PHYSICAL ACTIVITY PREDICTING COLLEGE STUDENTS' EXECUTIVE FUNCTIONING DIMENSIONS

By

Ashley Mayhew

A Thesis Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Arts in Psychology

Middle Tennessee State University

December 2015

Thesis Committee:

Dr. Seth Marshall, Chair

Dr. Aimee Holt

ACKNOWLEDGEMENTS

I would like to thank God first and foremost for giving me the strength and perseverance to accomplish this goal. Second, I would like to thank my family and friends for their loving support through this process. Without the support of my dad, Myron Mayhew, and my mom, Sherry Mayhew, I would not have been able to see the finish line and fulfill this dream of mine. I would like to especially thank Dr. Seth Marshall for being willing to work with me on this project for countless hours as my chair member and for encouraging/challenging me to do my best. Additionally, I would like to thank Dr. Aimee Holt for her commitment as my committee member and encouragement/ dedication to helping with this project. Finally, I would like to thank Dr. Rust for his support by being my critical reader and pushing me to finish this great accomplishment.

ABSTRACT

There is a shortage of research that investigates how, and to what extent, chronic physical activity predicts executive functioning (EF) dimensions in non-clinical, young adult populations (Guiney & Machado, 2013; Verburgh, Scherder, Oosterlaan 2014). To address this, the current study analyzes how young adults' physical activity predicts two core EF dimensions, namely inhibition (i.e. behavioral regulation) and working memory (i.e. metacognition) skills. Participants ($N = 99$) were administered the Personal Wellness Profile (PWP; Wellsource Inc., 1998), a self-report behavioral rating form that assesses the amount of chronic physical activity an individual partakes in on a regular basis. Additionally, EF was assessed using the Behavior Rating Inventory of Executive Function-Adult Version (BRIEF-A; Roth, Isquith, & Gioia, 2005), which assesses EF behavior regulation and metacognitive skills. Results indicated that college students' self-reported levels of chronic physical activity successfully predicted global EF skills. Moreover, physical activity significantly predicted EF metacognitive skills though did not predict to EF behavior regulation. This suggests that physical activity impacts the ability to systematically organize and initiate planned actions more so than inhibitory or behavioral regulation skills.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

CHAPTER I

Introduction

Overview

Physical activity is recognized as a key aspect of health and well-being. Multiple health organizations, such as the World Health Organization, US Department of Health and Human Services, The National Institutes of Health, the American Council on Exercise, the American College of Sports Medicine, Center for Disease Control and Prevention, and the National Foundation on Fitness, Sports, & Nutrition, have noted that increased bodily movement is associated with a number of positive outcomes. For example, multiple studies have documented that increased physical activity is related to cardiovascular health (Gilen, Schular, & Adams, 2010; Haskell et al., 2007; Warburton, Nicol, & Bredin, 2006), decreased risk of diabetes (Thomas, Elliott, & Naughton, 2006; Umpierre, et al., 2011), and a lower risk of chronic health conditions (Booth, Gordon, Carlson, & Hamilton, 2000; Casaburi, et al., 1997).

Moreover, studies indicate that physical activity is positively associated with a variety of mental health outcomes such as improved mood (Arent, Landers, & Etnier, 2000; Penedo & Dahn, 2005), lower levels of anxiety (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Salmon, 2001; Strohle, 2009), improved perception of quality of life (Reid et al., 2010), and emotional and neurological benefits (Cesar et al., 2006; Cotman & Berchtold, 2002; Cotman, Berchtold, & Christie, 2007; Kramer, 2007; Praag et al., 2009; Salmon, 2001; Smith et al., 2010). In general, these studies and others support that physical activity is fundamental to maintaining and improving health

(Cotman & Berchtold 2002; Cotman et al., 2007; Ladabaum, Mannalithara, Myer, & Singh, 2014; Salmon, 2001).

Conversely, other studies have documented that decreased levels of physical activity is associated with a number of poor health outcomes such as obesity (Ali, 2003; Ladabaum et al., 2014), increased risk of cardiovascular diseases (Castelli, 1984; Flynn et al., 2009; Peterson, Charlson, Wells, & Altemus, 2014), and increased risk of developing high blood pressure (Whelton, Chin, & Xin, 2002). Physical inactivity has also been identified by the World Health Organization (2015) as the fourth leading risk factor for global mortality. It is estimated that over three million deaths internationally can be attributed to a lack of physical activity. This is supported by a growing body of research that indicates that physical inactivity is associated with a host of problematic health conditions (Booth, Gordon, Carlson, & Hamilton, 2000; Gilen et al., 2010), mental health problems (Penedo & Dahn, 2005; Peterson et al., 2014), and neurological problems (Cotman & Berchtold, 2002; Cotman et al., 2007).

Despite the noted importance of physical activity, recent research suggests that US rates of engaging in deliberate physical activity are significantly decreasing and, correspondingly, rates of sedentary activity are increasing (Brownson, Boehmer, & Luke, 2005; CDC, 2010; Gordon-Larsen, McMurray, & Popkin, 2000; Hallal et al., 2012; Haskell et al., 2007; Warburton et al., 2006). For example, The Center for Disease Control (2012) reported that about half, or approximately 48 percent, of US adults do not currently meet the 2008 Physical Activity Guidelines outlined by the U.S. Department of Health and Human Services. Specific to Tennessee, where the current study was conducted, The Center for Disease Control reported that in 2012 approximately 30% of adults did not participate in any type of deliberate physical activity. Other studies have documented similar decreases in exercise for young adults, (Deforche, Dyck, Deliens, & Bourdeaudhuij, 2015; Filla, Hays, Gonzales, Hakkak, 2013). For example, Racette, Deusinger, Strube, Highstein, and Deusinger (2005) reported that the number US college students who met the physical activity recommendation decreased by 34% when comparing freshman and seniors. Likewise, Caspersen et al. (2000) noted that individuals' regular aerobic and strengthening activity declined in a step-wise fashion from ages 12 to 21. In general, these studies and others document a growing concern that US college students are not getting enough exercise. Furthermore, based on the research reviewed, this trend may lead to a myriad of health complication.

In response to the noted importance and decreases in physical activity rates, organizations such as the U.S. Department of Health and Human Services have developed exercise standards, also known as Physical Activity Guideline, for the purpose of maintaining health and disease prevention. These guidelines have generally incorporated a dose-response relationship between exercise and health that recognizes that some physical activity is better than none and, up to a certain point, more physical activity is better than less. For example, in 1995, the Center for Disease Control and the American College of Sports Medicine recommended that individuals participate in thirty minutes of moderate aerobic exercise five days a week to receive health benefits (Haskell et al., 2007). Later, these guidelines were revised into the current Physical Activity Guidelines (2008) issued by the U.S. Department of Health and Human Services. These guidelines recommend 150 minutes of moderate to intense aerobic exercise each week. This equates to three (50 minute) sessions of aerobic exercise weekly. In addition to aerobic (endurance training) the guidelines also recommend muscle-strengthening (resistance training), two days a week.

Physical Activity

Though there are a variety of definitions of physical activity, researchers generally define the construct, as any bodily movement via skeletal muscles that results in energy expenditure (e.g., Brownson et al., 2005; Casperson, Powell & Christenson; 1985; Colberg et al., 2010; Thompson et al., 2003). Similarly, Janssen et al. (2005) defined physical activity as an activity that increases an individual's heart rate. Generally, the terms exercise and physical activity are used interchangeably in the literature (Brownson, et al., 2005; Caspersen et al., 1985; Shephard & Balady, 1999). However, exercise is recognized as incorporating the dimension of deliberate preparation. That is, exercise connotes a planned, structured, and repetitive event that has a final or an intermediated objective to the improvement or maintenance of physical fitness (Caspersen et al., 1985). For example, this deliberate preparation might include planning ahead to determine the type, duration, intensity, and location of the exercise. On the other hand, physical activity is viewed as movement and energy expenditure that is not planned and part of the routine of daily living. For example, this spontaneous movement may include walking, cleaning a house, walking to work, and gardening in a yard. For the purpose of this study exercise and physical activity are treated as synonymous. That is, exercise and physical activity are both activities that involve major muscles resulting in energy expenditure and calories burned.

Though, the current study did not categorize different types of exercises, researchers have attempted to categorize exercise into different types. For example, Pontifex et al. (2009) delineated two major types of exercises, namely aerobic and resistance. First, aerobic is defined as an activity that uses a large or major muscle group continuously for an extended period of time (Salmon, 2001). Examples of aerobic exercise include activities such as running, swimming, dancing, and circuit training (Salmon, 2001). Essentially, this type of activity is associated with increased heart rate, improved cardiovascular health, lower blood pressure, increased aerobic endurance, reduced stress, weight loss, and increased metabolism rates (Dimeo et al., 2012; Rognmo, Hetland, Helgerud, Hoff, & Slordahl, 2004; Ryan et al., 2014; Schjerve et al., 2008). Second, resistance training is defined as any activity that causes muscles to contract against an external force (Sundell, 2010). Examples of resistance training activities include activities that require lifting, holding, pulling, pushing, and using weight machines, dumb bells, bar bells, and free weights. Some goals of this type of exercise are to increase muscle size, strength, balance, coordination, speed, power, local muscular endurance, lower blood pressure and reduce stress (Flex, 1999; Kraemer & Ratamess, 2004; Sundell, 2010). This type of activity is associated with a number of health outcomes such as prevention of osteoporosis (Winett & Carpinelli, 2002), increased glycemic control for diabetes patients (Warburton et al., 2006), increased bone density

(Sothern, Loftin, Suskind, Udall, & Blecker, 1999), and prevention of metabolic syndromes and frailty syndromes (Sundell, 2011).

