EFFECT OF AN ACUTE AEROBIC VS. RESISTANCE VS. AEROBIC-RESISTANCE EXERCISE BOUT ON COGNITION AND BRAIN-DERIVED NEUROTROPHIC FACTOR (BDNF)

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ABSTRACT

Purpose: This study examined the effect of an acute aerobic vs. resistance vs. aerobic-resistance exercise bout on cognition and brain-derived neurotrophic factor (BDNF).

Methods: Ten healthy, physically active and/or trained subjects (5 males, 5 females: age 27.9 ± 8.1 yrs) performed three acute exercise sessions: a 30 minute run at ~85% max heart rate (MHR), a 15 minute run at ~85% MHR followed by a 15 minute super-set resistance training bout, and a 30 minute super-set resistance training bout in a random cross-over design. Pre, immediately post (post), and 30-minutes post (post 30) exercise, BDNF and Stroop Incongruent tests were administered.

Results: BDNF levels were significantly greater at post measurement compared to pre (p < .05). Post levels were significantly less than post 30 (p < .05); there were no differences between pre and post 30 (p ≥ .05). There were no statistically significant differences in BDNF across the exercises (p ≥ .05). The Stroop Incongruent times were significantly quicker at post compared to pre (p < .05); there were no significant differences in mean reaction times between post and post 30 (p = .246) or between pre and post 30 (p = .078). There were no significant differences in reaction times across the exercises (p ≥ .05).

Conclusion: Under the study conditions, all modalities elicited a significant rise in BDNF and a cognition improvement with no mode demonstrating a greater effect than another. These findings provide indicate that more than one mode of exercise may prove promising in neuronal and cognitive health.
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CHAPTER I

INTRODUCTION

It is well known that aerobic exercise can help prevent obesity, heart disease, stroke, hypertension, diabetes, and certain cancers. Resistance exercise has positive effects on body composition, insulin sensitivity, muscular strength, muscle mass, and bone density (McArdle, Katch, & Katch, 2015; Nieman, 2011). Exercise has also been shown to have positive effects on brain health including: reduced depression, slowing of Alzheimer’s disease progression, improved brain structure and improved cognitive function (Erickson, Miller & Roecklein, 2012; Huang, Larsen, Ried-Larsen, Moller, & Anderson, 2014; Piepmeier & Etnier, 2015; Voss, Nagamatsu, Liu-Ambrose, & Kramer, 2011; Yarrow, White, McCoy & Borst, 2010). Recent research has shown that brain-derived neurotrophic factor (BDNF) is a powerful facilitator in the benefits of exercise on brain health (Huang et al., 2014; Yarrow et al., 2010). BDNF is located in high concentrations in the hippocampus, hypothalamus, cerebellum and cortex (Erickson et al., 2012). BDNF is a growth factor involved with protection against neurodegeneration by aiding in generating and nourishing neurons (Chang, Chu, Chen & Wang, 2011; Chang & Etnier, 2009) and assisting in their synaptic growth and neuroplasticity (Pontifex,
With aging, portions of the brain atrophy at varying rates. Erickson et al. (2012) suggested a 1%-2% annual atrophy in the hippocampus in non-dementia individuals older than 55 years. The hippocampus region of the brain controls memory, cognition and emotions. It also houses high concentrations of BDNF. Numerous studies have been conducted on varying types of chronic and acute exercise effects on both BDNF and cognition in college-aged or elderly subjects. Pontifex et al. (2009) have suggested a further heightened interest in a single session of exercise and its effects on cognition, as well as other health benefits specifically where aerobic and resistance-training exercises are combined.

**Purpose**

The purpose of this study was to determine and compare the effect of an acute aerobic, resistance, or aerobic-resistance exercise bout on cognition and BDNF.

**Hypothesis**

The expected outcome was that there would be experience a rise in BDNF and an improvement in cognition with all modalities, but the aerobic trial would elicit a greater effect than the other two modes.
CHAPTER II
LITERATURE REVIEW

Overview of BDNF

BDNF is a member of the neurotrophin family. These proteins are highly important in generating and nourishing neurons, maintaining neuroplasticity and protection against neurodegeneration. (Bathina & Das, 2014; Erikson et al., 2012; Kandola, Hendrikse, Lucassen & Yucel, 2016; Knaepen, Maaike, Heyman & Meusen, 2010). BDNF specifically assists in these processes through a signaling pathway involving tropomyosin-related kinase (TrkB) (Bathina & Das, 2014; Erikson et al., 2012).

BDNF is initially synthesized as a precursor protein called “preproBDNF” within the endoplasmic reticulum of a cell. Cleavage of preproBDNF allows proBDNF to move through the Golgi apparatus to either bind with receptor p75NTR, which is related to neuron cell death, or to be synthesized into mature BDNF (mBDNF) by an enzyme called tissue-type plasminogen activator (tPA). The mBDNF has a high affinity for its receptor tropomyosin-related kinase B (trkB). This binding elicits a series of signaling events with the end result being neurogenesis, plasticity and degradation prevention (Bathina & Das,
Circulating BDNF is mainly, but not solely, attributed to that synthesized within the brain in healthy populations (Knaepen et al., 2010). BDNF is also a myokine. Skeletal muscles produce BDNF and muscle contractions during exercise increase this production. As BDNF mRNA production increases during physical activity, it is not released into circulation, but is associated with an increase in fat oxidation within the skeletal muscles in an AMPK-dependent pathway (Matthews et al., 2009; Pedersen, 2011).

BDNF has also been shown to be involved in energy homeostasis. Increased levels of BDNF suppress appetite and decrease energy intake, resulting in a decrease in body weight. There is also a correlation with LDL cholesterol, total cholesterol and triglycerides in that excess amounts of dietary fat and cholesterol, as well as that in the blood, decreases synthesis of BDNF causing neuron degradation (Bathina & Das, 2014; Knaepen et al., 2010).

**Hippocampal Health, BDNF and Exercise**

The hippocampus is a portion of the brain essential for memory, cognition and affective processing. Hippocampus atrophy and decreased neurotrophic factor family presence is associated with dementia, Alzheimer’s disease, Parkinson’s disease, mental disorders, and other neurological disorders (Erikson et al., 2011; Erikson et al., 2012; Kendola et al., 2016).

