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Dose-Response Association Between Acute Exercise Duration, Exercise Recovery and Cognitive Function

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DOSE-RESPONSE ASSOCIATION BETWEEN ACUTE EXERCISE DURATION, EXERCISE RECOVERY AND COGNITIVE FUNCTION

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ABSTRACT

Previous studies have shown moderate intensity exercise to be a desired intensity level to optimize cognitive function, however, this research has mostly been conducted among older adults despite the claim that cognitive function may start to decline in the early years (i.e., 20s). Another research gap within this population is our limited understanding of the effects of different exercise durations and recovery periods on cognitive function. Thus, the purpose of this study was to examine the effects of different exercise durations and recovery periods on cognition using a treadmill-based protocol. In a counterbalanced, cross-over randomized controlled design, 352 participants, ages 18-35, were placed into one of sixteen groups. Each participant visited the laboratory twice, with a one-week washout period between the two visits. Either visit one or two consisted of an acute bout of moderate-intensity treadmill exercise (10, 20, 30, 45, or 60 minutes) followed by a period of rest (5, 15, or 30 minutes) before taking a set of five cognitive function tests, while the other visit consisted of only completing the cognitive tests (no exercise). The cognitions assessed included multiple cognitive-related parameters including reasoning, concentration, memory, and attention. We did not observe strong evidence of an association between acute exercise and cognitive performance. Our findings did, however, suggest that short recovery period (i.e., 5 min recovery) may have a less favorable effect on planning-based cognition. Additionally, for various exercise durations and recovery periods, a group x time x baseline cognition interaction effect was observed. That is, for both memory and inhibitory-based cognition, acute exercise (vs. no exercise) had an enhanced effect on cognition

only for those with lower baseline cognition. Our findings suggest that the length of the recovery period and baseline cognition status, in particular, may influence exercise-associated cognition.

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CHAPTER 1

EXERCISE AND COGNITIVE FUNCTION FOCUSED ON UNDERLYING MECHANISMS

There is a large body of research demonstrating that exercise may improve cognitive function, as shown in a meta analysis from Ratey and Loehr[1]. Most of this research, however, has been conducted among older adults. This thesis will employ a population of young adults (ages 18-35) because fewer studies have been conducted among this population, despite evidence showing that cognitive function may start to decline in the early adult years (i.e. early 20s)[2]. One study that has used a population of young adults to study the effect of exercise on cognitive function is Loprinzi and Kane[3], where they showed that acute exercise at a level of moderate intensity was associated with cognitive-related parameters.

The underlying mechanisms through which physical activity may potentially influence cognitive function may occur at the systemic, molecular, and cellular levels[1]. At the systemic level, physical activity is said to be beneficial for attention, learning, and memory due to the increase in neuroelectric activity, brain volume, and cerebral blood flow. At the molecular level, chronic physical activity increases the amount of nerurotrophins such as brain-deprived neuroprophic growth factor (BDNF) and growth factors such as insulin-like growth factor-1 (IGF-1), fibroblast growth factor-2 (FGF-2), and vascular endothelial growth factor (VEGF). Brain function is supported at the cellular level including synaptic plasticity, and in particular, long-term potentiation[1].

With an increase in brain functions that influence attention, learning, and memory, the systems level shows these increases with electrophysiologic and neuroimaging studies. Electrophysiologic studies use electrodes placed on the scalp to record neural activity in the brain regions including the frontal lobes, anterior cingulate cortex, temporal lobe, and parietal cortex[4]. The amplitude used in these studies is proportional to the attention and cognitive evaluation needed for the stimulus to encode using acute exercise to increase the neuroelectric resources available to see increases in cognition processing and classification[5]. Studies using structural magnetic reasoning imaging (MRI) in older adults show that adults who are more physically active have a greater preservation of brain volume than less physically active adults[6,7]. Studies have shown that not only is there a greater preservation of brain volume in more fit adults, but they also show a faster reaction time and greater brain activity during cognitive function tasks[8].