Neuropsychological Skills Associated with Physical Activity

Recently, the field of cognitive epidemiology has focused on understanding the various healthy behaviors that promote and prevent mental processes (e.g., Best, 2010; Davis et al., 2011; Hillman, Erikson, & Kramer, 2008; Tomporowski, Davis, Miller, & Naglieri, 2008). Correspondingly, the relationship between neuropsychological processes and physical activity is now an area of empirical investigation. This is to be expected as physical activity, incorporates many cognitive aspects such as motivation, planning, and self-restraint (e.g., Davis et al., 2011; Hillman et al., 2003; Kramer, Erickson, & Colcombe, 2006; Kramer et al., 1999; Pontifex et al., 2009). Humans may display a strong predisposition to engage in regular physical activity. Psychologists and anthropologists have theorized that, to some extent, the human brain could have been molded and refined by a long history of movement and endurance (Raichlen & Gordon, 2011). Historically, humans have been required to engage in high levels of aerobic activity to obtain the food and the means to sustain life. This history of locomotor behavior could be associated with human brain size (Raichlen & Gordon, 2011). Raichlen and Polk (2012) explain that physical activity appears to contribute to processes related to neurogenesis, the protection of neurons, and increases in brain volume and cognition. Indeed, the supposition has been supported by a variety of studies that report correlations between mammal's physical activity capacity and brain size and cognitive processes (e.g., Cotman & Berchtold, 2002; Cotman et al., 2007; Kramer & Erickson 2007; Salmon, 2001).

Modernity appears to be decreasing physical activity and increasing rates of sedentary activity (Hallal et al., 2012). Medical anthropologists postulate that the industrial revolution vastly changed the nature of physical activity. Prior to modern advances, families were largely self-sufficient and grew a majority of the food they ate. Additionally, work outside of the home, such as farming, hunting, and traveling by foot to other villages, was more demanding and required substantial toil and labor compared to a modern office job. During the industrial revolution, machine-technology innovations largely replaced much of human labor. Today, modern work can be described as less physically active and more sedentary in nature (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008). For example, multiple studies have documented that individuals in the US spend a majority of their time each day engaged in sedentary behavior such as sitting in front of a computer, commuting to and from work, watching T.V., and sleeping (Cowan, 1976; Tremblay, Colley, Saunders, Healy, & Owen, 2010). Conceptually, increases in sedentary behavior may impact the development of many of the core neurocognitive processes that are associated with controlling thought, emotion, and behavior. However, there is a shortage of studies that investigate the specific neurocognitive process, namely executive function skills, that are associated with physical activity (Guiney, & Machado, 2013; Pontifex, et al., 2009; Verburgh et al., 2014).

Executive Functioning

Executive functioning (EF) is an "umbrella term" that generally refers to a broad set of supervisory cognitive processes that are responsible for higher order cognitive functioning such as planning, coordinating, shifting attention, sequencing and controlling cognitive and behavior operations (e.g., Alvarez & Emory, 2006; Anderson, 2002; Best, 2010; Gioia, Isquith, Retzlaff, & Espy, 2002; Hill 2004; Meltzer & Krishman, 2007; Salthouse, Atkins, & Berish, 2003). Researchers generally recognize that executive functioning skills are orchestrated by the frontal lobes of the brain, more specifically, the prefrontal cortex. (Berchicci, Lucci, & Di Russo, 2013; Garon, Bryson, & Smith, 2008; Miyake et al., 2000). This area of the brain appears to have strong connections with many other brain areas such as the hippocampus, parietal lobes, the dorsolateral caudate nucleus, anterior cingulate cortex, the ventromedial caudate, and the striatum (Meyer & Quenzer, 2013). In this sense, EF is not responsible for one skill or behavior per se. Rather, the construct is multifaceted and responsible for a myriad of self-regulatory skills that modulate thought and behavior (Brown, 2005; Denckla, 1996; Smith & Jonides, 1998).

Denckla (1996), one of the first researchers to use the term clinically, described EF as “a set of domain-general control processes that involve inhibition and delay of responding for the goal of organization and integration of cognitive and output processes over time” (p.265-266). Moreover, Denckla’s description of EF incorporated three main components, namely interference control, effortful and flexible organization, and strategic planning or the readiness to act. First, interference control contributes to the ability to disregard irrelevant information during a goal oriented task. This ability allows an individual to selectively focus attention while filtering out extraneous information. Second, effortful and flexible organization facilitates the ability to continually organize and rearrange thought and behavior toward goal achievement. Third, strategic planning or the readiness to act enables a person to mentally prepare for the future by anticipating responses that are appropriate to various situations. Together, these three core EF components facilitate the complex higher cognitive processes that allow an individual to organize and plan and focus during tasks.

Miyake et al. (2000) reviewed EF literature and developed a taxonomy of EF based on three basic functions: shifting, updating, and inhibition. First, shifting, also known as mental attention shifting, is comprised of the ability to perform a new task in the face of a proactive interference or negative priming. This allows an individual to smoothly transition from task to task. Second, updating is the ability to monitor working memory processes. Thus, the skill requires on-going monitoring and coding incoming information. This entails the active manipulation of relevant information in working memory rather than storing only. Third, inhibition requires purposefully stopping dominant automatic or prepotent responses when necessary. This skill allows an individual to actively stop a relatively automatic response. Overall, these three functions, namely shifting, updating, and inhibition, contribute to the ability to focus, plan, and organize which are skills that comprise EF.

Moran and Gardner (2007) also provide a three parameter model of EF that includes: hill, skill, and will. First, hill is the term used to describe the ability to set clear goals for the future. This capacity allows an individual to establish clear goals that aid in planning for the future. Second, skill describes an individual's capacity to learn, perform, and master new information. Third, will refers to an individual's volition, determination, and perseverance to begin and accomplish set goals. These three EF parameters are highly integrated and operate together to formulate goals and acquire the information and means to work through time, social, and mental contexts. Though there are a variety of theoretical models of EF, most researchers generally agree that EF is essential to daily activities; incorporating skills such as planning, attention, organizing, and memory, work together to regulate thought and behavior.

EF Inhibition and Working Memory

Of the many EF skills, inhibition and working memory are viewed as most central (Berchicci et al., 2013; Garavan, et al., 2002). Inhibition is defined as the cognitive ability to over-ride or stop mental prepotent processes (Macleod, 2007). In other words, inhibitory control allows for the processing of new information by preventing old information from one's attention (Miyake et al., 2000). This cognitive control is generally recognized as coinciding with the orbitofrontal area of the prefrontal cortex (Elliott & Deakin, 2005; Garavan et al., 2002; Rolls, 2003). This brain region appears to be responsible for "selecting an appropriate course of action in the face of competing or interfering demands" (Garavan et al., 2002). Multiple studies have documented that inhibitory problems are associated with a variety of conditions such as attention deficit hyperactivity disorder (Aron & Poldrack, 2005; Barkley, 1997), obesity (Batterink, Yokum, & Stice, 2010; Nederkoorn, Jansen, Mulkens, & Jansen, 2007), and obsessive-compulsive disorder (Bannon, Gonsalvez, Croft, & Boyce, 2002).

Working memory is also viewed as a core EF skill. This construct is defined as the ability to hold, recall, manipulate, and associate information to other ideas and new incoming information (Baddeley, 1992; Barkely, 1997). Working memory skills allow individuals to hold information in mind while following complex instructions and executing a sequence of actions or multistep activities (Conway, Jarrold, Kane, Miyake, & Towse, 2007; Roth et al., 2005). This capacity provides a foundation for the flexible manipulation of information needed to problem solve (Redick, Calvo, Gay, & Engle, 2011). Studies suggest that the dorsolateral region of the frontal cortex is associated with working memory skills (Petrides, 2000). This area of the brain appears to be stimulated as individuals actively maintain verbal and visual information in working memory (Levy & Goldman-Rakic, 2000; Petrides, 2000). Working memory dysfunction has been linked to difficulties completing multiple step tasks, losing track of situational demands, and difficulty remember rules for a specific task (Roth et al., 2005). Moreover, working memory problems are associated with a number of conditions such as attention deficit hyperactivity disorder (Alderson, Hudec, Patros, & Kasper, 2013), dyslexia (Menghini, Finzi, Carlesimo, & Vicari, 2011), math deficits (Passolunghi & Siegel, 2004), and Alzheimer's disease (Geldorp et al., 2015).

Though EF inhibition and working memory can be viewed as distinct, the cognitive skills are to some degree interdependent (Miyake et al., 2000). That is, deficits with inhibition may set the stage for problems with working memory. For instance, if an individual is unable to inhibit irrelevant information when following directions, the individual performance on tasks may be negatively affected. Generally, research has found that inhibition is essential for the normal performance of working memory (Barkley, 1997; Garavan et al., 2002; St. Clair-Thompson & Gathercole, 2006). In this sense, inhibition and working memory are viewed as discreet yet they rely on each other

(Miyake et al., 2000). Put differently, these two core EF skills demonstrate both diversity and unity concurrently (Duncan et al., 1997; Miyake et al., 2000).

Physical Activity and EF

Theoretically, physical activity may implicate EF skills such as inhibition and working memory. In modern low-energy-expenditure environments, engaging in high-energy expenditure activities, such as exercise, requires inhibitory control and working memory. Many sedentary behaviors are associated with immediate reinforcement and become strong proponent responses that are difficult to change. In order to override these sedentary behaviors or goal-inconsistent responses, inhibition is needed to create a delay between impulse and action that facilitates a shift to physical activity. Likewise, metacognitive skills such as working memory are important for planning, organizing, and initiating healthy physical activity over time. In other words, the mental ability to hold and rearrange information in mind can be viewed as imperative to establishing and carrying out deliberate physical activity plans.