Research surrounding the molecular signaling and pathways associated with hippocampal mass, health and relatable cognition has become of significant interest recently (Erikson et al., 2012). According to an animal study by Ding et al., (2012),
BDNF, along with trkB, is recognized as a positive factor in hippocampal volume, cognition and memory. Within the central nervous system (CNS), including the hippocampus, the enzyme tPA is extensively dispersed where it is important for BDNF transformation and synaptic plasticity. The purpose of this study was to determine if exercise is capable of using tPA to regulate BDNF processing in the hippocampus (Ding et al., 2012). Twenty-eight adult male rats were randomized into four groups; sedentary, exercise, sedentary tPA-STOP, and exercise tPA-STOP. Those in the exercise groups were provided an exercise wheel and those in the sedentary group were placed in a cage without access to a wheel for 7 days. Those in the exercise and sedentary tPA-STOP groups had the substance injected into the hippocampus to block tPA. Upon being sacrificed, the hippocampus of each was dissected and prepared for protein analysis. Results showed that exercise elevated levels of proBDNF to 148% and mBDNF to 211% as compared to the sedentary group. Those in the exercise group with the infusion of tPA-STOP showed proBDNF levels dropped from 148% to 107% and mBDNF levels from 211% to 96%. Those in the sedentary tPA-STOP group showed mBDNF levels 79% lower than those in the sedentary group but a 158% increase in proBDNF. The application of tPA-STOP reduced the exercise induced enzyme activity from 160% to 72% as compared to the control exercise group. The tPA-STOP infusion also affected the necessary phosphorylation steps in BDNF signaling. From these results, Ding et al. (2012) determined that exercise influences the levels of proBDNF, tPA and mBDNF and that the activation of tPA is an essential step in exercise BDNF regulation. If tPA is blocked, the downstream effect decreases the actions of BDNF on neuron health and cognition (Ding et al., 2012).
It is well understood that BDNF is a major factor in the effects of exercise on hippocampal health. However, since BDNF cleaved within skeletal muscles has been shown to remain within the muscles, research has yet to determine how exercise increases BDNF within the hippocampus. Moon et al. (2016) reported a novel, peripheral myokine, cathepsin B(CTSB), may cross the blood brain barrier and play a role in the signaling pathway associated with muscular activity and its effects on BDNF and hippocampal health. In a review of this study, Suzuki (2016), explained that rodents were first tested to discover an increase in plasma levels of CTSB with wheel running. Rodent hippocampus slices showed that plasma CTSB crosses the blood brain barrier and increases hippocampal BDNF expression (Suzuki, 2016). Cognition was also improved as tested by the Morris water maze task. According to Suzuki (2016), Moon et al. (2016) then tested humans and discovered that four months of treadmill running also increased plasma levels of CTSB and improved cognitive function, as correlated with performances on a complex figure drawing recall test associated with hippocampal function (2016). These are novel findings within the area of neurotrophic signaling and hippocampal function in which further research is needed (Suzuki, 2016), but provides insight to a direct link between acute exercise and cognitive function.

**Acute Aerobic Exercise, Cognition and BDNF**

Studies have been conducted on both chronic and acute bouts of aerobic exercise of varying intensities with the majority of studies showing exercise having a positive effect on BDNF and cognition (Chang et al., 2014; Erickson et al., 2012; Ferris, Williams, & Shen, 2007; Piepmeier & Etnier 2015; Voss et al., 2011). Regarding acute aerobic exercise, several multi-study reviews reported positive findings on cognition and
BDNF (Erickson et al., 2012; Huang et al., 2014; Piepmeier & Etnier, 2015; Voss et al., 2011;). The vast majority of the studies reviewed were of college-aged subjects performing running or cycling exercise bouts ranging from 20 to 75 minutes of low, moderate or high intensity. Piepmeier & Etnier (2015) reviewed seven studies that all showed BDNF levels increased and cognitive performance improved following an acute bout of aerobic exercise. Of particular interest was how the intensity of acute aerobic exercise affected cognition and BDNF. It seems that there is a transient rise from moderate to high intensity aerobic exercise in peripheral BDNF, thereby counteracting potential negative effects on cognition in the aging brain (Chang et al., 2014; Erickson et al., 2012; Ferris et al., 2007; Piepmeier & Etnier, 2015; Voss et al., 2011).

Ferris et al. (2007) had 15 physically active subjects (11 males, and 4 females), mean age of 25 years, perform two, 30-minute bouts of cycling. One session was performed at ventilatory threshold (Vth) minus 20% (low intensity, ~56% VO\textsubscript{2} max) and another at Vth plus 10% (high intensity, ~75% VO\textsubscript{2} max) based on a graded exercise test (GXT). The Vth-20 trial showed a 10% rise in serum BDNF; the Vth+10 trial showed a 13% increase, and during the GXT BDNF rose 30% thereby demonstrating an intensity-dependent effect on BDNF (Ferris et al., 2007). Stroop test incongruent, a specific condition of the cognitive test, improved significantly by over six seconds. However, there was not a significant correlation between cognition and BDNF.

With regard to fitness level, Chang et al. (2014) had 25 college-aged adults (25 men, 11 women) of low, moderate and high fitness levels perform a 20 minute run at 65% VO\textsubscript{2} max. Cognition was measured by the Stroop Test under two conditions; a congruent condition in which a color was shown in its matching written word form; and
an incongruent condition in which a color was shown written in a different color. All three groups showed an improvement in both Stroop conditions. However, the low and moderate fitness level subjects showed significantly shorter response times; 38.6 milliseconds and 27.5 milliseconds faster respectively, over the high fitness level group within the incongruent Stroop condition (Chang et al., 2014). Of particular interest was the curvilinear relationship between performance and fitness level such that those of moderate fitness level had the quickest reaction times on the Stroop Test incongruent condition, both pre- and post- run.

Schmolesky, Webb, & Hansen (2013) assessed the effects of both aerobic exercise intensity and duration on BDNF. Forty- five healthy adult males, ages 18 to 25 years, were randomly assigned to one of six groups: vigorous 20 minutes at 80% heart rate reserve (HRR), vigorous 40 minutes at 80% HRR, moderate 20 minutes at 60% HRR, moderate 40 minutes at 60% HRR, control 20 minutes, and control 40 minutes. The activity groups rode cycle ergometers, while the control group remained seated. When analyzing the mean pre to post data, all activity groups experienced a BDNF increase while both control groups experienced a decrease. The highest proportion of participants that experienced a rise in serum BDNF were amongst the vigorous activity groups (Schmolesky et al., 2013).

**Acute Resistance Training, Cognition and BDNF**

Research has also been conducted on chronic and acute resistance training effects on BDNF and cognition with mixed results (Chang & Etnier, 2009; Chang et al., 2011; Erickson et al., 2012; Huang et al., 2014; Pontifex et al., 2009; Voss et al., 2011; Yarrow et al., 2010). Only one of the seven resistance training studies reviewed by Huang et al.
(2014) showed an increase in BDNF post-acute resistance training. Yarrow et al. (2010) had 20 untrained males, mean age of 21.9 years, perform five weeks of progressive resistance training. Participants were randomized into two progressive resistance training groups: traditional (TRAD) or eccentric enhanced (ECC+). TRAD consisted of bench press and squats performed for four sets of six repetitions, both concentrically and eccentrically. Rest between sets and exercises was one minute. Subjects started the five weeks lifting 52.5% one repetition max (1RM) and progressed to 75% 1RM. The ECC+ group performed squats and bench press for three sets of six repetitions. Subjects began the five weeks lifting the concentric portion at 40% 1RM and the eccentric at 100% 1RM, then progressed to 50% 1RM concentrically and 120% 1RM eccentrically. BDNF data was obtained pre-, post one minute, post 30 minutes and post 60 minutes each exercise session. Collectively, baseline BDNF levels post one minute after the first session of both groups increased 32%, and steadily decreased to 41% below baseline levels at the post 60-minute mark (Yarrow et al. 2010). After five weeks of training, baseline to immediately post exercise BDNF increased 77%, and 98% above initial BDNF baseline (Yarrow et al. 2010). This large increase in BDNF from resistance exercise is the first report that progressive resistance training may be another avenue for increasing brain proteins (Yarrow et al., 2010).