The increase of neurotrophins (BDNF) and growth factors (IGF-1) have been shown to increase during physical activity. Animal studies (e.g. rats and mice) have shown increases in BDNF in the hippocampus during voluntary exercise[9]. When assessed in humans, increased BDNF has been found in young adults participating in acute exercise[10]. It has been shown in animal studies that IGF-1 is stimulated by exercise and when IGF-1 is blocked, there is no increase in adult neurogenesis[11]. When IGF-1 levels are decreased in animals, they tend to have diminished learning and memory[12]. When studied in humans, it has been shown that IGF-1 levels decrease as age increases, and a greater amount of IGF-1 in older adults is associated with greater cognitive performance whereas decreased amounts of IGF-1 lead to a decreased cognitive performance[12]. BDNF production in the hippocampus is influenced by IGF-1 as a response to exercise[13].

At the cellular level, increasing synaptic plasticity, neurogenesis, and vascular function has been shown to increase cognition via physical activity.[14] Synaptic plasticity is increased during exercise as shown in a study with a group of rats given access to a running wheel as compared to a group of sedentary rats.[14] BDNF in the hippocampus was also increased in the active rats, suggesting that an increase in BDNF could have an effect on the increase in synaptic plasticity due to exercise[14]. Research in rodents have shown that even in mice who have been sedentary until old age, running still increases neurogenesis[15]. A key mechanism in which physical activity can increase synaptic plasticity and cognition is via neurogenesis[16]. Neurogenesis and angiogenesis, along with the vascular environment can increase the survival of newly formed cells[17]. The vascularity of the hippocampus can affect the movement of neurogenic growth factors to the dentate gyrus[18]. Taken together, there is some biological plausibility through which physical activity may influence cognitive function, ultimately occurring at the systemic, cellular and molecular levels.

CHAPTER 2

INTRODUCTION

Habitual engagement in physical activity is associated with numerous cognitive-related outcomes[3]. For example, we recently demonstrated that an acute 30 min treadmill bout of moderate-intensity exercise was associated with several cognitive-related parameters, such as increased concentration-related cognitive function[1]. The underlying mechanisms through which physical activity may potentially improve cognition are likely a result of physical activity-induced changes at the systemic, molecular, and cellular levels[3,19]. For example, physical activity may influence neural systems (e.g., improved information processing and memory encoding) involved in attention, learning, and memory[13]; increase molecular mediators (e.g., brain-derived neurotrophic factor [BDNF]) by which physical activity affects cognition; and promotes a cellular environment that enhances cognition through physical activity-induced neurogenesis and vascular function.[19,20]

Studies have begun to examine whether exercise intensity moderates the relationship between exercise and cognitive function.[1,21,22] Although not conclusive, and with regard to acute exercise, at this point moderate-intensity exercise appears to be a desired intensity level to optimize cognitive function.[1] Although speculative, low-intensity exercise may not be a strong enough stimulus to trigger changes in molecular mediators (BDNF) and high-intensity exercise may result in large increases in catecholamines, ultimately inducing 'neural' noise and inhibiting exercise-induced cognitive changes.[1,3,22]

Compared to acute exercise *intensity*, much less research has examined the effects of acute exercise *duration* on cognitive performance. Most of the acute exercise research, to date, has examined the intensity-related effects of a 30 minute bout of exercise on cognition. To our knowledge, only 2 studies have specifically examined the dose-response relationship between exercise duration on cognition. In a sample of 26 healthy young men, Chang et al.,[22] utilizing a cycling protocol, examined the effects of moderate-intensity exercise (65% of HR reserve) for 10, 20, or 45 minutes on cognition. The specific cognitive test assessed was the Stroop test, which was administered 5 minutes post exercise. Chang et al. found that a 20 minute bout of moderate-intensity exercise, with a 5 minute warm-up and cool-down, improved Stroop-assessed cognition, whereas the longer and shorter durations of exercise did not see that same cognitive improvement.[22] In the second study, Basso et al[23] had participants engage in vigorous intensity physical activity for 60 minutes followed by 30, 60, 90, or 120 minute resting periods before taking a series of cognitive function tests. It was found that the acute exercise led to an increase in prefrontal cortex cognitive functioning, but not in hippocampal cognitive functioning. There was no cognitive function differences between the different resting period, and thus, Basso et al. concluded that acute exercise lead to increases in functioning in the prefrontal cortex, and that these increases can last for up to two hours post exercise[23].

