation rho H0 = 0.0, alpha = 0.05 and 1-beta = 0.80, a total of 63 participants are needed to identify a lower and upper critical r = 0.25.

Even though the authors adjusted for puberty, maturation and / or development, this may have confounded the strength of association observed in the study by Ruiz et al., so we proposed to oversample and recruit 100 college students (50 males and 50 females) for this pilot study. Although this sample size
was sought, we were unable to achieve 100 participants after exhausting all means of recruitment. A total of 58 participants were enrolled in the study, with a total of 49 used for analysis. Sample size estimates were calculated using G*Power Version 3.1.373 available at [http://www.psychology.uni-duesseldorf.de/abteilungen/aap/gpower3/](http://www.psychology.uni-duesseldorf.de/abteilungen/aap/gpower3/).

**Statistical Analysis**

Data were analyzed using PASW 18. Descriptive characteristics were presented as means ± the standard deviation, percentages, and proportions. Values that are not normally distributed were log transformed to allow for parametric analyses. The relationship between executive functioning and physical activity were compared using Pearson Partial Correlations (controlling for intelligence). A p-value < 0.05 was considered statistically significant. For our exploratory aim, the relationship between physical activity and executive functioning is independent of obesity, Pearson Partial Correlations controlling for obesity (percent body fat) were used.
Chapter 4

RESULTS

A total of 58 subjects were enrolled in the study, and upon screening 49 (20 males, 29 females) participants were eligible for the study and were used in analysis. Participants that were not included in the analysis did not meet age requirements or reported a disorder such as depression, ADD/ADHD, or anxiety.

Table 1 presents descriptive characteristics of the participants separated by gender. No significant gender differences were noted for age. Males were significantly taller, heavier, and had less body fat compared to females. However, there were no differences in the prevalence in overweight or obesity between groups.

<table>
<thead>
<tr>
<th></th>
<th>Males (n=20)</th>
<th>Females (n=29)</th>
<th>Total (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>19.6 ± 0.3</td>
<td>19.4 ± 0.1</td>
<td>19.5 ± 0.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>179 ± 1.4</td>
<td>163.1 ± 1.8</td>
<td>170 ± 1.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>79 ± 3.9</td>
<td>66.7 ± 3.5*</td>
<td>72.1 ± 2.7</td>
</tr>
<tr>
<td>Body Fat %</td>
<td>17.7 ± 1.7</td>
<td>29 ± 1.7*</td>
<td>23.4 ± 1.6</td>
</tr>
<tr>
<td>BMI (kg/m2)</td>
<td>24.7 ± 1.1</td>
<td>25.1 ± 1.3</td>
<td>24.9 ± 0.9</td>
</tr>
<tr>
<td>Lean</td>
<td>75.0%</td>
<td>72.4%</td>
<td>73.5%</td>
</tr>
<tr>
<td>Overweight/Obese</td>
<td>25.0%</td>
<td>28.0%</td>
<td>26.5%</td>
</tr>
</tbody>
</table>

Means ± Standard Error, Lean; BMI 18.5-24.9, Overweight/Obese; BMI ≥ 25
*p<0.05 #p< 0.01 •p< 0.001

Table 2 shows demographic characteristics of the participants. Males and females did not differ by education, race/ethnicity, country of birth, or stress. However, females were more likely to report higher socioeconomic status compared to males.
Because of the potential for gender influencing physical activity levels, we also compared physical activity between male and female participants in this study. There were no significant gender differences between groups for moderate exercise in minutes per week (304.8 ± 93.5 male vs. 216.3 ± 85.0 female), days of moderate activities per week (3.7 ± 0.5 vs. 2.6 ± 0.4), moderate intensity MET minutes per week (6217.3 ± 2345.3 vs. 3551.7 ± 1710.0), sitting minutes per week (2126.3 ± 191.2 vs. 2247.6 ± 182.0), total physical activity minutes per week (7341.0 ± 2435.0 vs. 4021.6 ± 1787.6). However, there were significant gender differences noted for vigorous activities days per week (3.4 ±
0.4 vs. 1.7 ± 0.3), minutes of vigorous activities per week (336.8 ± 77.0 vs. 134.2 ± 41.3), vigorous physical activity MET minutes per week (11577.0 ± 3237.0 vs. 4078.8 ± 1528.4), number of days walking per week (6.5 ± 0.2 vs. 4.9 ± 0.4), walking minutes per day (786.9 ± 218.4 vs. 335.7 ± 88.0), walking MET minutes per week (17927.3 ± 5081.8 vs. 6048.7 ± 1566.1), total physical activity MET minutes per week (35721.6 ± 7678.2 vs. 13679.2 ± 3472.3).