Pontifex et al. (2009) had 21 college-aged subjects (12 males, nine females; ~20 years old) perform acute aerobic or resistance exercise or seated rest to determine the effects of each on working memory via the Sternberg Task. Similar to other studies, after a 30-minute treadmill run at 60-70% HRmax, the subjects showed an improvement in working memory via reduction in reaction time on the cognition test (approximately 50
ms faster). A similar response was not induced with the resistance exercise and seated rest conditions, showing that varying modes of exercise produce different effects on cognition (Pontifex et al., 2009). Different from Yarrow et al. (2010), the resistance exercise protocol consisted of triceps press, bicep curl, lat-pull down, military press, leg curl and leg press all performed at 80% 1RM for three sets of 8-12 repetitions based on the National Strength and Conditioning Association’s (NSCA) guidelines (Pontifex et al., 2009). Between each set, participants rested 60 seconds, and then 90 seconds before moving onto the next exercise. This type of resistance training, although beneficial to muscular strength, is time consuming with the longer rest period. Pontifex et al. (2009) suggested that the differing results were due to how the metabolic and physiological demands of each mode of exercise stressed the body.

As with aerobic exercise, there has been a recent interest in the intensity and dose response to resistance training protocols and the effect on cognition. Chang and Etnier (2009) used four different resistance exercise intensities of the same weight lifting routine in search of a dose response effect on cognition. Sixty-five subjects (33 males, 32 females), mean age of ~25 years, were randomly assigned to a control group or one of three exercise intensity groups: 40%, 70% or 100% 10 RM. A baseline cognition analysis was administered using the Stroop Test and the Paced Auditory Serial Addition Task (PASAT). Post-acute resistance exercise, the tests were administered again. It is important to note that the resistance training program consisted of six exercises, performed for two sets of 10 repetitions, with 2-4 minutes rest between sets and exercises (Chang and Etnier, 2009). The results showed a linear trend ($r^2 = 11\%$) in regard to intensity and basic speed of processing in the Stroop Color condition (SC). However, a
quadratic relationship was found between intensity and the Stroop incongruent component (SCW) which measures brain executive function ($r^2 = 19\%$) (Chang and Etnier, 2009). This showed that the 70% 10 RM group performed the best on the Stroop test.

In 2011, Chang et al. used a very similar research design yielding the same outcome with middle aged adults. Thirteen females and four males, age 40 to 65 years, were stratified to a control group or one of three exercise intensity groups: 40%, 70% or 100% 10 RM. A baseline cognition test called the Tower of London (TOL) was administered, and then re-administered post exercise. The TOL requires subjects to move puzzle pieces in a specific order in the least amount of moves, as quickly as possible. Scores are calculated based on total move score, total correct score, rule violation score, time violation score, total initial time, total executive time and total planning-solving time (Chang et al., 2011). The resistance training bout consisted of nine exercises performed for two sets of 10 repetitions, with one-minute rest between sets and exercises (Chang et al., 2011). The post total correct score was significantly different among the four conditions with higher scores in the 40% 10-RM condition (13.5% higher than control; 6% higher than 100% 10-RM) and 70% 10-RM (23.8% higher than control; 16% higher than 100% 10-RM) condition showing a quadratic trend similar to Chang and Etnier’s (2009) research (Chang et al., 2011).

**Combination Exercise, Cognition and BDNF**

Research specifically targeted at combining aerobic and resistance training is extremely limited, longitudinal, focused on subjects with disease (i.e. diabetes and multiple sclerosis), and the elderly. Swift et al. (2012) investigated the effects of running,
resistance training or their combination on BDNF in subjects with Type 2 diabetes over the course of nine months. One-hundred fifty sedentary men and women with diabetes, age 30 to 75 years, were randomly assigned into one of four groups: control, aerobic, resistance or combination. Aerobic exercise was performed for 150 minutes over the course of a week at 50-80% of max VO2. The resistance group performed nine exercises, 10-12 repetitions, for 2-4 sets. The combination group performed 150 minutes of aerobic activity at 50-80% VO2 max, and only one set of nine exercises for 10-12 repetitions, over the course of a week (Swift et al., 2012). None of the modes of exercise showed a significant rise in BDNF compared to the control (Swift et al., 2012).

Murawaska-Cialowicz, Wojna, & Zuwala-Jageiello (2015) studied the effect of a three-month Crossfit training program on BDNF levels while at rest, post Wingate and post Progressive exercise test. The Progressive exercise test was done on a cycle ergometer by pedaling between 70 and 80 rpm against an initial resistance of 50 Watts which was then increased an additional 50 W every three minutes. Crossfit is a type of high intensity, circuit interval training that utilizes both resistance and cardiovascular modes. In this study, seven male subjects (age 26.8 ± 6.8 yrs) and 5 females (age 24.0 ±1.8 yrs) trained bi-weekly, 60 minutes each session in which the workouts of the day (WOD) consisted of 30 minutes of full body resistance exercises followed by 30 minutes of cardiovascular exercise. Each session elicited an average heart rate that ranged from 85 – 95% HR_{max} (Murawask-Cialowicz et al., 2015). At baseline and post three-month training, BDNF was measured at rest, after a Wingate test of anaerobic power, and after a Progressive exercise test to exhaustion. Results yielded a significant rise in resting BDNF; 55% increase in women and 45% increase in men. Pre and post Wingate BDNF
insignificantly rose in all subjects and Progressive exercise test BDNF decreased insignificantly (Murawask-Cialoweicz et al., 2015). Although the results did not produce a rise in BDNF from an acute exercise bout, the training increased resting BDNF thereby making it possible that a Crossfit type training could be beneficial to neurotrophins and cognition (Murawask-Cialowicz et al., 2015).

Several research reviews (Huang et al., 2014; Piepmeier and Etnier, 2015; and Voss et al. 2011) agree that moderate to high intensity, acute aerobic exercise elicits an increase in BDNF as well as cognition improvements, but further research is needed on resistance training. Voss et al. (2011) observed that while some may respond well to aerobic exercise and others to resistance exercise, further research is needed into the combination of these modalities.
CHAPTER III

METHODS

Research Design

The research used an experimental design to determine the effects of an acute aerobic, resistance, or aerobic-resistance exercise on BDNF and cognition. The independent variable was the exercise modes. The dependent variables were cognitive performance (Stroop Test) and serum BDNF. The study was delimited to healthy and physically active subjects, aged 18-40 years.

Subjects

The study consisted of 10 subjects (5 males, 5 females; age 27.9 ± 8.1 yrs). Subjects were healthy, physically active and/or trained and capable of at least 30 minutes of vigorous activity. Subjects were obtained through convenience sampling via flyers (Appendix C) on the Cleveland State University (CSU) campus and word of mouth.