Indeed, researchers have begun to link physical activity and EF in non-clinical young adult populations. However, as noted by Verburgh et al. (2014), most of the research has focused on how acute physical exercise impacts EF skills. There remains a shortage of studies that focuses on how chronic physical activity impacts EF. Moreover, many of the exercise studies do not incorporate a dimensional EF approach. In other words, the studies have not directly compared how physical activity predicts each of the core EF dimensions of inhibition and working memory both together and separately.

Currently, most of the studies investigate overall EF or analyze each core dimension separately.

For instance, Verburgh et al. (2014), in a meta-analysis, examined the affects of acute exercise (i.e., single short bouts of physical activity) and chronic exercise (multiple training sessions per week over a longer period of time) on EF in young adults. Findings generally concluded that acute physical exercise enhanced EF. However, the authors noted that it remained unclear whether chronic physical exercise demonstrated a similar effect on EF. Further, the authors suggested that research examining the relationship between chronic exercise and EF is limited and needs further investigation. In another meta-analysis, Smith et al. (2010) analyzed 19 studies that investigated aerobic exercise and EF related neurocognitive skills among non-demented adults. Studies were analyzed that, among other criteria, included non-demented adults, randomized treatments that lasted longer than one month and a control group to compare to experimental groups. The meta-analytic results indicated that aerobic exercise was associated with modest improvements in overall EF. Moreover, duration, intensity, or type of exercise was not associated with improvements in executive function. The authors explained that the modest improvements in neurocognitive function, specifically EF skills among other attention and processing skills were most likely promoted by exercise. However, the authors also noted that duration, intensity, or type of exercise was not associated with improvements in executive function.

Similarly, Loprinzi, and Kane (2015) experimentally investigated a potential dose-response relationship between exercise and EF processes in young healthy adults (*N*

= 87) with a mean age of 21. Participants were assigned to one of four groups: moderate exercise, intense exercise, free living physical activity, or sedentary behavior. Over two visits with seven days between, participants completed a variety of self-report questionnaires including measures of attention, memory, reasoning, concentration, and planning. Results indicated that individuals in the moderate exercise group, on average, demonstrated increased concentration performance scores in comparison to participants in other groups. The authors generally concluded that moderate-intensity exercise increases attention processes in young adults. In another study, Davis et al. (2011) conducted an exercise intervention and fMRI study to investigate EF in children, ages seven to eleven who were identified as overweight ($N = 171$). Participants were randomized to one of three conditions, a low dose of aerobic exercise (20 minutes), high dose of aerobic exercise (40 minutes), or non-aerobic exercise group. The daily intervention lasted 13 weeks Baseline and post-intervention laboratory testing included an EF measure of planning among many other cognitive measures. Results indicated that children in the high dose of aerobic exercise group displayed significant increases in planning skills in comparison to the low dose exercise group and control. Similarly fMRI results suggested comparably significant increases in prefrontal cortex activity in the high dose of aerobic exercise group. Researchers concluded that engaging in aerobic exercise improved cognitive skills, specifically planning by increasing activity in the prefrontal cortex.

Though the majority of EF and physical activity studies have focused on a variety of EF dimensions, there have been studies that have specifically targeted EF inhibition (e.g., Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Sibley, Etnier, & Le Masurier, 2006; Weinstein et al., 2012). For example, in a review of multiple studies, Guiney and Machado (2013) investigated the potential benefits of aerobic exercise on EF in groups of children, young adults, and older adults. The analysis indicated that exercise was associated with a variety of EF increases, particularly inhibition skills. However, the findings were mixed across different age groups. For instance, older adults were found to exhibit improved performance on inhibition tasks following aerobic exercise. Also, their fitness levels significantly predicted performance on inhibitory control tasks. Corresponding inhibition improvements were not found for children and young adult populations. The authors advised that more research is needed to clarify the relationship between exercise and EF studies in younger populations. Chu, Alderman, Wei, and Chang (2015) also investigated the relationship between exercise and inhibition in college students ($N = 21$) ages 19 to 24. Participants were administered a physical activity questionnaire and a clinical go/no-go task. Participants were tested on three occasions. The first two times, participants were asked to participate in 30 minutes of aerobic exercise on a treadmill prior to completing the go/no-task. The third time, participants did not engage in exercise before completing the laboratory task. Results indicated that, in comparison to participants who did not exercise before testing, participants who exercised demonstrated significantly enhanced inhibition performance Researchers concluded that acute exercise appears to augment an individual's ability to control motor response inhibition. Similarly, Hillman et al. (2003) examined the impact of exercise on inhibitory control. College students ($N = 20$) were administered the Erickson flanker task, a clinical measure of inhibitory control, before and after and running on a treadmill for 30 minutes. Participants repeated the procedure twice over the course of seven days. Results indicated that the treadmill cardiovascular running increased inhibition performance. The authors generally concluded that aerobic exercise appears to increase performance accuracy which indirectly increases inhibition.

Other EF dimensional studies have investigated young adult working memory in relationship to physical activity. However, these studies have reported mixed results. In a meta-analysis, Smith et al. (2010) examined 12 studies to better understand the relationship between exercise and working memory using. The studies met the following criteria and included: an exercise group, a control group, and neurocognitive measures previously used in other studies. Overall, results indicated that older adults who participated in a combination of aerobic and resistance training performed better on working memory task than individuals who participated in no exercise or solely aerobic exercise. However, this relationship was not found in younger adults. Researchers generally concluded that aerobic exercise improves performance on working memory tasks for older adults. Conversely, Pontifex, Hillman, Fernhall, Thompson, and Valentini (2009) examined the effects of acute aerobic and resistance exercise on working memory. Participants ($N = 21$ young adults) were assigned to one of two conditions, an aerobic exercise or resistance condition. Participants were administered a clinical working memory task on three occasions, namely, prior to exercise, immediately after exercise, and 30 minutes after exercise. When comparing working memory performance between the groups, results indicated that individuals in the aerobic exercise group demonstrated significantly increased performance. In particular, reaction times on the working memory task decreased significantly for participants in the aerobic exercise group immediately after exercise and 30 minutes post exercise. Researchers did not observe corresponding improvements in resistance-training participants group. Overall, the researchers concluded that aerobic exercise increases EF skills, particularly working memory. Similarly, Pesce, Crova, Cereatti, Casella, and Bellucci (2009) studied the effects of physical activity on memory performance in pre adolescents ($N = 52$) ages 11 and 12. Participants were administered a free recall memory task and a delayed recall test to assess short-term and long-term memory. The study consisted of three sessions. Two of the sessions were preceded with an hour of aerobic physical activity (i.e., aerobic game or circuit training) in a school physical education class, while the baseline session was not preceded by physical activity. Results indicated that recall scores, both initial and delayed, were significantly higher following physical activity sessions when compared to non-physical activity sessions. Researchers concluded that physical activity may be an important factor in increase in memory such as working memory and long term memory.

Purpose

More studies are needed that investigate how chronic physical activity impacts young adult EF skills (Guiney & Machado, 2013; Verburgh, Scherder, Oosterlaan 2014). Moreover, there is a shortage of research that incorporate a dimensional EF approach that directly compares how physical activity predicts core EF dimensions, namely Behavioral Regulation (i.e., inhibition) and Metacognition skills (i.e., working memory). Moreover, previous physical activity and EF studies have focused predominately on the immediate effects of acute bouts of exercise (e.g., Chu et al., 2015; Hillman et al., 2003; Loprinizi & Kane, 2015; Pontifex, et al., 2009). Further research is need that utilizes behavioral self-reporting to assess chronic exercise and EF. Moreover, previous physical activity and EF studies have focused predominately on older adults, children, and clinical populations. More studies are needed that are based on non- clinical young adult populations.

To address this, the current study addressed three main hypotheses. First, it was hypothesized that physical activity levels will significantly predict overall EF ratings. This was anticipated as increased exercise has been previously associated with increased cognitive control (e.g. Best, 2010; Davis et al., 2011; Loprinizi & Kane 2015; Smith et al., 2010). Second, it was hypothesized that participants' physical activity levels will successfully predict the core EF dimensions of Behavioral Regulation and Metacognition, independently. This was anticipated as physical activity has been shown to have direct and indirect effects on executive functioning domains, particularly Behavioral Regulation and Metacognition (Colcombe & Kramer, 2003; Hillman et al., 2003; Hogervorst et al., 1996; Pontifex et al., 2009; Sibley et al., 2006; Smith et al., 2010). Furthermore, it was anticipated that physical activity levels will better predict Metacognition when compared to Behavioral Regulation. This was theorized because more research has shown a positive relationship in fitness levels as more predictive of working memory (i.e., Metacognition) performance than inhibition (i.e., Behavioral Regulation) in younger adults (Guiney & Machado, 2013; Pesce et al., 2009; Smith et al., 2010; Weinstein et al., 2012).

CHAPTER II

Methods

Participants

Undergraduate college students ($N = 99$; 49 females and 50 males) were recruited at Middle Tennessee State University in the mid-south United States. Potential participants were required to comprehend spoken and written English and have normal vision. Prior to participation, each participant provided written consent and following consent, each participant completed self-reported instruments described below in one laboratory session. The sample consisted of students from the following ages: (a) 25.3% were 18 years old ($n = 25$); (b) 25.3% were 19 years old ($n = 25$); (c) 24.2% were 20 years old ($n = 24$); (d) 9.1% were 21 years old ($n = 9$); and (e) 16.2% were 22 years old or older ($n = 16$). Based on the students' report of their ethnicity 61.0% were Caucasian ($n = 60$), 24.2% were African American ($n = 24$), 2.0% were Asian ($n = 2$), 4.0% were Hispanic or Latino ($n = 4$), 5.1% were other ($n = 5$), and 4.0% did not report their ethnicity ($n = 4$).