Mean scores on the verbal ability tests were also compared between genders. There were no significant differences for analogies (8.3 ± 0.8 vs. 9.3 ± 0.7 number correct) synonyms (2.2 ± 0.5 vs. 1.8 ± 0.4 number correct) antonyms (3.5 ± 0.5 vs. 3.8 ± 0.4 number correct) and combined verbal ability score (15.1 ± 6.5 vs. 16.0 ± 1.1 number correct).

To examine associations between physical activity/inactivity and executive function, Pearson Partial Correlations after controlling for intelligence (verbal ability test) were run (Table 4). Overall, the correlation coefficients were relatively small and not significant. However, there was a significant inverse correlation between log moderate physical activity minutes per week and Stroop interference scores, indicating a moderate to large effect size, as described by Cohen (Cohen, 1998). Interestingly, a trend towards significance was noted in the correlation between sitting minutes per week and Stroop interference scores.
Because studies suggest that obesity may be associated with lower executive functioning scores, Table 4 presents Pearson Partial Correlations between physical activity minutes per week and executive functioning scores after controlling for intelligence and body composition (percent body fat). Overall, controlling for body composition did not affect the relationship between physical activity/inactivity and executive functioning scores.

Table 4: Physical Activity and Executive Functioning Scores

<table>
<thead>
<tr>
<th></th>
<th>Stroop I Score</th>
<th>LogTrails A</th>
<th>LogTrails B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PA</td>
<td>r=-0.29 p=.14</td>
<td>r=0.01 p=.98</td>
<td>r=-0.03 p=.87</td>
</tr>
<tr>
<td>LogTotal PA Met Min/Week</td>
<td>r=-0.14 p=.47</td>
<td>r=0.04 p=.84</td>
<td>r=0.17 p=.39</td>
</tr>
<tr>
<td>LogVigorous Met Min/Week</td>
<td>r=-0.03 p=.15</td>
<td>r=0.03 p=.89</td>
<td>r=0.04 p=.83</td>
</tr>
<tr>
<td>LogModerate Met Min/Week</td>
<td>r=-0.48 p=.01*</td>
<td>r=0.02 p=.93</td>
<td>r=0.04 p=.83</td>
</tr>
<tr>
<td>LogWalking Met Min/Week</td>
<td>r=0.05 p=.78</td>
<td>r=0.05 p=.80</td>
<td>r=0.20 p=.31</td>
</tr>
<tr>
<td>Sitting Min/Week</td>
<td>r=0.32 p=.09</td>
<td>r=-0.12 p=.56</td>
<td>r=-0.09 p=.67</td>
</tr>
</tbody>
</table>

*p<.05 #p<.01 ●p<.001
All PA variables reported as minutes/week
PA=physical activity

We also analyzed our data by using the subset scores from pages 1-3 of the Stroop test (Color, Word, and Color and Word) (Table 7). The relationship between log moderate MET min/week and Stroop interference score is lessened and significance is lost when Color and Word (C/W) replaces interference score.
(r=0.29 p=0.07). No other significant relationships were found between log moderate MET min/week and Word or Color scores. However, the relationship between log vigorous MET min/week shows a trend towards significance at (r=-0.39 p=0.02), suggesting that individuals who had higher reported amounts of vigorous activity answered less items correctly on the C/W subtest. Sitting time no longer trended towards significance for any of the individual scores (r = -0.12 p=0.45, r= 0.12 p=0.42, r=0.18 p=0.24, respectively).

Table 6: Physical Activity and Executive Functioning Scores

<table>
<thead>
<tr>
<th></th>
<th>Word</th>
<th>Color</th>
<th>C/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PA</td>
<td>r=-.04 p=.80</td>
<td>r=-.02 p=.90</td>
<td>r=-.15 p=.32</td>
</tr>
<tr>
<td>LogTotal PA Met Min/Week</td>
<td>r=-.11 p=.44</td>
<td>r=-.22 p=.14</td>
<td>r=-.16 p=.27</td>
</tr>
<tr>
<td>LogVigorous Met Min/Week</td>
<td>r=-.25 p=.14</td>
<td>r=-.18 p=.29</td>
<td>r=-.39 p=.02</td>
</tr>
<tr>
<td>LogModerate Met Min/Week</td>
<td>r=.06 p=.70</td>
<td>r=.06 p=.70</td>
<td>r=-.29 p=.07</td>
</tr>
<tr>
<td>LogWalking Met Min/Week</td>
<td>r=.11 p=.50</td>
<td>r=.09 p=.55</td>
<td>r=-.06 p=.07</td>
</tr>
<tr>
<td>Sitting Min/Week</td>
<td>r=-.12 p=.45</td>
<td>r=.12 p=.43</td>
<td>r=.18 p=.24</td>
</tr>
</tbody>
</table>

*p<.05  #p<.01  *p<.001

All PA variables reported as minutes/week
PA=physical activity
Chapter 5

DISCUSSION

Overview

The present study aimed to investigate the relationship between regular physical activity and executive functioning scores in college students ages 18-21. To our knowledge, this is the first study to examine the association between physical activity and executive functioning in this population.