All subjects were provided written informed consent (Appendix A) approved by the CSU Institutional Review Board (Appendix E). Each participant completed the American Heart Association (AHA) and ACSM health history questionnaire (AHA/ACSM, Appendix B) (ACSM, 2014). Only low risk subjects were included in the
study. All subjects were free of cardiopulmonary, metabolic, or musculoskeletal disease, joint conditions, arthritis, mental disorders and all were non-smokers.

**Measures**

**Stroop Cognition Test**

The Stroop Color and Word test was used for cognitive assessment. The Stroop test provides information on psychological processes and functions that affect cognition (Stroop, 1935). The incongruent condition or Stroop Color Word (SCW), consists of the words “red”, “green” or “blue” typed NOT in their respective colors (Appendix D). This condition is the most challenging on executive function, whereas other conditions of the Stroop Test measure speed. The subject had to name the color of the ink, not the word and a lower score is the better score (Ferris et al., 2007). The test-retest reliability is reported at .84 (Chang & Etnier, 2009).

**Serum Brain-derived neurotrophic factor (BDNF)**

A 5 mL blood sample was obtained via aseptic technique from the antecubital vein taken at rest, immediately post exercise, and 30- minutes post exercise, for a session total of 15 mL and study total of 45 mL. Only phlebotomy-trained individuals performed the blood draws. The blood draw site was thoroughly cleaned and sanitized with alcohol. Only sterile blood collection items were used. The researcher performing the blood draw washed their hands, and wore disposable medical rubber gloves, which were discarded upon completion of blood draw. All supplies used during the blood draw were discarded in accordance with biohazard regulations. Subjects were provided with instructions on venous blood draw during the initial fitness assessment. The samples were stored in a -80°C freezer until analyzed.
Brain derived neurotrophic factor was assessed using a commercially available enzyme-linked immunosorbent assays (ELISA) (BDNF, R&D Systems® Minneapolis, MN) and analyzed using a Bio-Tek Synergy plate reader.

**Body Composition**

Body composition was analyzed utilizing the BOD POD system (Life Measurement Instruments; Concord, CA). Whole body density was used to determine body fat percentage using the Siri equation:

\[
\% \text{ Body Fat} = \left( \frac{495}{\text{Body Density}} \right) - 450
\]

Subjects arrived on the day of testing in an over-night fasted state. Subjects wore minimal, form fitting clothing and a cloth skull cap during testing according to the device guidelines. Upon entering the Bod Pod, subjects were instructed to breath normally and remain still during the two-minute procedure.

**VO2 Max**

Prior to experimental trials, maximal aerobic power (VO2max) was measured by a treadmill graded exercise test (GXT). Participants were advised to refrain from eating three hours prior to the test. Height, weight, resting heart rate and blood pressure were measured and subjects completed the AHA/ACSM health history questionnaire (ACSM, 2014) prior to the VO2max. Subjects were allowed to warm up at a self-selected pace at 0% grade to attain 50-60% HR$_{max}$. The workload increased by 3% elevation every 3-minutes. The test was stopped when two of the following three criteria were met (or participants voluntarily opted to stop): 1- leveling off of VO2 occurred despite an increased workload; 2- Respiratory Exchange Ratio (RER) of greater than or equal to 1.15 was achieved; 3- age predicted maximum heart rate (APMHR) was achieved or
exceeded (McArdle et al., 2015). Age predicted max heart rate was determined by the Tanaka equation: $208 - (.7 \times \text{age}) = \text{Max Heart Rate}$ (ACSM, 2014). The Scott Care Telemetry System (Cleveland, OH) and Polar Heart Rate monitor (Lake Success, NY) was used to determine heart rate. The AEI Technologies Max-IIa System (Bastrop, TX) metabolic cart measured VO2max.

**Muscular Strength 1 RM test**

Also prior to the experimental trials, the loads for the resistance workout were determined through a 1 RM test for each exercise on the equipment in the CSU Physical Education Building’s sub-basement exercise room: leg press (Universal Gym), chest press (Icarian), seated row (Universal Gym), leg extension (Icarian), leg curl (Icarian), shoulder press (Icarian), lat pulldown (Icarian), tricep press down (Icarian), bicep curl (Icarian), back extension (Icarian) and abdominal crunch (Icarian). Subjects were provided with guidance on proper form and technique, allotted a 5-10 minute warm-up on a Concept 2 Rower (Morrisville, VT) and practiced each exercise with lighter loads before attempting a load they could perform only once with proper form (Baechle & Earle, 2008).

**Experimental Trials**

After VO2max and 1RM testing, the subjects reported to the Human Performance Laboratory after an overnight fast (10 hour) to performed their experimental trials. The order in which the subjects perform each protocol was randomized. To account for diurnal effects, all subjects performed each condition during the same time of day, approximately one week apart. Female subjects performed the three acute bouts within 10 days of the first day of menstruation and the same time of day, to account for potential
hormonal differences (Pluchino et al., 2009). All three conditions could not be performed within the 10-day period, therefore female subjects needed to perform the third condition within 10 days of the start of the following menstruation period (follicular phase).

The first experimental trial occurred no less than a week post initial assessment to account for any residual soreness or training effects. The subject arrived in a fasted state and had their body composition analyzed. The subject was then fitted with a Polar Heart Rate monitor (Lake Success, NY), performed a familiarization Stroop Test, venous blood was obtained for BDNF, and the pre-exercise Stroop Test was administered. Subjects performed one of three different protocols: aerobic training (AT), resistance training (RT), or combined aerobic and resistance training (CT).

For the CT, subjects performed a 15-minute treadmill run at 85% HR-max as determined during the VO2 max test, which equated to about 75-80% max VO2 (American College of Sports Medicine, 2014). Upon completion of the run, the subject immediately performed the resistance exercises. The resistance exercise employed a super-set/circuit type training. Super sets are a type of resistance training that uses one exercise for the agonist muscle followed immediately by another exercise for the antagonist (Morgan, 1958). Super sets consist of 2-5 exercises repeated in a sequence with very little to no rest between sets. Each exercise in each group of exercises was performed for 10 repetitions and repeated two times before moving on to the next circuit of super-set of exercises. Each group of exercises was performed in succession with little or no rest between repetitions or sets. For this mode of exercise, heart rate remains higher longer, similar to a cardiovascular bout of exercise. Super-set resistance training elicits a physiological response more similar to aerobic exercise than does traditional resistance
training. The entire combination bout was performed in approximately 30-minutes. A venous blood sample for BDNF was obtained and the Stroop Test was administered immediately following exercise and post 30-minutes exercise. The specific resistance exercises performed are listed in Table 1.

*Table 1. Super-Set Circuits*

| Super-Set Circuit 1 | Leg Press  
| | Chest Press  
| | Seated Row  
| | 2 sets, 10 repetitions, 75% 1 RM  
| Super-Set Circuit 2 | Leg Extension  
| | Leg Curl  
| | Lat pulldown  
| | Shoulder Press  
| | 2 sets, 10 repetitions, 75% 1 RM  
| Super-Set Circuit 3 | Tricep press down  
| | Bicep curl  
| | Back extension  
| | Abdominal crunch  
| | 2 sets, 10 repetitions, 75% 1 RM  

For the AT, which was no less than a week after the previous exercise trial, subjects performed a 30-min treadmill run at 85% HR-max (75-80% max VO2). Subjects were fitted with a Polar Heart Rate monitor (Lake Success, NY) to ensure the proper 85% HR-max protocol was maintained for the duration of the bout. A familiarization Stroop Test was administered. Venous blood was drawn for BDNF, and the Stroop Test administered before, immediately after and 30-minutes post exercise.