Measures

EF measure. The Behavior Inventory Executive Function-Adult Version (BRIEF-A; Roth et al., 2005) was used to assess dimensions of EF. The BRIEF-A is a self-report questionnaire created to assess an individual's ability to self-regulate in their everyday environment. The Brief is comprised of 75 questions that produce an overall score, the Global Executive Functioning Composite, and two index scores. The first index score is the Behavioral Regulation Index that measures an individual's ability to maintain appropriate regulatory control of his or her emotional responses and behavior. For example, regulatory control includes flexibility in shifting problem-solving set, monitoring ones actions, modulation of emotional response, and inhibiting thoughts and actions appropriately (e.g. I have outburst at inappropriate places). This index includes four scales (Inhibit, Shift, Emotional Control, and Self-Monitor). The second index is the Metacognition Index that represents the individual's ability to complete executive functions required for active working memory (e.g. I have trouble completing tasks that require multiple planned steps). For example, this scale is directly related to an individual's ability to actively solve problems in a myriad of modulation of emotional response, contexts. This index includes five scales (Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials). For the purposes of this study, the Global Executive Functioning Composite, the Behavioral Regulation Index, and the Metacognition Index were the primary metrics of interest. The BRIEF measure utilizes a three-point Likert scale for each of the 75 items. Response options are one (the behavior is never a problem), two (the behavior is sometimes a problem), and three (the behavior is often a problem). Participants chose the answer that best described his/her behavior over the last month. Higher scores on the BRIEF yield increased problems with self-regulation, inhibition, and working memory related skills.

Physical Activity. Physical activity was assessed with the physical activity section of the Personal Wellness Profile (PWP; Wellsource, 1998), a self-report rating scale developed to assess fitness status associated with exercise and daily activity. The instrument is widely used in the health sector and reflects physical activity recommendations from a variety of organizations such as the World Health Organization, US Department of Health, the American College of Sports Medicine, and the Center for Disease Control and Prevention. The physical activity section of the PWP is comprised of four questions (see Appendix A). The first question focuses on aerobic exercise and asks participants "how many days per week do you engage in aerobic exercise of at least 20 to 30 minutes". Participants indicate a Likert response that ranges from 0 (*no exercise program*) to 7 (*seven days per week*). The second question focuses on physical activity level, particularly amount and intensity, and asks participants to "mark the response that best describes your current activity level". Participants indicate a Likert response that ranges from 1 (*no regular exercise*) to 5 (*participates regularly in more active physical exercise*). If participants indicate that they participate regularly in more physical exercise (Likert response 5), they are then asked to "indicate how much time you spend exercising each week". Participants could indicate a Likert response that ranged from 1 (*less than 1 hour per week*) to 7 (*participating in more than12 hours weekly or running more than 26 miles weekly*). The third question focused on strength exercises and asks participants "how many days per week do you do strength-building exercises such as sit-ups, push-ups, or use weight training equipment". Participants indicate a Likert response that ranges from 0 (*none*) to 3 (*three plus times weekly*). The fourth question focuses on stretching exercises and asks participants "how many times per week do you do stretching exercises to improve flexibility of your back, neck, shoulders, and legs". Participants indicate a Likert response that ranges from 0 (*none*) to 3 (*three plus times weekly*).

Scoring procedures, outlined by the PWP, were followed to calculate a total Physical Activity Composite for each participant (see Appendix B). To calculate this, physical activity points were assigned to each Likert response. Points for each question were assigned differently based on type and intensity of exercise. For the first physical activity question that focused on aerobic exercise, as the frequency of aerobic exercise increased, participants received more physical activity points (i.e., (a) no regular exercise = 10 points, (b) 1 day per week = 24 points, (c) 2 days per week = 40 points, (d) 3 days per week = 55 points, (e) 4 days per week = 65 points, (f) 5 days per week = 80, (g) 6 days per week = 90 points, (h) 7 days per week = 100 points). For the second physical activity question that focused on activity level, as the amount and intensity of physical activity increased, participants received more physical activity points (i.e., (a) no regular exercise = 10 points, (b) occasional physical activity = 20 points, (c) modest physical activity up to 1 hour per week = 28 points, (d) modest physical activity more than 1 hour per week = 30 points, (e) more active physical exercise less than 1 hour per week = 35 points, (f) physical exercise 1 hour or run up to 5 miles weekly = 45 points, (g) physical exercise 2 to 3 hours, or run up to 5 miles weekly = 60 points, (h) physical exercise 4 to 5 hours, or run 11 to 15 miles weekly = 70 points, (i) physical exercise 6 to 8 hours, or run 16 to 20 miles weekly = 80 points, (j) physical exercise 9 to 11 hours, or run 21 to 25 miles weekly = 90 points, (k) physical exercise 12 plus hours or 26 plus miles weekly = 100 points. For the third physical activity question which focused on strength exercises, as the frequency of strength training increased, participants received a higher score (i.e., (a) none = 15 points, (b) once a week = 45 points, (c) twice a week = 65 points, and (d) three plus times a week = 90 points). For the fourth physical activity question that focused on stretching exercises, the scoring procedure was identical to question three. That is as the frequency of stretching exercises increased, participants received a higher score (i.e., (a) none = 15 points, (b) once a week = 45 points, (c) twice a week = 65 points, and (d) three plus times a week = 90 points). To calculate the physical activity score, all four fitness categories (aerobic exercise, physical activity level, strength exercises, and stretching exercises) were combined and divided by 4. Higher total scores reflected increased fitness levels (i.e., higher rates of physical activity).

Procedure

The current study utilized archival data by the thesis chair member, Dr. Seth Marshall. IRB approval was obtained see Appendix C.

CHAPTER III

Results

Hypothesis 1

Means, standard deviations, and correlations were examined for participant's Physical Activity Composite (PAC) scores and BRIEF scores (see Table 1). Moreover, Physical activity status percentages for the present sample were examined (see Table 2). This study's first main purpose was to investigate how physical activity (i.e., the Physical Activity Composite) predicted individuals' overall EF ability (i.e., Global Executive Functioning Composite). To address this purpose, one simple regression was conducted. Findings confirmed that the Physical Activity Composite significantly predicted Global Executive Functioning Composite (R^2 = .07, adjusted R^2 = .06, F (2, 97) = 6.76, p = .01) (see Table 3). The Physical Activity Composite scores accounted for approximately 6% of the variance of GEFC scores in the sample.

Hypothesis 2

This study's second main purpose was to investigate how, and to what extent, each of the core EF dimensions, namely EF Behavioral Regulation (i.e., inhibition) and EF Metacognition (i.e., working memory) predicted physical activity levels. Multiple regressions results indicated that EF Metacognition Index scores accounted for a significant proportion of the variance of Physical Activity, R^2 = .07, adjusted R^2 =.06, F (1, 97) = 7.32, p = .01. The BRIEF Behavior Regulation Index was then added to the regression equation and there was no significant change in the prediction of Physical Activity Scores, R^2 = .071, adjusted R^2 =.05, F (1, 96) =.05, p = .82 (see Table 4). Further investigation of the EF Metacognition scales supported this as the Initiate and Plan/Organize scales were both significantly correlated with physical activity levels (Initiate $r = -.35$, $p = <.01$; Plan/Organize -.21, $p = .04$). However, only one of the EF Behavioral Regulation scales, specifically Shift, was significantly correlated with physical activity ($r = -.29$, $p = <.01$; see Table 5). Lastly, the current sample's BRIEF means were compared with a similar aged normative group (see Table 6).

Table 1

Means, Standard Deviations, and Correlations for Physical Activity Composite Scores and Outcome Variables (N = 99)

Measures	*M*	*SD*	1.	2.	3.	4.
1. Physical Activity Composite	35.42	21.68		-.26**	-.27**	-.19
2. BRIEF Global	113.41	19.79			.94**	.88**
3. BRIEF Metacognition	65.01	12.46				.65**
4. BRIEF Behavioral Regulation	48.40	9.26				

Note. All scores based on raw scores, * $p <. 05$. ** $p < .01$

Table 2

Percentages of Self-Reported Physical Activity Status (N = 99)

Physical Activity Status	%
No regular physical activity and generally avoid it all together	6.0
Occasional physical activity for pleasure e.g. walking, and/or any type of exercise that results in heavy breathing	34.0
Modest physical activity (up to one hour per week) e.g. yard work, weight lifting, table tennis, calisthenics	11.0
Modest physical activity (more than one hour per week) e.g. yard work, weight lifting, table tennis, calisthenics	18.0
More active physical exercise (aerobic activity) e.g. brisk walking, jogging, swimming, tennis, rowing, cycling, running ranging from less than one hour a week up to 12 hours a week	31.0

Note. Each participant indicated only one of the above statuses

Table 3

Simple Regression Analysis of Physical Activity Composite Scores Predicting Global Executive Functioning Composite (N = 98)

Variable	*B*	*SEB*	*Beta*	*t*	*p*	Zero-Order *r*	Partial	Part
Global EF	-.23	.09	-.26	-2.60	.01	-.26	-.26	-.26
R^2		.07						

Table 4

Multiple Regression Analysis of Physical Activity Composite Scores Predicting EF Metacognition and EF Behavior Regulation Indexes (N = 99)

Variables	*B*	*SEB*	*Beta*	*t*	*p*	Zero-Order *r*	Partial	Part
EF Metacognition	-.47	.17	-.27	-2.71	.01	-.27	-.27	-.27
EF Behavior Regulation	-.07	.30	-.03	-.23	.82	-.19	-.02	-.02