In the current study executive functioning was not significantly correlated with most aspects of physical activity. The exceptions to this were significant associations between moderate physical activity minutes per week and executive functioning as measured by the Stroop interference score ($r=0.48$, $p=0.01$) and sitting time and the Stroop interference score ($r=0.32$, $p=0.09$). These findings are in contrast to what has been reported in the literature and suggest that in this population, physical activity and inactivity may not be cognitively protective. Our results may be unique to college students during a critical and dynamic period of development in terms of behaviors and higher-order cognitive functioning.

College students are in a unique period in their lives where although they have time constraints in their schedule due to class scheduling, their schedule is otherwise up to their discretion. This new freedom and the task of creating their own schedule may be a new endeavor for these students, which may result in differences in priorities. Research has shown that students who are seniors spent more time on the computer than freshmen, suggesting that seniors prioritize class projects and assignments over leisure-time activities (Buckworth & Nigg, 2004).
Since our sample included very few seniors, this could partially explain the high amount of physical activity reported.

Research has suggested that academic performance is a product of both motivation and ability (Nonis & Hudson, 2006).

\[ \text{Performance} = \text{Ability} \times \text{Motivation} \]

For the first time in many students’ lives, they may be able to set their own schedule and have freedoms they had not previously experienced. Without the structure they are used to, students may not prioritize studying and going to class, and may instead spend time on leisure-time activities such as engaging in moderate physical activities such as playing basketball with friends, going to group fitness classes, hiking, etc. Executive functioning is related to tasks such as memory, time management, and organization. If a student is having trouble with these tasks, academic performance may suffer. Lack of time to plan and prepare for school, coupled with decreased in time spent performing executive functioning tasks, may result in both ability and motivation to lessen (Brown, 2007).

Participants in this study were 18-21 years of age are considered to be in the later / final stages of development (Casey, Giedd, & Thomas, 2000). Studies suggest that physical activity may have a large influence on executive functioning in children and may be necessary for healthy neural development throughout growth (Kolb & Gibb, 2011; Halperin, 2011). In young adults, neural development may begin to plateau at around 18 to 20 years of age (Casey et al., 2000). Formation and development of the prefrontal cortex region occurs last and
research suggests it may be more susceptible to the aging process than other regions, which may explain the link between dementia and older adults. Tasks of executive functioning are usually associated with the prefrontal cortex region. This area is also thought to be more sensitive to environmental factors such as stimuli, and “brain training” (Casey, et al., 2000; Owen, 2010; Kolb & Gibb, 2011). These reasons may explain why the relationship between physical activity and executive functioning may differ in this population to what had been reported in younger and older groups. Students may be displacing time-spent training the prefrontal cortex (e.g. studying or in class) with participating in physical activity, resulting an inverse relationship between the two. Another explanation may be that brain development in college students is plateauing, resulting in very little influence of physical activity on executive functioning. Research has found positive associations between physical activity and executive functioning in both children (Tomporowski, 2011) and older adults (Scherder, 2010) periods where brain development/decline are more plastic. During these periods of life, physical activity may have a greater influence on executive functioning (Erickson, 2007; Kramer, 2007).

We also compared Trails A & Trails B scores with normative data from a matched sample group (Table 3). Although our sample included a wider range of scores, the averages in this sample for mean scores varied less than a second in scores between groups for medians for both Trails A and Trails B.

According to a 2005 meta-analysis, approximately 50% of college students are inactive (Keating, 2005). Our sample population exhibited high
levels of physical activity, with more than 60% exceeding the ACSM recommendations of 150 minutes of moderate-vigorous intensity exercise per week (American College of Sports Medicine, 2010). The mean time spent engaged in either moderate or vigorous physical activity per week was approximately 469 minutes. This high level of physical activity suggests that participants may have also been active throughout their childhood, which may have positively affected their executive functioning at an early age. As they become older and their physically active lifestyle continues, it is plausible that any influence of this lifestyle on executive functioning may be attenuated. Also, 75% of our sample was considered a lean by BMI. At Arizona State University approximately 65% of students are considered lean (National College Health Assessment, Reference Group Executive Summary 2010) which may suggest the sample in the present study may not be reflective of the greater student body.