Given the paucity of research on this specific topic (exercise duration and cognition), the purpose of this study was to extend our knowledge on the potential dose-response relationship between acute exercise duration on cognitive function. Similar to previous work examining exercise-intensity effects,[1] and the recent work by Chang et al.[22], Basso et al.[23], and Tsukamoto et al.,[24] we explored this topic among young healthy adults, as fewer exercise-cognitive function studies have been investigated among this population despite some evidence to suggest that

cognitive function may start to decline in the early adult years (i.e., 20's).[2] A distinction between the present study and that of Chang et al.[22] Basso et al.[23], and Tsukamoto et al.[24] is that, rather than employing a cycling protocol, we examined the dose-response relationship between acute exercise duration and cognition using a treadmill-based protocol, as ambulatory-based activities (e.g., walking and jogging) are the most common modes of exercise among adults.[25] Further, and unlike the majority of previous research on this topic, rather than employing a single measure of cognitive function, here, we will employ 5 different cognitive-function tests to assess multiple cognitive-related parameters (e.g., reasoning, concentration, memory, attention, planning).

We also attempted to further our understanding of the dose-response relationship by, in addition to examining the effects of a 10, 20 and 45 minute moderate-intensity bouts of acute exercise (as examined by Chang et al.[22]) and a 60 minute bout (as examined by Basso et al.[23]), we also investigated the effects of a 30 minute bout of moderate-intensity exercise (i.e., 10, 20, 30, 45, and 60 minute durations were tested). Tsukamoto et al.[24] included 10, 20, and 40 minutes of moderate intensity exercise in their investigation. Notably, a 60 min bout of exercise is consistent with the guidelines of the American College of Sports Medicine, which recommends at least 20-60 minutes/day of aerobic activity.[26]

Lastly, there is no consensus in the literature as to what time period after acute exercise that cognitive function may be impaired or optimized. For example, some studies have assessed cognitive function within 5 minutes of the cessation of exercise, as Chang et al. used[22], with others waiting 15 minutes post-exercise to allow for heart rate to approach baseline levels[1]. Other studies, such as Tsukamoto et al.,[24] evaluated cognitive function 30 min-post exercise and found that following a 40 minute bout of moderate-intensity exercise bout, differences between pre-exercise and post-exercise cognition was greater when compared to those who engaged in a 10 or

20 minute acute bout of moderate-intensity exercise. To our knowledge, Basso et al. [34] is the only study examining the influence of differing recovery periods on the relationship between acute exercise and cognitive function. They evaluated resting durations of 30, 60, 90, and 120 minutes, but kept the acute exercise time at 60 minutes of all participants. They found that there was no difference in the resting durations on prefrontal cortex nor hippocampal function cognition[23].This led us to consider shorter resting periods after acute moderate-intensity exercise (e.g. 5, 15, and 30 minutes of resting) for the present study. Such a recovery-specific effect is plausible as differing degrees of exercise-induced arousal may differentially influence cognition.[27] Furthering our understanding of this may have important implications for several populations (e.g., college students, working adults with cognitively-focused tasks), as this may help tailor exercise prescriptions to optimize cognitive performance. For example, if a 30 minute recovery period is the optimal length to maximize cognition, then a student may wish to start their 30 minute exercise bout 60 minutes prior to their study session/exam. Similar situations can be conceived in non-student populations (e.g., working adults who have cognitively-taxing tasks at certain times of the day).

To our knowledge, this is the first study to comprehensively examine the potential dose-response (*considering both exercise duration and recovery periods*) relationship between acute moderate-intensity exercise on various cognitive related parameters. Here, using a treadmill-based mode of exercise among young healthy adults, we specifically examined the effects of moderate-intensity exercise duration (10, 20, 30, 45, and 60 minutes) and post-exercise recovery period (5, 15, and 30 minutes) on concentration, attention, reasoning and memory-related cognitive function.