Subjects performed the RT no less than a week after the previous trial. Subjects were fitted with a Polar Heart rate monitor (Lake Success, NY) and administered a familiarization Stroop test. Subjects were allotted a 10 minute warm up period. The exercises from the resistance portion of the combination bout were used. However, for this component, subjects completed super-set circuit one, four times before moving on to subsequent circuits in which those were performed four times as well. Venous blood was
drawn for BDNF, and the Stroop Test was administered before, immediately after and 30-minutes post exercise.

Data Analysis

Descriptive statistics were obtained. A repeated measures ANOVA was used to assess the effect of exercise mode on BDNF and cognition function. When significant main effects for time or time by mode interactions were revealed, post-hoc analysis was conducted using the Bonferroni procedure. A Spearman correlation was used to assess the relationship between BDNF and cognitive function, as well as to assess the relationship between exercise intensity and BDNF levels. SPSS (version 22) was used for all analyses with .05 as the level of significance.
CHAPTER IV
RESULTS & DISCUSSION

Results from this study are displayed in the following tables and figures. Subject characteristics and fitness values are displayed in Table 2. Exercise intensity values are displayed in Tables 3.

Table 2. Subject Characteristics and mean fitness values (mean (±SD)).

<table>
<thead>
<tr>
<th>Measure</th>
<th>All</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>27.9 (8.1)</td>
<td>25.6 (8.2)</td>
<td>30.2 (8.11)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.8 (7.4)</td>
<td>176.8 (6.7)</td>
<td>168.8 (6.4)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.7 (10.5)</td>
<td>74.3 (8.7)</td>
<td>59.9 (6.4)</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>16.0 (7)</td>
<td>10.3 (3.72)</td>
<td>21.6 (3.9)</td>
</tr>
<tr>
<td>VO2Max (ml/kg/min)</td>
<td>43.8 (5.9)</td>
<td>48.68 (1.87)</td>
<td>38.9 (3.7)</td>
</tr>
<tr>
<td>HRmax bpm</td>
<td>144.8 (14.0)</td>
<td>189 (9.7)</td>
<td>187 (6.08)</td>
</tr>
<tr>
<td>85% MHR (bpm)</td>
<td>159.7 (6.6)</td>
<td>161 (8.8)</td>
<td>159.2 (5.0)</td>
</tr>
<tr>
<td>Leg press 1rm (lbs)</td>
<td>382.6 (133.2)</td>
<td>490.2 (97.3)</td>
<td>275.0 (38.7)</td>
</tr>
<tr>
<td>Chest press 1rm (lbs)</td>
<td>175.8 (79.7)</td>
<td>241.6 (52.1)</td>
<td>110.0 (27.4)</td>
</tr>
<tr>
<td>Seated row 1rm (lbs)</td>
<td>132.0 (43.4)</td>
<td>170.0 (18.7)</td>
<td>94.0 (16.7)</td>
</tr>
<tr>
<td>Leg curl 1rm (lbs)</td>
<td>150.0 (49.0)</td>
<td>184.0 (38.5)</td>
<td>116.0 (32.1)</td>
</tr>
<tr>
<td>Leg extension 1rm (lbs)</td>
<td>201.0 (68.9)</td>
<td>260.0 (30.8)</td>
<td>142.0 (31.9)</td>
</tr>
<tr>
<td>Shoulder press 1rm (lbs)</td>
<td>124.5 (58.7)</td>
<td>172.0 (43.2)</td>
<td>77.0 (15.7)</td>
</tr>
<tr>
<td>Lat pull down 1rm (lbs)</td>
<td>129.5 (39.5)</td>
<td>163.0 (19.2)</td>
<td>96.0 (18.2)</td>
</tr>
<tr>
<td>Tricep press 1rm (lbs)</td>
<td>77.5 (25.1)</td>
<td>98.0 (14.8)</td>
<td>57.0 (12.0)</td>
</tr>
<tr>
<td>Bicep curl 1rm (lbs)</td>
<td>87.0 (35.0)</td>
<td>116.0 (24.1)</td>
<td>58.0 (8.4)</td>
</tr>
<tr>
<td>Back extension 1rm (lbs)</td>
<td>239.3 (71.4)</td>
<td>278.6 (66.4)</td>
<td>200.0 (56.6)</td>
</tr>
<tr>
<td>Abdominal curl 1rm (lbs)</td>
<td>146.0 (44.3)</td>
<td>178.0 (34.9)</td>
<td>114.0 (25.1)</td>
</tr>
</tbody>
</table>
Table 3. Subject exercise intensity

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT %max HR</td>
<td>77.1 (7.2)</td>
</tr>
<tr>
<td>AT %max HR</td>
<td>83.2 (2.7)</td>
</tr>
<tr>
<td>CT %max HR</td>
<td>81.1 (3.0)</td>
</tr>
</tbody>
</table>

Serum BDNF responses

The intraassay covariate between duplicate samples was 2.5%. To determine effect of exercise mode (resistance training, aerobic training or combination training) on BDNF levels by time (pre, post and post 30), a repeated measures ANOVA was performed. The results revealed a significant effect of time ($F_{2,18} = 85.09, p \leq .001$). A Bonferroni post-hoc analysis showed that BDNF levels were significantly greater at post than pre ($p = .0001$). Additionally, post measurement was significantly less than post 30 levels ($p = .001$). There were no observed differences in mean BDNF levels between pre and post 30 values ($p = 1.00$). There was no observed main effect of exercise condition ($F_{2,18} = .606, p \geq .05$) (Figure 1) and no significant exercise x time interaction ($F_{4,36} = .721, p \geq .05$).
Figure 1. The effects of exercise mode (RT, AT, CT) on BDNF (pre, post, post 30). *Post is significantly greater than pre (p < .05). **Post 30 level is significantly less than to post (p < .05).

Serum BDNF pre, post and post 30 measurements are presented in Table 4. The relative magnitude of BDNF between pre and post exercise percent increases were as follows: CT (28%) < AT (31%) < RT (45%).