In addition to physical activity, college students are likely to engage in other behaviors that may influence executive functioning. We attempted to control for behaviors that can acutely impact executive function including alcohol / illicit drug use and sleep deprivation. Although we asked participants to refrain from these behaviors in the 24-48 hour leading up to testing and get at least 6-hours of sleep the night prior to testing, we did not account for the chronic use of alcohol or drugs or regular sleep patterns. A study in 2007 found that 36% of female and 49% male college students consume more than five drinks in one sitting in a two-week span. Also, 35% reported using illicit drugs (Amaro, 2010). College students are also likely to drink more than their peers that
are not in college (Slutske, 2005). Both of these behaviors are known to influence executive functioning (Giancola, 2000; National Institute On Alcohol Abuse and Alcoholism, 2004; Zeigler, 2005) and may contribute to the present findings. College students are also likely to have poor sleep habits when compared to older adults (Marhefka, 2011). Given the fact that lack of sleep can result in executive functioning impairment (Zhang, 2008) future studies should examine how chronic sleep patterns may moderate the associations between physical activity and executive function in college students.

Research suggests that adiposity may be related to decreases in executive functioning in children (Li, 2008), adults, and older adults (E. Smith, Hay, Campbell, & Trollor, 2011). For this reason, we controlled for obesity (body fat percentage) in our analysis but this did not impact our results. This may be due to the majority of our sample being classified as lean (74%) compared to the national average of 65% (National College Health Assessment, Reference Group Executive Summary 2010).

Instead of positively affecting executive functioning, higher amounts of physical activity and lower physical inactivity may actually be indicative of those students with lower cognitive capacity. In other words, it is plausible that students who have difficulty adapting to college coursework may chose to displace time spent in class or studying with other endeavors that support physical activity and limit sedentary time.

Limitations
There were 58 participants recruited for the study and only 49 were used in the analysis of date. Participants that were not included in the study did not meet age requirements (n=1) or reported they had been diagnosed with anxiety, depression, or ADD/ADHD (n=8). Research suggests that the number of college-age students diagnosed with ADHD is rapidly rising and has become the second largest subgroup in universities’ disability services (Parker, Hoffman, Sawilowsky, & Rolands, 2011). While we screened for psychological disorders such as depression, anxiety, and ADHD, our sample may have included students with ADHD who have not been diagnosed or did not report their disability in the screening process.

The study was cross-sectional, therefore no direct causation can be explained from these findings. Physical activity was assessed using self-reported measures from the IPAQ and which is subject to overestimations of time actually spent performing physical activity (Lee, Macfarlane, Lam, & Stewart, 2011).

Conclusions

This study aimed to examine the associations between physical activity and executive functioning in college students aged 18-21 years, and explore if the relationship between physical activity and executive functioning is independent of adiposity. Our results suggest that increased moderate physical activity result in lower executive functioning in college students ages 18-21 years. In addition, increased amounts of sitting time may be positively associated with higher executive functioning. Future studies should prospectively examine how changes
in physical activity and inactivity throughout the college years may influence executive function over time.
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APPENDIX A

CONSENT FORM
PHYSICAL ACTIVITY AND EXECUTIVE FUNCTIONING IN COLLEGE STUDENTS

INTRODUCTION
The purpose of this form is 1). Provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research and 2). Record your consent if you agree to be involved in the study.

RESEARCHERS
The Exercise and Wellness program in the School of Nutrition and Health Promotion at Arizona State University (ASU) as well as Dr. Gabriel Shaibi, Hillary Burks, Justin Ryder, and Rocio Ortega have invited you to participate in a research study.

STUDY PURPOSE
The purpose of this study is to examine the association between physical activity and executive functioning in college students between the ages of 18-21. Participants will be recruited from ASU and surrounding colleges. Approximately 100 participants will be in this study.

DESCRIPTION OF RESEARCH STUDY
If you decide to participate, you will be asked to visit the Healthy Lifestyles Research Center (HLRC) or the Nursing and Health Innovation building at ASU.

You will be asked to get a minimum of 6 hours of sleep the night before and refrain from consuming alcohol 24 hours before your visit and avoid taking drugs 48 hours before the visit. You will also be asked not to eat 2 hours before the appointment but no more than 4 hours.

During the visit we will:
- Document your agreement to participate in this form.
- Ask you to complete a health screening form and a physical activity questionnaire.
- Measure your height and weight.
- Measure your body composition (total body fat and lean tissue) via an electronic scale.
- You will be given two different tests to assess executive function.

The visit will last approximately 1 hour.

RISKS
The risks of this study may include psychological discomfort and breach of confidentiality. As with any research study, there is some possibility that you may be subjected to risks that have not yet been identified.