CHAPTER 3

METHODS

Study Design and Participants

Participants were eligible for the study if they were 18-35 years of age, 'ready' to engage in physical activity as determined by the Physical Activity Readiness Questionnaire, spoke English, and provided written informed consent. The study was approved by the authors' institutional review board. Participants were excluded from the study if they perceived having any difficulty completing all tests or presented with a current illness.

Participants were recruited by the student researcher using a non-probability convenience sampling approach at the authors' university (e.g., student researchers proposed the study to students enrolled in university courses). Participants completed two visits (around the same time of day) and these visits occurred approximately one-week apart. Prior to the visits, participants were asked to not exercise or consume any stimulants (e.g., caffeine, smoke, etc.) within 8 hours of the visit. At the beginning of their first visit, participants completed an informed consent and reported demographic information.

We employed a counterbalanced, cross-over randomized controlled design, visually displayed in Figures 1A and 1B. That is, participants were randomly selected to have either their visit 1 or visit 2 include the cognitive assessment after exercise, and their other visit only assessing cognitive function (no exercise). Cognitive function was assessed after an acute bout of moderate-intensity treadmill exercise, with participants randomized into one of 16 different exercise groups:

1) 10 min exercise with 5 min recovery before cognitive assessment
2) 10 min exercise with 15 min recovery before cognitive assessment
3) 10 min exercise with 30 min recovery before cognitive assessment

4) 20 min exercise with 5 min recovery before cognitive assessment
5) 20 min exercise with 15 min recovery before cognitive assessment
6) 20 min exercise with 30 min recovery before cognitive assessment

7) 30 min exercise with 5 min recovery before cognitive assessment
8) 30 min exercise with 15 min recovery before cognitive assessment
9) 30 min exercise with 30 min recovery before cognitive assessment

10) 45 min exercise with 5 min recovery before cognitive assessment
11) 45 min exercise with 15 min recovery before cognitive assessment
12) 45 min exercise with 30 min recovery before cognitive assessment

13) 60 min exercise with 5 min recovery before cognitive assessment
14) 60 min exercise with 15 min recovery before cognitive assessment
15) 60 min exercise with 30 min recovery before cognitive assessment

16) No exercise (control group)

Based on expected means and SD from previous related studies,[1,28] using a two-tailed test with an effect size d of 0.62 and alpha error probability of 0.05, there were 22 participants in each acute moderate-intensity exercise group to have an achieved power (1-beta error probability) of 0.80 to detect differences in the evaluated cognitive function parameters. As a result, with 16 different groups, 352 (22*16) participants were recruited, with the analytic sample including 22 participants in each group.

Allocation concealment was employed by not informing the participants of which tests (e.g., cognitive testing only or cognitive testing after treadmill exercise) would take place on each visit. Randomization for the group assignment (e.g., 10, 20, 30, 45, 60 min exercise duration; 5, 15, 30 min rest duration), randomization for the cross-over design (i.e., which visit they completed the treadmill exercise; AB/BA), and randomization of the order of the cognitive tests was conducted using Excel's random list (RAND) feature.

Acute Exercise Testing

As stated above, participants were randomized into 1 of 16 different groups, with exercise durations including 10, 20, 30, 45 and 60 minutes, and recovery periods being 5, 15, and 30 minutes. For all exercise groups, the intensity level of the treadmill exercise was between 40% and 59% of heart rate reserve (HRR).[29] The HRR equation used was:

$HRR = [(HR_{max} - HR_{rest}) * \% \text{ intensity}] + HR_{rest}$

To calculate HR_{rest}, at the beginning of the first visit, participants sat quietly for 6 minutes, and HR was recorded from a Polar HR monitor at minute 5 and minute 6 of the rest; the average of these two values was used. To estimate HR_{max}, we calculated the participants estimated HR_{max} from 5 commonly used equations to estimate HR_{max}. We took the average of these 5 estimates and used that in the above HRR equation. The 5 HR_{max} equations that were used are:

Fox[29]: 220-age

Astrand[24]: 216.6 – (0.84*age)

Tanaka[30]: 208 – (0.7*age)

Gellish[31]: 207 – (0.7*age)

Gulati[32]: 206 – (0.88*age)

We then calculated each participant's HRR using % intensity anchors of 40% and 59%. This resulted in a HR range which we ensured that the participants stayed within during their

bout of treadmill exercise. Throughout the treadmill exercise, HR was continuously monitored using a Polar HR monitor, and HRs were recorded every 5 minutes.