Table 4. Subject BDNF levels (pg/ml)

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Post 30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (± SD)</td>
<td>Mean (± SD)</td>
<td>Mean (± SD)</td>
</tr>
<tr>
<td>RT</td>
<td>23994.2 (±4316.0)</td>
<td>34701.4 (±7528.2)*</td>
<td>25630.6 (±4709.8)**</td>
</tr>
<tr>
<td>AT</td>
<td>26860.9 (±5083.9)</td>
<td>35171.8 (±6448.2)*</td>
<td>27318.9 (±5748.2)**</td>
</tr>
<tr>
<td>CT</td>
<td>25905.8 (±5543.4)</td>
<td>33123.7 (±5602.9)*</td>
<td>26160.0 (±25396.0)**</td>
</tr>
</tbody>
</table>

*Post level is significantly greater than pre (p < .05)
**Post 30 level is significantly less than post (p < .05)

Cognitive Assessment

For the effect of exercise mode (resistance training, aerobic training or combination training on reaction time (pre, post and post 30) a repeated measures of ANOVA revealed a significant effect of time ($F_{2,18} = 1.383, p \leq .001$). A Bonferroni post-hoc analysis revealed that cognition was significantly better at post compared to pre ($p = .005$). Whereas there were no significant observed differences in mean reaction times between post and post 30 ($p = .246$), nor between pre and post 30 ($p = .078$). There was
no observed significant main effect of exercise condition ($F_{2,18} = .082, p ≥ .05$) (Figure 2) and no significant exercise x time interaction ($F_{4,36} = .281, p ≥ .05$).

**Figure 2.** The effects of exercise mode (RT, AT, CT) on Stroop Incongruent reaction time (pre, post, post 30). *Post cognitive assessment is significantly better than pre (p < .05)

Stroop Test reaction times are presented in Table 5. The relative improvement between pre and post exercise reaction times were: CT (~89.5 ms) < AT (~90.5 ms) < RT (~116.4 ms).

**Table 5.** Subject Stroop reaction time (ms).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Post 30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (± SD)</td>
<td>Mean (± SD)</td>
<td>Mean (± SD)</td>
</tr>
<tr>
<td>RT</td>
<td>870.25 (±248.07)</td>
<td>753.85 (±128.13)*</td>
<td>831.90 (±269.40)</td>
</tr>
<tr>
<td>AT</td>
<td>864.39 (±305.64)</td>
<td>773.88 (±230.97)*</td>
<td>799.98 (±169.66)</td>
</tr>
<tr>
<td>CT</td>
<td>854.26 (±222.63)</td>
<td>764.75 (±234.90)*</td>
<td>784.90 (±223.26)</td>
</tr>
</tbody>
</table>

*Post cognitive assessment is significantly quicker compared to pre (p < .05)
Correlation between Change in BDNF and Cognitive Assessment

For each mode, a Spearman correlation was calculated examining the relationship change between pre and post BDNF and cognitive changes; post and post 30 BDNF and cognitive changes; and pre and post 30 BDNF and cognitive change (Tables 6, 7 and 8). Although all three modes significantly improved in both BDNF and Stroop Incongruent assessment independently, they did not reach statistical significance with the exception of one comparison. During the CT condition, the relationship between BDNF and Stroop pre and post 30 showed a significant, strong, positive correlation (rho(8)= .794, p < .01). A BDNF returned to baseline the cognition further improved as shown in Figure 3.

Table 6. Correlation of BDNF and Stroop change during Resistance Training (N=10).

<table>
<thead>
<tr>
<th></th>
<th>ΔBDNFprepostRT</th>
<th>ΔBDNFpostp30RT</th>
<th>ΔBDNFprep30RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Stoop prepostRT</td>
<td>Correlation Coefficient</td>
<td>-0.382</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.276</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Stoop postp30RT</td>
<td>Correlation Coefficient</td>
<td>-0.612</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Stoop prep30RT</td>
<td>Correlation Coefficient</td>
<td>0.479</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.162</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Correlation of BDNF and Stroop change during Aerobic Training (N=10).

<table>
<thead>
<tr>
<th></th>
<th>ΔBDNFprepostAT</th>
<th>ΔBDNFpostp30AT</th>
<th>ΔBDNFprep30AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔStroop prepostAT</td>
<td>Correlation Coefficient</td>
<td>0.152</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.676</td>
<td></td>
</tr>
<tr>
<td>ΔStroop postp30AT</td>
<td>Correlation Coefficient</td>
<td>-0.491</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>ΔStroop prep30AT</td>
<td>Correlation Coefficient</td>
<td>-0.103</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.777</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Correlation of BDNF and Stroop change during Combined Training (N=10).

<table>
<thead>
<tr>
<th></th>
<th>ΔBDNFprepostCT</th>
<th>ΔBDNFpostp30CT</th>
<th>ΔBDNFprep30CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔStroop prepostCT</td>
<td>Correlation Coefficient</td>
<td>0.236</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.511</td>
<td></td>
</tr>
<tr>
<td>ΔStroop postp30CT</td>
<td>Correlation Coefficient</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.987</td>
<td></td>
</tr>
<tr>
<td>ΔStroop prep30CT</td>
<td>Correlation Coefficient</td>
<td>.794**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.006</td>
<td></td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed).
Correlation between exercise intensity and BDNF increase

To determine if exercise intensity related to percent BDNF increase pre to post exercise a Spearman Correlation was calculated for each mode. The results for each computation did not reach statistical significance as shown in Table 9.

Figure 3. Correlation between delta BDNF and delta Stroop CT, pre to post 30 (p = .006)
Table 9. Correlation of Exercise Intensity and Percent BDNF Increase.

<table>
<thead>
<tr>
<th>Δ%RT BDNF</th>
<th>Correlation Coefficient</th>
<th>RT %max HR</th>
<th>AT %max HR</th>
<th>CT %max HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>prepost</td>
<td>Correlation Coefficient</td>
<td>0.523</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ%AT BDNF</td>
<td>Correlation Coefficient</td>
<td></td>
<td>0.071</td>
<td></td>
</tr>
<tr>
<td>prepost</td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>0.845</td>
<td></td>
</tr>
<tr>
<td>Δ%CT BDNF</td>
<td>Correlation Coefficient</td>
<td></td>
<td></td>
<td>0.357</td>
</tr>
<tr>
<td>prepost</td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td>0.311</td>
</tr>
</tbody>
</table>

Discussion

The present study examined how an acute exercise bout of different modes affected serum BDNF and cognition. The findings indicated a significant rise in BDNF in all conditions from pre to post exercise in support of the hypothesis. There was also a significant decrease in BDNF from post to post30 minutes exercise in all conditions as serum levels returned near baseline. Similarly, there was a significant improvement in the Stroop Incongruent cognitive result from pre to post, also in support of the hypothesis. However, this was only observed at the immediately post exercise indicating a transient occurrence. The AT condition did not elicit a significantly greater rise in BDNF or cognition improvement over the RT or CT modes. There were no significant gender differences or correlations.

Research has demonstrated that acute and chronic aerobic exercise has a positive effect on BDNF. The BDNF increase in response to the AT in this study proved consistent with the literature. It has also been suggested that aerobic exercise of moderate to high intensity yields a greater rise in BDNF (Ferris et al., 2007; Huang et al., 2014; Piepmeier & Etnier, 2015; Voss et al., 2011). The 85% MHR condition used for the AT
produced an average 31% increase in pre to post exercise BDNF, comparable to the results of Ferris et al. (2007). A significant improvement in the Stroop Incongruent cognitive result was also observed pre to post AT with an average of 90.5 ms reduction in reaction time. Although the pre to post 30 minutes exercise results were not statistically significant, the average reaction time was still 84.4 ms quicker than the pre exercise value. These results support the literature in that exercise has a positive effect on cognition (Change et al., 2014; Huang et al., 2014; Piepmeier & Etnier, 2015). The AT data from this study further solidified that neurological health could benefit from exercise prescription of this kind, instead of pharmacological options (Ferris et al., 2007; Voss et al., 2011).