BENEFITS
Although there may be no direct benefits to you for your participation, you will be assisting researchers in examining the relationship between physical activity and executive function in college-aged students. If you want, we will give you the results of the body composition test.

NEW INFORMATION
If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

CONFIDENTIALITY
All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications but you will not be identified. In order to maintain confidentiality of your records, you will be assigned a unique study ID number to be used on

Participant's Initials  Version 2 Revised 2-15-12

Signature: (Signature)
Date: 2/27/12
all study documents. The consent will serve as a link between identifiers and study ID numbers. The consents will be kept separate from data charts and stored under lock and key.

WITHDRAWAL PRIVILEGE
It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time. Your decision will not affect your grade.

COSTS AND PAYMENTS
The researchers want your decision about participating in the study to be absolutely voluntary, yet they recognize that your participation may pose some inconvenience. You will be entered into a drawing for a 1 in 25 chance to win a $50 Amazon gift card. 

COMPENSATION FOR ILLNESS AND INJURY
If you agree to participate in the study, your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

VOLUNTARY CONSENT
Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by Dr. Gabriel Q. Shaibi at gshaibi@asu.edu or Hillary Burks at hburks@asu.edu.

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480 965 6798. 

This form explains the nature, demands, benefits and any risk of the project. By signing this form you agree knowingly to assume any risks involved. Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefits. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be given (offered) to you. 

Your signature below indicates that you consent to participate in the above study.

Participant's Signature __________________________ Printed Name __________________________ Date __________

INVESTIGATOR'S STATEMENT
"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

Signature of Investigator __________________________ Date __________

Printed Name __________________________

Version 2 Revised 2-15-12

ASU IRB
Approved 2

Sign, Approved

Date
APPENDIX B

MEDICAL SCREENER
MEDICAL HISTORY
Check the conditions below which you have now, or have had in the past. Indicate the year you first experienced symptoms.

☐ Abnormal pap smear  ☐ Diabetes  ☐ Pregnancy
☐ Acne (severe)  ☐ Eating disorders  ☐ Psychological problems
☐ Alcohol/substance abuse  ☐ Eczema or psoriasis  ☐ Seizures
☐ Allergies needing medication  ☐ Headaches (migraine)  ☐ Sexually transmitted infection
☐ Add/adhd  ☐ Heart disease  ☐ Smoker presently
☐ Anxiety or depression  ☐ Hepatitis  ☐ Thyroid disorder
☐ Asthma  ☐ Herpes simplex  ☐ Tuberculosis or (+) test
☐ Bleeding disorder  ☐ High blood pressure  ☐ Ulcers
☐ Blood clot in vein  ☐ Intestinal disorder  ☐ Urinary tract disease
☐ Cancer or tumor  ☐ Mononucleosis  ☐ None of the above
☐ Chicken pox  ☐ Pneumonia/lung problems  ☐ Other_________________

Briefly give details of any of the conditions you have checked.

Please tell us if you have any conditions/physical restrictions or other health problems (including emotional and/or mental health), or any other restrictions which may require special arrangements.

SURGICAL, HOSPITALIZATION, TRAUMA HISTORY
Please list the type and date of any surgeries, hospitalizations, or serious injuries you have had.

FAMILY HISTORY
Alcohol/Drug Abuse ___________________________  Intestinal Disorder ___________________________
Asthma ___________________________  Kidney Disease ___________________________
Bleeding Disorder ___________________________  Mental Illness ___________________________
Blood clot in leg or lung ___________________________  Migraine headaches ___________________________
Cancer ___________________________  Neurologic Disorder ___________________________
Depression ___________________________  Premature death ___________________________
Diabetes ___________________________  Stroke ___________________________
Eating Disorder ___________________________  Suicide attempt ___________________________

2. Race/ Ethnicity:
### 3. Age: 18 19 20 21

### 4. Socioeconomic Status:
- Lower
- Lower middle
- Middle
- Upper middle
- Upper

### 5. Current level of college education
- Freshmen student
- Sophomore
- Junior
- Senior
- Graduate

### 6. Country of Birth
- USA
- Mexico
- Canada
- Other (please indicate) ______________

### 7. If you were not born in the USA, how old were you when you moved here? ______________

### 8. Is English your primary language? Yes No

### 9. If no, what language is your primary language? __________________________
For each of the following 20 items, rate how much of the time each applies to you.