Table 5

Means, Standard Deviations, and Correlations for Physical Activity Composite Scores and Individual Scales of EF (N = 98)

Executive Functioning Indexes and Scales	*M*	*SD*	Correlation
BRIEF Behavioral Regulation Index	48.40	9.26	-.19
Inhibit	13.97	2.99	-.11
Shift	9.23	2.34	-.29**
Emotional Control	15.56	4.64	-.17
Self-Monitoring	9.64	2.27	.01
BRIEF Metacognition Index	65.01	12.46	-.27**
Initiate	13.16	2.99	-.35**
Working Memory	13.25	3.11	-.16
Plan/Organize	15.35	3.52	-.21*
Task Monitoring	10.31	2.11	-.14
Organization of Materials	12.95	3.81	-.18

Note. All scores based on raw scores, $*p < .05$ $**p < .01$

Table 6

Comparison Between Means and Standard Deviations For the Present Sample (N = 99) and the Normative Sample Group (N = 169) Ages Ranging From 18-29 On The BRIEF Executive Functioning Measure

Executive Functioning Measure	Sample *M*	*SD*	Norm group *M*	Norm group *SD*
BRIEF Global	113.41	19.79	106.80	27.54
BRIEF Behavioral Regulation Index	48.40	9.26	46.88	12.59
Inhibit	13.97	2.99	11.78	3.34
Shift	9.23	2.34	8.85	2.59
Emotional Control	15.56	4.64	16.65	5.23
Self-Monitor	9.64	2.27	9.60	2.88
BRIEF Metacognition Index	65.01	12.46	59.91	16.30
Initiate	13.16	2.99	12.05	3.47
Working Memory	13.25	3.11	11.10	3.41
Plan/organize	15.35	3.52	14.66	4.42
Task Monitor	10.31	2.11	8.72	2.62
Organization of materials	12.95	3.81	13.39	4.47

Note. Participants in the presents study and the norm study were in the same age range

CHAPTER IV

Discussion

First, this study examined the extent to which chronic physical activity predicted EF skills. As proposed, college students' self-reported levels of physical activity successfully predicted overall levels of executive functioning. This is noteworthy as most of the existing physical activity and EF research is based on acute bouts of exercise. Our study appears to be one of the first studies that links chronic exercise and EF in young adults. One explanation for this finding is that physical activity potentially boosts EF skills. That is, participating in physical activity may bolster a variety of EF skills that are responsible higher-order cognitive skills that are required for daily functioning and regulating emotions. This finding corresponds with previous studies that have documented similar results. For example, Verburgh et al. (2013) utilized meta-analytic methods and reported that acute exercise enhanced a variety of EF skills in children and young adults. Likewise, Loprinizi and Kane (2015) reported a dose-response relationship between exercise and EF processes in healthy young adults. That is, moderate-intensity exercise appeared to increase scores on a variety of clinical and self-report EF measures.

One interpretation of the correspondence between physical activity and overall EF ability may be explained in neuropsychological terms. Multiple studies have documented that acute bouts of aerobic physical activity corresponds with increased activity and blood flow to the prefrontal cortex, the area of the brain responsible for EF (e.g., Berchicci et al., 2013; Garon et al., 2008; Miyake et al., 2000). This exercise-induced blood flow and prefrontal activity may account for the EF increases. Another interpretation may be related to the cognitive processes that are inherent in complex physical movement.

Exercise requires a high degree of cognitive engagement. This effortful thinking may cultivate the skills such as planning, monitoring and changing tasks through contextual interference which places demands on EF processes leading to more elaborate thinking and learning (Best, 2010). An additional possible explanation is that exercise promotes neurogenesis to brain areas that contribute to EF. This has been documented in a number of animal studies that suggest that exercise promotes multiple neurotrophic factors and guards against neurodegeneration in areas of the brain responsible for EF (Cotman, et al., 2007; Cotman, et al., 2002; Van Praag, Shubert, Zhao, & Gage, 2005). In addition, it is important to consider a bidirectional relationship where individuals with increased EF skills are more likely to engage in physical activity. Engaging in physical activity requires a complex set of EF skills. From the onset, individuals with increased global EF skills may be more likely to plan and initiate the mental and behavioral tasks related to physical activity. Likewise individuals with poor EF skills may have more difficulty inhibiting the prepotent responses that prevent physical activity tasks.

Second, this study investigated the extent that chronic physical activity predicts two core dimensions of EF, namely metacognition and behavior regulation. Regarding EF metacognitive skills, findings from this study suggested that participants' overall physical activity level indeed predicted this core EF domain. Specifically the amount of time students spent engaging in physical activity (e.g., aerobic exercise, strength training, and stretching exercises) predicted their overall metacognitive skills, or their ability to problem solve in a myriad of situations. This finding generally corresponds with previous studies that link exercise and metacognitive skills such as working memory and planning.

For example, Pontifex et al. (2009) reported that aerobic exercise in young adults produced significant improvements on clinical cognitive working memory tasks. Similarly, Pesce et al. (2009) concluded that in pre adolescents' physical activity was related to increased working memory and long term memory performance on a free recall and delayed recall memory tasks. Moreover, in the current study, of the five metacognitive skills measured by the BRIEF (i.e., initiate, working memory, plan/organize, task monitor, and organization of materials), participants' physical activity most corresponded with EF initiate skills and planning/organizing skills. This may suggests that individuals who regularly participate in physical activity may be more prone to successfully begin tasks independently and to appropriately manage information and means to complete set goals. Another practical possibility is that individuals with better EF metacognitive skills are more prone in the first place to perform the necessary mental and behavioral tasks required for initiation, structure, organization physical activity tasks.

Regarding EF behavioral regulation skills, participants' physical activity did not significantly predict self-report ratings of EF behavioral regulations. This was a surprising finding in that multiple studies have documented a link between EF inhibition skills and physical activity outcomes (e.g., Guiney & Machado, 2013; Hillman et al., 2003). For example, Chu et al., (2015) indicated that college students who engaged in thirty minutes of aerobic exercise demonstrated significantly enhanced EF inhibition performance on laboratory tasks. Similarly, Hillman, Snook, and Jerome (2003) examined the impact of exercise on inhibitory control and concluded that aerobic exercise increased inhibitory skills related to performance accuracy. Even though our study did not find this, it is important to mention that, of the four EF behavior regulation scales (i.e., inhibit, shift, emotional regulation, and self-monitor), one EF scale, specifically, shifting was significantly linked to physical activity. This suggests that an individual's ability to smoothly transition from one activity to another is linked to physical activity. This is anticipated in that engaging in physical activity necessitates moving from a period of inactivity to partaking in physical activity. Additionally, certain types of exercise (e.g., cross fit, circuit training, triathlon training) place strong demands on the ability to switch freely from one activity to another. Thus, physical activity may be more associated with the ability to shift rather than with global behavioral regulation skills as a whole. Furthermore, when comparing the two core EF dimensions, chronic physical activity better predicted EF metacognitive skills in comparison to EF behavior regulation skills. This is an important finding that has not been documented in previous studies. This may imply that physical activity impacts an individual's ability to systematically organize, and initiate planned actions more so than inhibitory or behavioral regulation skills.

Limitations and Future Research

Several important limitations of the current study are noteworthy. First, it is difficult to infer cause and effect relationships when utilizing correlational methods. Subsequent experimental studies are needed that examine the relationship of chronic physical activity and EF. Second, EF is a multi-dimensional and complex construct. Though the current study investigated two core domains of EF (i.e., metacognitive and behavior regulation) composed of nine subscales, there are feasibly other EF skills that were not assessed. In this sense, construct under representation is a potential limitation. Third, the method that we used to calculate physical activity, though unique in ascertaining a global indicator of chronic physical activity, did not take into account body mass index (BMI) or nutritional aspects (i.e., food intake). Future studies might consider further investigating these potential moderating variables. Fourth, physical activity measurement may be improved by having subjects record activity levels in a journal or wear a device that monitors activity level (i.e., pedometer or hear rate monitor). Finally, the current study was based on a convenience sample of college students. Thus, generalizability beyond this population may be limited. Further research is needed that investigates physical activity and EF dimensions in clinical samples, children, and older adults.

Future studies may consider utilizing behavioral interventions to increase chronic physical activity in young adults. This would provide an opportunity to investigate potential EF improvements corresponding with the interventions. Regarding self-reported physical activity rates in the current study, 51% of the participants indicated that they participated in 60 minutes or less of physical activity per week. Of this group, 6% reported participating in no physical activity on a regular basis, 34% reported only light physical activity (e.g., walking) for less than one hour each week, and 11% indicated modest physical activity (e.g., yard work, weight lifting, and table tennis) for less than one hour each week. This contrasts with the U.S. Department of Health and Human Services' guidelines for adults that recommend 150 minutes of moderate to intense aerobic exercise each week. Behavioral interventions could be employed to improve these rates and potentially increase other areas of health functioning including overall EF skills and core EF dimensions.

Conclusion

Overall self-ratings of physical activity successfully predicted college students' global EF skills. Moreover when utilizing a dimensional EF approach, physical activity scores significantly predicted the EF metacognitive Index (i.e., initiating, planning and organizing scales). However scores did not predict the EF behavior regulation Index (e.g., inhibitory control). Similarly, when investigating how, and to what extent, the core EF dimensions predicted physical activity together; EF metacognitive skills were a better predictor when compared to EF behavior regulation skills. This appears to suggest that physical activity is more related to metacognitive skills, specifically, initiating, planning, and organizing skills than behavioral regulation or inhibitory control skills.