Research on the effect of resistance training on BDNF, whether acute or chronic, has shown conflicting results (Huang et al., 2014; Voss et al., 2011; Yarrow et al., 2010). The resistance training protocol in previous studies used more traditional resistance training programs in which subjects lifted anywhere from 40-100% 1RM, with varying repetitions and sets, then allotted anywhere from one to four minute recovery periods between sets. Novel to this area of research, the present study employed a super-set/circuit type training where subjects performed resistance exercises at 75% 1RM for 10 repetitions with little to no rest between sets and exercises. The intent of this type of resistance training was to mimic the continuous motion and achieve a degree of steady state associated with the AT training (Knaepen et.al, 2010). Average heart rate during this protocol was 77.1% (±7.2) MHR which was well within the moderate to high intensity exercise range associated with a greater rise in BDNF (Ferris et al., 2007; Huang et al., 2014; Piepmeier & Etnier, 2015; Voss et al., 2011). The RT condition produced a
significant 45% increase in pre to post exercise BDNF which supports the findings of Yarrow et al. (2010). To the best of our knowledge, this type of resistance training is novel and may be a beneficial exercise mode, in addition to aerobic exercise, for neurological and cognitive health. A significant improvement in Stroop Incongruent cognitive result was also found pre to post RT with an average 116.4 ms reduction which supports research by Chang & Etnier (2009). Although the pre to post 30 minutes exercise results were not statistically significant, the average assessment was 38.4 ms better than that of the pre exercise value.

As suggested by Voss et al. (2011), this study included a combined aerobic and resistance exercise mode. The CT mode elicited a statistically significant 28% increase in pre to post BDNF. Average heart rate during this mode was 81.1% (±3.0) MHR, which was similar to the other two exercise modes used in this study. The Stroop Incongruent cognitive results from CT produced similar results to the other two modes at an average of 89.5 ms faster reaction time. This data demonstrates that in addition to aerobic exercise being positive for brain health, combining different modes of exercise holds promise of similar results.

In accordance with previous literature, the Stroop Test was used to analyze cognition. This information was further used to extrapolate a potential relationship between increases in BDNF and improvements in cognition pre to post as a result of an acute bout of exercise. Despite this study’s lack of correlational significance, research has shown that a chronic positive increase in BDNF is associated with improved cognition and over time, increased hippocampal mass (Erickson et al., 2011; Kandola et al., 2016; Voss et al., 2011). It is important to note that the improvement in pre to post exercise
cognitive function may have been attributed to an escalation in attention and physiological responses to higher intensity exercise, as opposed to the increase in BDNF (Ferris et al., 2007; Knaepen et al., 2010).

It was originally hypothesized that AT would result in a greater increase in BDNF. The failure to observe this may be attributed to similar intensities between modes. Knaepen et al. (2010) suggested that BDNF responses are likely exercise intensity related. Voss et al. (2011) agreed with the additional speculation that genetic factors may cause variability in subject responses to different exercise modes. This study did not demonstrate a statistically significant correlation between modes dependent on exercise intensity and percent change in BDNF. However, this was probably due to the similarities in average percent MHR across the modes.
CHAPTER V
SUMMARY AND CONCLUSION

Limitations

Although this research supported previous findings and contributed novel findings, a few limitations were noted during the study. All subjects were healthy and physically fit; however, training background may have impacted the results. For instance, subjects accustomed to endurance training but untrained in resistance exercise produced 1RM values less than those who focused workouts on resistance training and vice versa. A few subjects had an adverse reaction to the blood draws not only delaying, but potentially impacting their Stroop Test performances. One subject, although meeting the 30-minute stipulation for the RT and CT protocols, did not finish the entire circuit training program due to nausea and vomiting. Another subject continually attempted to hold a conversation with study personnel while taking the Stroop test. Finally, the small sample size and relatively broad age range present potential limitations within the study as well.

Future Research

Sufficient BDNF levels are important for proper neuron production and conservation at all ages (Erikson et al., 2012; Ferris et al., 2007; Voss et al., 2011). In
regard to exercise modes, more research is needed on varying styles of resistance training and combining modes, such as performing resistance training prior to cardiovascular training. Another suggestion is to alternate resistance and cardiovascular exercises within a set time period. Recording physiological effects of each condition (i.e. max heart rate, average heart rate, blood lactate, rate of perceived exertion, etc.) may provide insight into the changes in BDNF with exercise intensity and mode. Further research is needed to understand the physiological effects of varying exercise modes and the impact on BDNF, as well as the relationship of these to cognition.

**Conclusion**

This study compared the impact of an acute aerobic, resistance or aerobic-resistance exercise bout on cognition and BDNF. All modalities elicited a significant rise in BDNF and cognition improvement with none of the modes demonstrating a greater effect than another. These novel findings with new types of training hold promise for a greater array of exercise modalities to maintain neuronal and cognitive health.
References


Appendix A

INFORMED CONSENT FOR PARTICIPATION

Effect of an acute aerobic vs. resistance vs. aerobic-resistance exercise bout on cognition and brain-derived neurotrophic factor (BDNF)

Introduction
Thank you for considering participation in this study. My name is Deborah Paul and I am working on my Master’s Thesis at Cleveland State University. This study will be conducted under the supervision of Dr. Emily Kullman, Assistant Professor in the Health and Human Performance Department.
The purpose of this study is to observe how different exercise types affect BDNF levels and thinking ability. BDNF is a protein that helps nourish and create neurons. It also protects against neuron decay.
The research study will be conducted in the Human Performance Laboratory (HPL) at Cleveland State University (CSU).

Procedures
BDNF will be measured through venous blood draw. Thinking ability will be measured using the Stroop test. For this test, subjects will be shown color words printed in a different ink than the word. Subjects will name the color of the ink of each word. This will be done as quickly and accurately as possible.
We will recruit 10 healthy male and female subjects (18-40 yrs.). They must be regular exercisers. They will be able to perform at least 30 minutes of vigorous exercise. They will be free of any cardiovascular or metabolic disease. They will be free of orthopedic issues or injuries. They will not be pregnant or lactating. Subjects will complete an AHA/ACSM pre-screening questionnaire to determine medical history. The information will be used to determine eligibility for the study.
Subjects will come to the HPL on 5 separate occasions. Each session will last approximately 1 ½- 2 hrs. The total study time commitment is expected to be 7 ½ -10 hrs spread over 4-6 weeks.
Session one will be a treadmill graded exercise test. ECG will be used to determine max heart rate. A metabolic cart will be used to determine aerobic capacity.
During the second session, 1 rep max (RM) will be done for 11 different resistant training exercises.
The order of the last three sessions will be randomized. One session will be a 30-minute run at 85% max HR. Another session will be a 15- minute run (85% max HR). This is followed by 3 circuits of resistance exercises performed for 2 sets of 10 repetitions at
75% 1 RM. A third session will be 3 circuits of resistance exercises performed for 4 sets of 10 repetitions at 75% 1 RM. A blood sample and Stroop test will be completed before, immediately after, and 30 minutes after each trial. There will be a total of three, 5 mL blood draws for each exercise session. The study total will be nine blood draws and 45 mL of blood. On the first session of the randomized sessions, body composition will be assessed. Body composition is a measure of the amount of fat mass and fat-free mass on a person. We will measure body composition using air displacement plethysmography (Bod Pod) in the CSU HPL. This procedure takes about 10 minutes to complete, and requires you to be dressed in a bathing suit, or form-fitting clothes.