Almost Always= 1 Usually=2 Sometimes=3 Almost Never=4 Never=5

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
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</thead>
<tbody>
<tr>
<td>1. I eat at least one hot, balanced meal a day.</td>
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<tr>
<td>2. I get 7-8 hours of sleep, at least 4 nights a week.</td>
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<tr>
<td>3. I give and receive affection regularly.</td>
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<td>4. I have at least 1 relative within 50 miles on whom I can rely.</td>
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<td>5. I exercise to the point of perspiration at least twice a week.</td>
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<td>6. I smoke less than half a pack of cigarettes a day (non-smokers = almost always).</td>
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<tr>
<td>7. I drink fewer than 5 alcoholic drinks a week. (non-drinkers = almost always).</td>
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<td>8. I am the appropriate weight for my height.</td>
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<td>9. I have an income adequate to meet my basic needs.</td>
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<tr>
<td>10. I get strength from my religious/spiritual beliefs.</td>
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<tr>
<td>11. I regularly attend club or social activities.</td>
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<td>12. I have a network of friends and acquaintances.</td>
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<td>13. I have at least 1 friend in whom I confide about personal matters.</td>
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<td>14. I am in good health (including eyesight, hearing, teeth, etc.).</td>
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<tr>
<td>15. I am able to speak openly about my feelings when angry or worried.</td>
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<tr>
<td>16. I have regular conversations with my housemates about domestic problems.</td>
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<tr>
<td>17. I do something fun at least once a week.</td>
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<tr>
<td>18. I am able to organize my time effectively.</td>
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<tr>
<td>19. I drink fewer than 3 caffeine drinks a day.</td>
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<tr>
<td>20. I take quiet time for myself during the day.</td>
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</tbody>
</table>

Total

0 - 10 indicates you have excellent resistance to the vulnerability of stress
11 - 29 little vulnerability to stress
30 - 49 some vulnerability to stress
50 - 74 serious vulnerability
75 - 80 extreme vulnerability

Adapted from: University of California, Berkeley Wellness Letter.
Read the following list and put a check mark by each sign that sounds like you:

<table>
<thead>
<tr>
<th>Sign</th>
<th></th>
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<tbody>
<tr>
<td>I am really sad most of the time.</td>
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<td>I don't enjoy doing the things I've always enjoyed doing.</td>
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<tr>
<td>I don't sleep well at night and am very restless.</td>
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<tr>
<td>I am always tired. I find it hard to get out of bed.</td>
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<tr>
<td>I don't feel like eating much.</td>
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<tr>
<td>I feel like eating all the time.</td>
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<td>I have lots of aches and pains that don't go away.</td>
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<td>I have little to no sexual energy.</td>
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<tr>
<td>I find it hard to focus and am very forgetful.</td>
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<tr>
<td>I am mad at everybody and everything.</td>
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<tr>
<td>I feel upset and fearful, but can't figure out why.</td>
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<tr>
<td>I don't feel like talking to people.</td>
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<tr>
<td>I feel like there isn't much point to living, nothing good is going to happen to me.</td>
<td></td>
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<tr>
<td>I don't like myself very much. I feel bad most of the time.</td>
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APPENDIX C

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE
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 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. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   ____ days per week

   [ ] No vigorous physical activities \(\rightarrow\) Skip to question 3

2. How much time did you usually spend doing vigorous physical activities on one of those days?

   ____ hours per day
   ____ minutes per day

   [ ] Don’t know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   ____ days per week

   [ ] No moderate physical activities \(\rightarrow\) Skip to question 5

4. How much time did you usually spend doing moderate physical activities on one of those days?
Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

___ days per week

☐ No walking  ➤ Skip to question 7

6. How much time did you usually spend walking on one of those days?

___ hours per day

___ minutes per day

☐ Don’t know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent 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.

7. During the last 7 days, how much time did you spend sitting on a weekday?

___ hours per day

___ minutes per day

☐ Don’t know/Not sure

This is the end of the questionnaire, thank you for participating.
APPENDIX D

VERBAL ABILITY TEST
Antonym Vocabulary

Each item in this test consists of a word in capital letters followed by five words. Circle the word that is most nearly the **OPPOSITE** in meaning to the word in capital letters. Since some of the items require you to distinguish fine shades of meaning, consider all the choices before deciding which is best. Please guess if you are not sure because there is no penalty for wrong responses.