REFERENCES

Alderson, R., Hudec, K., Patros, C., & Kasper, L. (2013). Working memory deficits in adults with attention-deficit/hyperactivity disorder (ADHD): An examination of central executive and storage/rehearsal processes. *Journal of Abnormal Psychology, 122,* 532-541. doi: 10.1037/a0031742

Ali, J. (2001). The obesity epidemic. *Chemistry & Industry, 10,* 14-15. doi: 0313903923005

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: A meta-analytic review. *Neuropsychology Review, 16,* 17-42. doi: 10.1007/s11065-006-9002-x

Anderson, E. S., Winett, R. A., & Wojcik, J. R. (2007). Self-regulation, self-efficacy, outcome expectations, and social support: Social cognitive theory and nutrition behavior. *Annals of Behavioral Medicine, 34,* 304-312. doi: 10.1007/BF02874555

Anderson, P. (2002). Assessment and development of executive function (ef) during childhood. *Child Neuropsychology: A Journal of Normal and Abnormal Development in Childhood and Adolescence, 8,* 71-82. doi: 10.1076/chin.8.2.71.8724

Arent, S. M., Landers, D. M., & Etnier, J. L. (2000). The effects of exercise on mood in older adults: A meta-analytic review. *Journal of Aging and Physical Activity, 8,* 407-430. doi: 10.3389/fpsyg.2013.00187

Aron, A. R., & Poldrack, R. A. (2005). The cognitive neuroscience of response inhibition: Relevance for genetic research in attention-deficit/hyperactivity disorder. *Biology Psychiatry, 57,*1285-1292. doi: 10.1016/j.biopsych.2004.10.026

Bannon, S., Gonsalvez, C. J., Croft, R. J., & Boyce, P. M. (2002). Response inhibition deficits in obsessive-compulsive disorder. *Psychiatry Research, 110,*165-174. doi: 10.1016/S0165-1781(02)00104-X

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of adhd. *Psychological Bulletin, 121,* 65-94. doi: 10.1037/0033-2909.121.1.65

Batterink, L., Yokum, S., & Stice, E. (2010). Body mass correlates inversely with inhibitory control in response to food among adolescent girls: An FMRI study. *Neuroimage, 52,* 1696-1703. doi: 10.1016/j.neuroimage.2010.05.059

Berchicci, M., Lucci, G., & Di Russo, F. (2013). Benefits of physical exercise on the aging brain: The role of the pre-frontal cortex. *Journals of Gerontology, 68,* 1337-1341. doi: 10.1093/gerona/glt094

Berlin, L., Bohlin, G., Nyberg, L., & Janols, L. (2004). How well do measures of inhibition and other executive functions discriminate between children with ADHD and controls. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 10,* 1-13. doi: 10.1076/chin.10.1.1.26243

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30,* 331-551. doi: 10.1016/j.dr.2010.08.001

Booth, F. W., Gordon, S. E., Carlson, C. J., Hamilton, M.T. (2000). Waging war on modern chronic diseases: Primary prevention through exercise biology. *Journal of Applied Physiology, 88,* 774-787. doi: 10.1111/j.1600-0838.2000.100509.x

Brown, T. E. (2005). Attention deficit disorder: The unfocused mind in children and adults. [DX Reader version]. Retrieved from http://www.drthomasebrown.com/ pdfs/brownChapter.pdf

Brownson, R. C., Boehmer, T. K., & Luke, D.A. (2005). Declining rates of physical activity in the United States: What are the contributors? *Annual Public Health, 26*, 421-443. doi: 10.1146/annurev.publhealth.26.021304.144437

Casaburi, R. Porszasz, J., Burns, M. R., Carithers, E. R., Chang, R. S., & Cooper (1997). Physiologic benefits of exercise training in rehabilitation of patients with severe chronic obstructive pulmonary disease. *American Journal of Respiratory and Critical Care Medicine, 155,* 1541-1551. doi: 10.1164/ajrccm.155.5.9154855

Caspersen, C. J., Pereira, M. A., & Curran, Katy. M. (2000). Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Medicine & Science, Sports & Exercise, 32*, 1601-1609. doi: 10.1097/00005768-200009000-00013

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise and physical fitness: Definitions and distinctions for health related research. *Public Health. 100,* 126-130. doi: 10.1007/s00296-015-3292-3

Castelli, W. P. (1984). Epidemiology of coronary heart disease: The Framingham study. *The American Journal of Medicine, 76,* 4-12. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6702862

Chu, C. H., Alderman, B. L., Wei, G. X., & Chang, Y.K. (2015). Effects of acute aerobic exercise on motor response inhibition: An erp study using the stop-signal task. *Journal of Sport and Health Science, 4,* 73-81. doi:10.1016/j.jshs.2014.12.002.

Colberg, S. R., Sigal, R. J., Fernhall, B., Regensteiner, J. G., Blissmer, B. J., Rubin, R., … Braun. B. (2010). The American college of sports medicine and the American diabetes association: Joint position statement executive summary. *Diabetes Care, 33,* 2692-2696. doi: 10.2337/dc10-1548

Colcombe, S. J., Erickson, K. I., Scalf, P. E., Kim, J. S., Prakash, R., McAuley, E., … Kramer, A. F. (2006). Aerobic exercise training increases brain volume in aging humans. *Journal of Geronotology: Medical Sciences, 61,* 1166-1170. doi: 10.1093/gerona/58.2.M176

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14,* 125-130. doi: 10.1111/1467-9280.t01-1-01430

Collette, F., Hogge, M., Salmon, E., & Van der Linden, M. (2006). Exploration of the neural substrates of executive functioning by functional neuroimaging. *Neuroscience, 139,* 209-221. doi: 10.1016/j.neuroscience.2005.05.035

Conway, A. R., Jarrold, C., Kane, M., Miyake, A., Towse, J. N. (2007). *Variations in working memory.* New York, NY: Oxford University Press.

Cotman, C. W., & Berchtold, N. C. (2002). Exercise: A behavioral intervention to enhance brain health and plasticity. *TRENDS in Neuroscience, 25,* 295-301. doi: 10.1016/S0166-2236(02)02143-4

Cotman, C. W, Berchtold, N. C., & Christie, L. (2007). Exercise builds brain health: Key roles of growth factor cascades and inflammation. *TRENDS in Neuroscience, 30,* 464-472. doi: 10.1016/j.tins.2007.06.011

Cowan, R. S. (1976). The industrial revolution in the home: Household technology and social change in the 20th century. *Technology and Culture, 17,* 1-23. doi: 10.2307/3103251

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., … Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized controlled trial. *Health Psychology, 30,* 91-98. doi: 10.1037/a0021766

Deforch, B., Dyck, D. V., Deliens, T., & De Bourdeaudhuji, I. (2015). Changes in weight, physical activity, sedentary behavior, and dietary intake during the transition to higher education: A prospective study. *International Journal of Behavioral Nutrition, 12,* 1-10. doi: 10.1249/MSS.0b013e3181c9216b

Denckla, M.B. (1994). Measurement of executive functioning. In G.R. Lyon (Ed.), *Frames of reference for the assessment of learning disabilities: New views on measurement issues* (pp.117-142). Baltimore, MD: Paul H. Brookes.

Denckla, M. B. (1996). A theory and model of executive function: A neuropsychological perspective. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 263-278). Baltimore, MD: Paul H. Brookes.

Dimeo, F., Pagonas, N., Seibert, F., Arndt, R., Zidek, W., Westhoff. T. H. (2012). Aerobic exercise reduces blood pressure in resistant hypertension. *Hypertension, 60,* 653-658. doi: 10.1161/HYPERTENSIONAHA.112.197780

Duncan, J., Johnson, R., Swales, M., & Freer, C. (1997). Frontal lobe deficits after head injury: Unity and diversity of function. *Cognitive Neuropsychology, 14,* 713-741. doi: 10.1080/026432997381420

Elliott, R., & Deakin, B. (2005). Role of the orbitofrontal cortex in reinforcement processing and inhibitory control: Evidence from functional magnetic resonance imaging studies in healthy human subjects. *International Review of Neurobiology, 65,* 89-116. doi: 10.1016/S0074-7742(04)65004-5

Filla, C., Hays, N. P., Gonzales, D., & Hakkak, R. (2013). Self-reported changes in weight, food intake, and physical activity from high school to college. *Nutritional Disorders & Therapy*, 3, 129. doi: 10.4172/2161-0509.1000129

Flex, S. J. (1999). Periodized strength training: A critical review. *Journal of Strength and Conditioning Research, 13,* 82-89. doi: 10.1080/02640414.2015.1022574

Flynn, N., & James, J. E. (2009). Relative effects of demand and control on task-related cardiovascular reactivity, task perceptions, performance accuracy, and mood. *International Journal of Psychophysiology, 72,* 217-227. doi: 10.1016/j.ijpsycho.2008.12.006

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection. *Journal of Memory and Language, 29,* 336-360. doi: 10.1016/0749-596X(90)90004-J

Garon, N., Bryson, S. E., & Smith. I., M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134,* 31-60. doi: 10.1037/0033-2909.134.1.31

Garavan, H., Ross, T. J., Murphy, K., Roche, R. A., & Stein, E. A. (2002). Dissociable executive functions in the dynamic control of behavior: Inhibition, error detection, and correction. *NeuroImage, 17,* 1820-1829. doi: 10.1006/nimg.2002.1326.