All storage and analysis of blood will be at CSU HPL by study personnel. Each session will be performed during the same time. There will be at least one week apart from each other. Each session will be performed in an overnight fasted state (10 hours). Females will be tested within ten days of onset of menses. This accounts for any hormonal effects.

**Risks**

Risks of these tests are minimal and do not exceed those of normal training for an athletic population. Risks in this study include the muscle soreness, shortness of breath, fatigue, heart attack, death, overtraining, acute injuries, muscle strain and/or joint injury, delayed muscle soreness onset, abnormal heart beats and or abnormal blood pressure due to exercise.

The needle stick may hurt. There is also a small risk of bruising, infection, or lightheadedness. Every effort will be made to minimize these risks. The HPL is equipped with an AED. All lab personnel are certified in CPR and First Aid. Emergency procedures include calling EMS (x911) stating to the dispatcher: “We have a medical emergency in the Human Performance Laboratory PE Building- Room B60.” CPR/First aid will be performed until EMS arrives. CSU will not provide compensation for necessary nor elective medical care. You can voluntarily stop at any time during the study.

**Benefits**

I understand that there are no direct benefits for participating in the study other than engaging in three exercise sessions.

**Confidentiality**

To protect privacy, any data and information obtained during participation will be confidential. It will not be disclosed to anyone without consent. A number will be assigned to each subject in place of a name. The information may be used for a statistical or scientific purpose with the right of privacy retained. Dr. Emily Kullman and Debbie Paul will be the only witnesses of the information. Data will be stored in the HPL PED B60 in a locked filing cabinet.

**Participation**

I understand that participation in this project is voluntary. I have the right to withdraw at any time with no consequences. I attest and verify that I have no known health problems that could prevent me from successfully participating in the testing. If I have any
questions about the procedures, I can contact Dr. Emily Kullman at (216) 687-4854 or Debbie Paul at (216) 409-0886.

I understand that if I have any questions about my rights as a participant, I can contact Cleveland State University’s Institutional Review Board at (216) 687-3630.

**Subject Acknowledgement**
The procedures, purposes, known discomforts and risks, possible benefits to me and to others have been explained to me. I have read the consent form or it has been read to me, and I understand it. I also understand that all data, even data collected to determine eligibility for the study will be stored in a secured file in the HPL for at least 3 years then shredded. After blood analysis, unused samples will be stored for up to five years for potential future analysis of exercise related blood analysis pending a future IRB approval. Blood will not be used for genetic analysis. Any unused blood samples will be disposed of in an approved biohazard container.

I agree to participate in this study. I am at least 18 years of age.

I have been given a copy of this consent form.

**Signature:** _______________________________  **Date:** ___________

**Witness:** _______________________________  **Date:** ___________
Appendix B

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all true statements.

History
You have had:
___ A heart attack
___ Heart surgery
___ Cardiac catheterization
___ Coronary angioplasty (PTCA)
___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
___ Heart valve disease
___ Heart failure
___ Heart transplantation
___ Congenital heart disease

If you marked any of the statements in this section, consult your physician or other appropriate healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Other health issues
___ You have diabetes
___ You have or asthma other lung disease.
___ You have burning or cramping in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Symptoms
___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, blackouts.
___ You take heart medications.

Cardiovascular risk factors
___ You are a man older than 45 years.
___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
___ You smoke, or quite within the previous 6 mo.
___ Your BP is greater than 140/90.
___ You don’t know your BP.
___ You take BP medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You don’t know your cholesterol level.
___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
___ You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your physician or other appropriate healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

___ None of the above is true.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.


www.acsm-msse.org/pdpt-core/template-journal/MSSEmedia/0689c.htm
Volunteers Wanted for Exercise Study

If you are:
A highly active person 18-40 yrs., regularly exercise or train, you may qualify!

Volunteers will be expected to:
Perform a VO₂max test and exercise testing, cognition testing, have blood drawn for brain protein analysis, and receive personal training.

Have Questions?

Debbie Paul
216-409-0886
littledebpaul@aol.com
or
Dr. Emily Kullman
216-687-4854
ekullman@csuohio.edu
Volunteers Wanted for Exercise Study

If you are:
A highly active person 18-40 yrs., regularly exercise or train, you may qualify!

Volunteers will be expected to:
Perform a VO$_2$max test and exercise testing, cognition testing, have blood drawn for brain protein analysis and receive personal training.

Are you a fit, trained and healthy individual?

Are you able run 30 min. at 85% maxHR and lift 75% 1RM on resistance exercises?

We are recruiting for a study observing the effects of exercise on cognition and brain protein.

Have Questions?

Debbie Paul
216-409-0886
littledebpaul@aol.com
or
Dr. Emily Kullman
216-687-4854
ekullman@csuohio.edu
Appendix D

In the following trials you will see words presented in different colors.

Your task is to indicate the COLOR in which each word is printed in while ignoring what the words actually say.

Indicate the color of the word by pressing either of the following keys:
- d for red words
- f for green words
- j for blue words
- k for black words

Example: if you see the word RED printed in the color GREEN press 'f' for green words regardless of the meaning of the word.

Try to respond as quickly and accurately as you can, because you will be timed. If an incorrect response is made, a red X will be flashed on the screen.

Place your index and middle fingers on the 'd', 'f', 'j', and 'k' keys so that you are ready to respond.
Appendix E

May 19, 2016

Dear Emily Kullman,

RE: IRB-FY2016-271

Effect of an acute aerobic vs. resistance vs. aerobic-resistance exercise bout on cognition and brain-derived neurotrophic factor (BDNF)

The IRB has reviewed and approved your application for the above named project, under the category noted below. Approval for use of human subjects in this research is for a one-year period as noted below. If your study extends beyond this approval period, you must contact this office to initiate an annual review of this research.

Approval Category: Expedited, Category 2a and 4
Approval Date: May 19, 2016
Expiration Date: May 18, 2017

By accepting this decision, you agree to notify the IRB of: (1) any additions to or changes in procedures for your study that modify the subjects’ risk in any way; and (2) any events that affect that safety or well-being of subjects. Notify the IRB of any revisions to the protocol, including the addition of researchers, prior to implementation.

Thank you for your efforts to maintain compliance with the federal regulations for the protection of human subjects. Please let me know if you have any questions.

Sincerely,

Mary Jane Karpinski
IRB Analyst
Cleveland State University
Sponsored Programs and Research Services
(216) 687-3624
m.karpinski2@csuohio.edu