1. **SATED**  
   (a) famished  
   (b) finished  
   (c) finicky  
   (d) fulfilled  
   (e) fortunate

2. **COMPLAISANT**  
   (a) distasteful  
   (b) egotistical  
   (c) alone  
   (d) ugly  
   (e) recalcitrant

3. **ALOOF**  
   (a) happy  
   (b) deadly  
   (c) gregarious  
   (d) manly  
   (e) varied

4. **ABOMINATE**  
   (a) adore  
   (b) despair  
   (c) abate  
   (d) deplore  
   (e) attach

5. **VERBOSE**  
   (a) garulous  
   (b) magnificent  
   (c) grandiloquent  
   (d) taciturn  
   (e) calculating

6. **DEARTH**  
   (a) birth  
   (b) brevity  
   (c) abundance  
   (d) splendor  
   (e) renaissance

7. **CORPULENT**  
   (a) sallow  
   (b) affilicated  
   (c) emaciated  
   (d) entrepreneur  
   (e) anemic

8. **GERMANE**  
   (a) teutonic  
   (b) healthful  
   (c) irrelevant  
   (d) massive  
   (e) puny

9. **VACUOUS**  
   (a) bankrupt  
   (b) loose  
   (c) livid  
   (d) superficial  
   (e) profound

10. **SPORADIC**  
    (a) germinal  
    (b) antiseptic  
    (c) incessant  
    (d) summery  
    (e) wintry
Synonym Vocabulary

Each item in this test consists of a word in capital letters followed by five words. Circle the word that is most nearly the SAME in meaning to the word in capital letters. Since some of the items require you to distinguish fine shades of meaning, consider all the choices before deciding which is best. Please guess if you are not sure because there is no penalty for wrong responses.

1. CONCUR
   (a) acquiesce
   (b) extricate
   (c) divulge
   (d) concoct
   (e) ransack

2. CONFISCATE
   (a) harass
   (b) repulse
   (c) console
   (d) appropriate
   (e) congregate

3. SOLICIT
   (a) purge
   (b) spurn
   (c) entrance
   (d) exert
   (e) beseech

4. FURTIVE
   (a) ecstatic
   (b) heinous
   (c) stealthy
   (d) flimsy
   (e) facile

5. ASTUTE
   (a) bizarre
   (b) ascetic
   (c) sagacious
   (d) lineal
   (e) irritable

6. COVET
   (a) crave
   (b) claim
   (c) avenge
   (d) clutch
   (e) comply

7. OSCILLATE
   (a) premeditate
   (b) irradiate
   (c) vacillate
   (d) recapitulate
   (e) furbish

8. INDOLENT
   (a) contrite
   (b) inexhaustible
   (c) impervious
   (d) arduous
   (e) slothful

9. DISPARITY
   (a) despondency
   (b) mediocrity
   (c) serenity
   (d) incongruity
   (e) assiduity

10. INDIGENT
    (a) refractory
    (b) fiscal
    (c) destitute
    (d) tolerable
    (e) diligent
Synonym Vocabulary Answer Key

1. (a) acquiesce
2. (d) appropriate
3. (e) beseech
4. (c) stealthy
5. (c) sagacious
6. (a) crave
7. (c) vacillate
8. (e) slothful
9. (d) incongruity
10. (a) refractory

Antonym Vocabulary Answer Key

1. (a) famished
2. (e) recalcitrant
3. (c) gregarious
4. (a) adore
5. (d) taciturn
6. (c) abundance
7. (c) emaciated
8. (c) irrelevant
9. (e) profound
10. (c) incessant
Participant #__________

AFQT ANALOGIES TEST

This test requires you to reason and see relationships between words. Each item will present you with an incomplete analogy. You are to choose the answer that best completes the analogy developed at the beginning of each item.

Mark your answer by circling the number in front of the answer that you select.

Please try the following example as practice, without looking at the answer below. Circle what you think is the best answer.

A. LIGHT is to DARK as DAY is to:
   a) sun
   b) moon
   c) night
   d) bright
   e) sky

You should have selected answer "e" because light is to dark as day is to night. That is, light describes day in the same way that dark describes night. Do you have any questions about that item?

When I say "go," please turn the page and work through the 18 items that appear on the following pages. There is only one correct answer to each problem. You may not finish all the problems before I call time in 5 minutes, so just do as many as you can. It is the accuracy of your work that matters most.
Circle the letter next to the answer you choose to complete each analogy

1. SAUCER is to COFFEE as TABLE is to:
   a) cup
   b) leaf
   c) food
   d) chair
   e) kitchen

2. BASKETBALL is to HORSESHOES as BASKET is to:
   a) horse
   b) toss
   c) shoe
   d) metal
   e) stake

3. FINALE is to SYMPHONY as HOME STRETCH is to:
   a) race
   b) muscle
   c) sleep
   d) girdle
   e) concert

4. EXCITEMENT is to BOREDOM as PASSION is to:
   a) nostalgia
   b) ignorance
   c) fatigue
   d) interest
   e) indifference

5. EDIBLE is to DELECTABLE as INTEREST is to:
   a) principal
   b) concern
   c) notice
   d) apathetic
   e) fascination