Geldorp, B. V., Heringa, S. M., Berg, E. V., Olde Rikkert, M. G., Biessels, G. J., & Kessels, R. P. (2015). Working memory binding and episodic memory formation in aging, mild cognitive impairment and Alzheimer's dementia. *Journal of Clinical and Experimental Neuropsychology, 37,* 538-548. doi: 10.1080/13803395.2015.1037722

Gioia, G. A., Isquith, P. K., Retzlaff, P. D., & Espy, K. A. (2002). Confirmatory factor analysis of the behavior rating inventory of executive function (BRIEF) in a clinical sample. *Child Neuropsychology: A Journal of Normal and Abnormal Development in Childhood and Adolescence, 8,* 249-257. doi: 10.1076/chin.8.4.249.13513

Gilen, S., Schuler, G., & Adams, V. (2010). Cardiovascular effects of exercise training molecular mechanisms. *Circulation, 122,* 1221-1238. doi: 10.1161/CIRCULATIONAHA.110.939959

Gordon-Larsen, P., McMurray, R. G., & Popkin, B. M. (2000). Determinants of adolescent physical activity and inactivity patterns. *Pediatrics, 105,* 83. doi: 10.1542/peds.105.6.e83.

Guiney, H., & Machado, L. (2013). Benefits of regular aerobic exercise for executive functioning in healthy populations. *Psychology Bulletin Review, 20,* 73-86. doi: 10.3758/s13423-012-0345-4.

Hallal, P.C., Andersen, L. B., Bull, F., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet, 380,* 247-257. doi:10.1016?S0140-6763(12)60646-1.

Hamilton, M. T., Healy, G. N., Dunstan, D.W., Zderic, T. W., & Owen, N. (2008). Too little exercise and too much sitting: Inactivity physiology and the need for new recommendations on sedentary behavior. *Current Cardiovascular Risk Response, 2,* 292-298. doi: 10.1007/s12170-008-0054-8.

Haskell, W. L., Lee, I. M., Pate, R.R., Powell, K.E., Blair, S. N., Franklin, B.A., ... Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116,* 1081-1093. doi: 10.1161/CIRCULATION.107.185649.

Hill, E. L. (2004). Executive dysfunction in autism. *TRENDS in Cognitive Sciences, 8,* 26-32. doi: 13646613.

Hillman, C. H., Erickson, K. I., & Kramer, A.F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature, 9,* 58-65. doi: 10.1038/nrn2298

Hillman, C. H., Snook E. M., & Jerome G. J. (2003). Acute cardiovascular exercise and executive control function. *International Journal of Psychophysiology*, *48*, 307-314. doi: 10.1016/S0167-8760(03)00080-1

Hogervorst, E., Riedel, W., Jeukendrup, A., & Jolles, J. (1996). Cognitive performance after strenuous physical exercise. *Perceptual and Motor Skills, 83,* 479-488. doi: 10.2466/pms.1996.83.2.479

Janssen, I., Katzmarzyk, P. T., Boyce, W. F., Vereccken, C., Mulvihill, C., Roberts, C., . . . Pickett, W. (2005). Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obesity Reviews, 6,* 123-132. doi: 10.1111/j.1467-789X.2005.00176.x

Kamijo, K., & Takeda, Y. (2009). General physical activity levels influence positive and negative priming effects in young adults. *Clinical Neurophysiology, 120,* 511-519. doi: 10.1016/j.clinph.2008.11.022

Kraemer, W. J., & Ratamess, N. A. (2004). Fundamentals of resistance training: Progression and exercise prescription. *The American College of Sports Medicine, 36,* 674-688. doi: 10.1249/01.MSS.0000121945.36635.61.

Kramer, A. F., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: Influence of physical activity on cognition and brain function. *TRENDS in Cognitive Sciences, 11,* 342-348. doi: 10.1016/j.tics.2007.06.009.

Kramer, A. F., Erickson, K. I., and Colcombe, S. J. (2006). Exercise, cognition and the aging brain. *Journal of Applied Physiology, 101,* 1237-1242. doi: 10.1152/japplphysiol.000500.2006.

Kramer, A., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., … Colcombe, A. (1999). Ageing fitness and neurocognitive function. *Nature, 400,* 418-419. doi:10.1038/22682

Ladabaum, U., Mannalithara, A., Myer, P. A., & Singh, G. (2014). Obesity, abdominal obesity, physical activity, and caloric intake in US adults: 1988 to 2010. *The American Journal of Medicine, 127,* 717-727. doi: 10.1016/j.amjmed.2014.02.026

Levy, R., & Goldman-Rakic, P. S. (2000). Segregation of working memory functions within the dorsolateral prefrontal cortex. *Experimental Brain Research, 133,* 23-32. doi: 10.1007/s002210000397.

Loprinizi, P. D., & Kane, C. J. (2015). Exercise and cognitive function: A randomized controlled trial examining acute exercise and free-living physical activity and sedentary effects. *Mayo Clinical Proceedings, 90,* 450-460. doi: 10.1016/j.mayocp.2014.12.023.

MacLeod, C. M. (2007). The concept of inhibition in cognition. In D. S. Gorfein and C. M. MacLeod (Eds.), *Inhibition in cognition* (pp. 3-23). Washington, DC: American Psychological Association.

Meltzer, L., & Krishman, K. (2007). Executive function difficulties and learning disabilities: Understanding and misunderstanding. In L.Meltzer (Eds.), *Executive function in education: From theory to practice* (pp. 77-105). New York, NY: Guilford Press.

Menghini, D., Finzi, A., Carlesimo, G., and Vicari, S. (2011). Working memory impairment in children with developmental dyslexia: Is it just a phonological deficit? *Developmental Neuropsychology, 36,* 199-213. doi: 10.1080/87565641.2010.549868.

Meyer, J. S. & Quenzer, L. F. (2013). *Psychopharmacology drugs, the brain, and behavior, second edition.* Sunderland, Maine: Sinauer Associates, Inc.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A., & Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100. doi: 10.1006/cogp.1999.0734

Moran, S. & Gardner, H. (2007). Hill, skill, and will: Executive function from a multiple-intelligences perspective. In L. Meltzer (Ed.). *Executive function in education from theory to practice*. (pp. 55-70). New York, NY: Guildford Press.

Nederkoom, C., Jansen, E., Mulkens, S., & Jansen, A. (2007) Impulsivity predicts treatment outcome in obese children. *Behaviour Research and Therapy, 45,* 1071-1075. doi: 1016/j.brat.2006.05.009

Passolunghi, C. M., & Siegel, L. S. (2004). Working memory and access to numerical information in children with disability in mathematics. *Journal of Experimental Child Psychology, 88,* 348-367. doi: 10.1016/j.jecp.2004.04.002

Pendeo, F. J., & Dahn, J. R. (2005). Exercise and well-being: A review of mental and physical health benefits associated with physical activity. *Behavioural Medicine, 18,* 189-193. doi: 10.1097/00001504-200503000-00013

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity, 2,* 16-22. doi: 10.1016/j.mhpa.2009.02.001

Peterson, J. C., Charlson, M. E., Wells, M. T., & Altemus, M. (2014). Depression, coronary artery disease, and physical activity: How much exercise is enough? *Clinical Therapeutics, 36,* 1518-1530. doi: 10.1016/j.clinthera.2014.10.003.

Petrides, M. (2000). The role of the mid dorsolateral prefrontal cortex in working memory. *Experimental Brain Research, 133, 44-54.*

Petruzzello, S. J., Landers, D. M., Hatifield, B. D., Kubitz, K. A., & Salazar, W. (1991). A meta analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11,* 143-182. doi: 10.1186/s12966-015-0201-9

Pontifex, M. B., Hillman, C. H., Fernhall, B., Thompson, K. M., Valentinit, T. A. (2009). The effect of acute aerobic and resistance exercise on working memory. *Medicine.Science.Sports.Exercise, 41*, 927-934. doi: 10.1249/MSS.0b013e3181907d69

Racette, S. B., Deusinger, S. S., Strube, M. J., Highstein, G. R., & Deusinger, R. H. (2005). Weight changes, exercise, and dietary patterns during freshman and sophomore years of college. *Journal of American College Health, 53,* 245-251.

Raichlen, D. A., & Gordon, A. D. (2011). Relationship between exercise capacity and brain size in mammals. *PLos ONE, 6*. doi: 10.1371/journal.pone.0020601

Raichlen, D. A., & Polk, J. D. (2012). Linking brains and brawn: Exercise and the evolution of human neurobiology. *Proceedings, Biological Sciences/ The Royal Society, 280*. doi: 10.1098/rspb.2012.2250

Reid, K. J., Baron, K. G., Lu, B. Naylor, E., Wolfe., & Zee, P. C. (2010). Aerobic exercise improves self-reported sleep quality of life in older adults with insomnia. *Sleep Medicine, 11,* 934-940. doi:10.1016/j.sleep.2010.04.014

Redick, T., Calvo, A., Gay, C., & Engle, R. (2011). Working memory capacity and go/no-go task performance: Selective effects of updating, maintenance, and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37,* 308-324. doi: 10.1037/a0022216

Rognmo, O., Hetland, E., Helgerud, J., Hoff, J., & Slordahl, S. A. (2004). High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *The European Society of Cardiology, 11,* 216-221. doi: 10.1097/01.hjr.0000131677.96762.0c

Rolls, E. T. (2000). The orbitofrontal cortex and reward. *Cerebral Cortex, 10,* 284-294. doi: 10.1093/cercor/10.3.284

Rolls, E. T. (2003). The functions of the orbitofrontal cortex. *Brain and Cognition, 55,* 11-29. doi: 10.1016/S0278-2626(03)00277-X

Roth, R., Isquith, P., Gioia, G. (2005). *Behavior rating inventory of executive functioning-adult version (BRIEF-A)*. Lutz, FL: Psychological Assessment Resources.

Ryan, A.S., Shealinna, G., Blumenthal J. B., Serra, M. C., Prior., S. J., Golberg, A. P. (2014). Aerobic exercise and weight loss reduce vascular markers of inflammation and improve insulin sensitivity in obese women. *Journal of American Geriatrics Society, 62,* 607-614. doi: 10.1111/jgs.12749

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: A unifying theory. *Clinical Psychology Review, 21,* 33-61. doi: 10.3389/fpsyt.2013.00027

Salthous, T. A., Atkins, T. M., & Berish D.E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology: General, 132,* 566-594. doi: 10.1037/0096-3445.132.4.566

Schjerve, I. E., Tyldum, G. A., Tjonna, A. E., Stolen, T., Loennechen, J. P., Hansen, H. E. …Wisloff, U. (2008). Both aerobic endurance and strength training programmes improve cardiovascular health in obese adults. *Clinical Science, 115,* 283-293. doi: 10.1042/CS20070332

Shephard, R. J., & Balady, G. J. (1999). Exercise as cardiovascular therapy. *Circulation, 99,* 963-972. doi: 10.1161/01.CIR.99.7.963

Sibley, B. A., Etnier, J. L., & Le Masurier, G. C. (2006). Effects of an acute bout of exercise on cognitive aspects of stroop performance. *Journal of Sports and Exercise Psychology, 28,* 285-299. Retrieved from http://journals .humankinetics.com/AcuCustom/Sitename /Documents/DocumentItem/6056.pdf

Stohle, A. (2009). Physical activity, exercise, depression and anxiety disorder. *Journal of Neural Transmission, 116*, 777-7784. doi: 10.1007/s00702-008-0092-x

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662. doi: 10.1037/h0054651

Smith, P.J., Blumenthal, J. A., Hoffman, B. M., Cooper, H., Strauman, T. A., Welsh-Bohmer, … Sherwood, A. (2010). Aerobic exercise and neurocognitive performance: A meta-analytic review of randomized controlled trials. *Psychosomatic Medicine, 73,* 239-252. doi: 10.1097/PSY.0b013e3181d14633

Smith, A., & Jonides, J. (1998). Neuroimaging analyses of human working memory. *Proceedings of the National Academy of Sciences, USA, 95,* 12061-12068. doi: 10.1073/pnas.95.20.12061

St. Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59,* 745-759. doi: 10.1080/17470210500162854

Sundell, J. (2010). Resistance training is an effective tool against metabolic frailty syndromes. *Advances in Preventive Medicine, 2011,* 1-7. doi:10.4061/2011/984683

Sothern, M.S., Loftin, M., Suskind, R. M., Udall, J. N., & Blecker, U. (1999). The health benefits of physical activity in children and adolescents: Implications for chronic disease prevention. *European Journal of Pediatrics, 158,* 271-274. doi: 10.1007/s004310051070

Taras, D., & Potts-Datema, W. (2005). Obesity and student performance at school. *Journal of School Health, 75,* 291-295. doi: 10.1111/j.1746-1561.2005.tb07346.x

Teuber, H. L. (1972). Unity and diversity of frontal lobe functions. *Acta Neurobiology Experimental, 32,* 675-656. doi: 10.1006/cogp.1999.0734

Thomas, D. Elliott, E. J., & Naughton, G. A. (2006). Exercise for type 2 diabetes mellitus. *Cochrane Database of Systematic Reviews, 3,* doi: 10.1002/14651858.CD002968.pub2

Thompson, P.D., Bauchner, D., Pina, I. L., Balady, G. J., Williams, M. A., Marcus, B. H. … Wenger, N. K. (2003). Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease. *Circulation, 107,* 3109-3116. doi: 10.1161/01.CIR.0000075572.40158.77

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychological Review, 20,* 111-131. doi: 10.1007/s10648-007-9057-0

Tremblay, M. S., Colley, R. C., Saunders, T.J., Healy, G.N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. Applied. Physiology. *Nutrition, Metabolism, 35,* 725-740. doi: 10.1139/H10-079

Umpierre, D., Ribeiro, P. A., Kramer, C. K., Leitao, C. B., Zucatti, A. T., Azevedo, M. J., . . .Schaan, B.D. (2011). Physical activity advice only or structured exercise training and association with HbA_{1c} levels in type 2 diabeties: A systematic review and meta-analysis. *American Medical Journal, 305,* 1791-1799. doi: 10.1001/jama.2011.576

Van Pragg, H., Christie, B. R., Sejnowski, T. J., & Gage, F. H. (1999). Running enhances neurogenesis, learning, and long-term potentiation in mice. *Proceedings of the National Academy of Sciences*, *96*, 13427-13431.

Van Pragg, H., Shubert, T., Zhao, C., & Gage, F. H. (2005). Exercise enhances learning and hippocampal neurogenesis in aged mice. *The Journal of Neuroscience*, *25*, 8680-8685.

Verburgh, L., Konigs, M., Scherder, E. J., Oosterlaan, J. (2013). Physical exercise and executive functions in preadolescent children, adolescents, and young adults: A meta-analysis. *British Journal of Sports Medicine, 0,* 1-8. doi: 10.1136/bjsports-2012-091441

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: the evidence. *Canadian Medical Association Journal, 176,* doi: 10.1503/cmaj.051351

Weinstein, A. M., Voss, M. W., Prakash, R. S., Chaddock, L., Szabo, A., Siobhan, M., … Erickson, K. I. (2012). The association between aerobic fitness and executive function is mediated by prefrontal cortex volume. *Brain Behavioral Immune, 26,* 811-819. doi: 10.1016/j.bbi.2011.11.008

Wellsource Inc. (1998). ‘Personal Wellness Profile – Questionnaire’ Wellsource Inc., Oregon.

Whelton, S. P., Chin, A., & Xin, X. (2002). Effect of aerobic exercise on blood pressure: A meta-analysis of randomized, controlled trials. *Annual Internal Medicine, 136,* 493-503. doi: 10.7326/0003-4819-136-7-200204020-00006

Winett, R. A., & Carpinelli, R. N. (2002). Potential health-related benefits of resistance training. *Preventive Medicine, 33,* 503-513. doi: 10.1006/pmed.2001.0909

APPENDICES

APPENDIX A

Physical Wellness Profile

1. **Exercise.** How many days per week do you engage in aerobic exercise of at least 20 to 30 minutes in duration (brisk walking, cycling, Jogging, swimming, aerobic dance, active sports or gardening?

(0) no exercise program
(1) one day per week
(2) two days per week
(3) three days per week
(4) four days per week
(5) five days per week
(6) six days per week
(7) seven days per week

2. **Physical activity status.** Mark the response that best describes your current activity level.
    1. I have **no regular exercise** program, generally avoid walking or exertion when possible.
    2. I **occasionally** walk for pleasure or exercise sufficiently to cause heavy breathing or perspiration (sweat).
    3. I get regular exercise in work or recreation requiring **modest physical activity** such as golf, yard work, calisthenics, weight lifting, table tennis, **up to 1 hour per week.**
    4. I get regular exercise in work or recreation requiring **modest physical activity** such as golf, yard work, calisthenics, weight lifting, table tennis**, more than 1 hour per week.**
    5. I participate regularly in **more active physical exercise** (brisk walking jogging, swimming cycling, rowing, active sports like tennis or handball). <u>If yes, indicate how much time you spend exercising</u> **each week.**

(1) less than 1 hour per week
(2) 1hour, or run up to 5 miles weekly
(3) 2 to 3 hours, or run 6 to 10 miles weekly
(4) 4 to 5 hours, or run 11 to 15 miles weekly
(5) 6 to 8 hours, or run 16 to 20 miles weekly
(6) 9 to 11 hours, or run 21 to 25 miles weekly
(7) 12+ hours, or run 26+ miles weekly

3. **Strength exercises.** How many times per week do you do strength-building exercises such as sit-ups, push-ups, or use weight training equipment?

(0) none
(1) once a week
(2) twice a week
(3) three plus times weekly

4. **Stretching exercise.** How many times per week do you do stretching exercises to improve flexibility of your back, neck, shoulders, and legs?

(0) none
(1) once a week
(2) twice a week
(3) three plus times weekly

APPENDIX B

Physical Wellness Profile Scoring Procedure

Physical Activity Question 1

Aerobic Exercise	Score
No Regular Exercise	10
1 days per week	24
2 days per week	40
3 days per week	55
4 days per week	65
5 days per week	80
6 days per week	90
7 days per week	100

Physical Activity Question 2

Physical Activity Level	Score
No Regular Exercise	10
Occasionally	20
Modest Activity < 1 hour per week	28
Modest Activity > 1 hour per week	30
Less than 1 hour per week	35
1 hour, or run up to 5 miles weekly	45
2 to 3 hours, or run 6 to 10 miles weekly	60
4 to 5 hours, or run 11 to 15 miles weekly	70
6 to 8 hours, or run 16 to 20 miles weekly	80
9 to 11 hours, or run 21 to 25 miles weekly	90
12+ hours, or run 26+ miles weekly	100

Physical Activity Question 3

Strength Exercises	Score
None	15
Once a week	45
Twice a week	65
Three plus times weekly	90

Physical Activity Question 4

Stretching Exercises	Score
None	15
Once a week	45
Twice a week	65
Three plus times weekly	90

Note. Every participant received a score for each question based on their response. A Physical Activity Composite score is derived by adding the four scores (one from each table above) and dividing by 4. Higher scores indicate increased physical activity levels.

APPENDIX C

IRB Approval

9/11/2012

Names: Christy Elliott

Protocol Title: Executive Functioning and Physical Wellness

Protocol Number: 13-034

Elliottpc@bellsouth.net

Dear Investigator,

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 and 21 CFR 56.110.

Approval is granted for one (1) year from the date of this letter for 200 participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Andrew Jones, Box 134) before they begin to work on the project. Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

This protocol will expire 9/11/2013. You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

William H. Leggett

MTSU Institutional Review Board