6. OFFENSE is to DEMERIT as ACHIEVEMENT is to:
   a) discipline
   b) commendation
   c) success
   d) penalty
   e) effort
7. WHO is to WHAT as:
   a) TIME is to LOCATION
   b) CAUSATION is to OCCURRENCE
   c) MEANS is to PURPOSE
   d) PLACE is to EXPLANATION
   e) IDENTITY is to NATURE

8. EARLY is to WHEN as EASILY is to:
   a) which
   b) hard
   c) how
   d) what
   e) where

9. QUART is to LITER as INCH is to:
   a) kiloliter
   b) kilogram
   c) hectare
   d) decimeter
   e) decagram

10. SPOUT is to CUP as CHUTE is to:
    a) pour
    b) shunt
    c) bin
    d) store
    e) artie

11. HONEST is to CHARACTER as CHEERFULNESS is to:
    a) individuaal
    b) personality
    c) happiness
    d) smile
    e) peaceful

12. BREAK is to BRITTLE as STRETCH is to:
    a) rubber
    b) pull
    c) soft
    d) muscle
    e) elastic
13. SPARSE is to DENSE as SCATTER is to:
   a) increase
   b) tighten
   c) concentrate
   d) expand
   e) flatten

14. JAIL is to ARREST as SCHOOL is to:
   a) graduate
   b) student
   c) learn
   d) enrollee
   e) attend

15. BOUGHT is to HAVE as SOLD is to:
   a) own
   b) loan
   c) give
   d) get
   e) lack

16. BODY is to MIND as:
   a) HEART is to SOUL
   b) FORM is to CHARACTER
   c) ANIMAL is to HUMAN
   d) PHYSICAL is to MENTAL
   e) WORK is to LEISURE

17. LUXURY is to NECESSITY as:
   a) WASTE is to USE
   b) ENJOYMENT is to REQUIREMENT
   c) WANT is to POSSESSION
   d) EXPENSE is to COST
   e) VICE is to VIRTUE

18. GRASS is to LAWN as:
   a) STONE is to CEMENT
   b) TREE is to ORCHARD
   c) ROSE is to FLOWER
   d) BUSH is to BERRY
   e) GARDEN is to VEGETABLES
APPENDIX E

TRAIL MAKING TEST
Trail Making Test Part A – SAMPLE

End

2

8

Begin

1

4

3

6

5
Trail Making Test Part A
Trail Making Test Part B – SAMPLE

Begin

A

B

C

D

1

2

3

4

End
APPENDIX F

STROOP COLOR AND WORD TEST
STROOP
COLOR AND WORD TEST
ADULT VERSION

Name: ______
Age: _ Sex: _ Date: ______

FOR PROFESSIONAL USE ONLY

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<th></th>
<th>Raw Score</th>
<th>Age/Ed. Predicted*</th>
<th>Residual</th>
<th>T-Scores**</th>
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<td>Interference (Table V)</td>
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* This comes from Tables I - III.
**This should come from Table IV or VI.
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APPENDIX G
SCRIPT
Hello my name is , and we would like to invite you to participate in a research study. The purpose of this study is to examine the relationship between physical activity and executive functioning (memory, cognitive flexibility, attention, and task-switching). If you decide to participate we will ask you to complete a physical activity questionnaire, measure your height, weight, and body fat, and assess executive functioning. All tests will be performed at either the Nursing and Health Innovation building at the ASU-Downtown Phoenix campus or the Healthy Lifestyles Center at the ASU-Polytechnic Campus (location will depend on what is best for you). You will participate in 1 session for approximately 1 hour.

You will be asked to get a minimum of six hours of sleep before you come in for testing. You will also be asked to refrain from alcohol consumption for 24 hours and drug use for 48 hours before the appointment. Also, you will need to refrain from eating two hours but no more than four hours before appointment. Upon arrival at your appointment and after the study has been fully explained, you will fill out a brief questionnaire, measurements of your height, weight and body composition will be taken, and two executive functioning tests will be given.

Time Commitment for session: Approximately 45-60 minutes.

Compensation: You will be entered into a drawing for a 1 in 25 chance to win a $50 Amazon gift cards. Would you like to participate in this study?

If “yes” proceed to next question.

If “no” thank individual for their time.

Would you classify yourself free of any health problems? How old are you?
Which location would you prefer
(Downtown OR HLRC)? Any
questions or concerns I can
answer or address?

Instructions to arrive for
your complete screening:

Date for session:

Location: Downtown_____HLRC_______

This was some general information about our study if you have specific
questions, you can call Gabriel Shaibi who is the principle investigator at (602)
496-0909 or Hillary Burks who is the graduate student in charge of the study
(432) 661-5661.

Revised 10-20-2011