Rate of perceived exertion (RPE) based on the Borg 6-20 scale, was also collected during each exercise bout, asking participants to rate their RPE after 5 minutes of exercise, in the middle of their exercise bout, and at the completion of exercise[33].

Lastly, the Physical Activity Readiness Code questionnaire (assessment of self-reported PA), coupled with measured BMI and information on age and gender, was used to predict cardiorespiratory fitness (VO_{2max})[34].

Cognitive Tests

In a randomized order, participants completed several cognitive-based tests, which assessed different areas of brain function and varied in task complexity; there is evidence suggesting that cognitive task complexity may moderate the relationship between exercise and cognition, and different areas of the brain (e.g., frontal lobe and temporal lobe) may be differentially influenced by exercise.[35] Five cognitive-function tests were administered, which included two paper-and-pencil tests (Trail Making A and B), with these two tests assessing cognitive-related visual attention and task switching.[36] The following 3 tests were administered using electronic software: Spatial Span (assesses memory)[37], Stroop (assesses attention and cognitive inhibition)[35], and the Tower of London (assesses planning).[38,39]

Trail Making A and B[40]

Both Trail Making A and B included a practice session of an abbreviated version of this test. Trail Making A has the participant draw a line connecting circles in sequential order up to

25. Trail Making B involves alternating between numbers and letters in ascending order (e.g. 1-A-2-B-3-C-4-D). Participants were instructed to complete these assessments as quickly and accurately as possible. Participants were timed during this test, with a faster time (lower number) indicating greater cognitive function. This test is a measure of various cognitive processes, including psychomotor speed, fluid cognitive ability, attention, visual search and scanning, sequencing and shifting, abstraction, working memory, cognitive flexibility, and ability to execute and modify a plan of action.[2,35] A functional neuroimaging analysis of the Trail Making B test indicates that the calcarine cortex and intraparietal sulcus are primary brain regions activated during this test.[41]

Spatial Span[3]

Spatial Span is a memory based learning last whereby the participants are asked to recreate a pattern that they are shown. Participants had a 30 second practice session before the test. There are a series of 16 gray blocks on the screen (4x4) and four blocks are illuminated in green color. The participant then attempts to recreate the pattern. Successful attempts subsequently increase the difficulty level of the next task. Higher scores on the spatial span reflect greater memory function. This test is an electronic variation of the original test by Corsi[42] that has been shown to be reliable and valid to assess non-verbal memory via visuospatial memory. The areas of the brain that have been seen to be active during visuospatial learning and memory are the mid-ventrolateral frontal, posterior parietal, and right premotor corticies.[43]

Stroop[35]

Participants were given a 30 second practice period before the color-based Stroop test was administered. The Stroop color word test is a well-documented prefrontal activation task indicative of executive function.[44] Neuropsychological testing of the Stroop effect was performed using computerized software. Specifically, the color word Stroop testing with keyboard responding was used. Participants were given color words written in color and asked to indicate the color of the word (not its meaning) by key presses. They were instructed to accomplish this as quickly and accurately as possible. There were 84 total trials, consisting of 4 colors (red, green, blue, black) x 3 color-stim congruency (congruent, incongruent, control) x 7 repetitions. The stimuli remained on the screen until the key response, with latencies measured from the onset of the stimuli. The congruent trials involved the color word and the color it presented being the same; incongruent trials involved the color word being different than the color it was presented in (e.g., it read GREEN, but this word was not in the green color); and the control trials involved colored rectangles. The outcome measure was the average latency (in milliseconds [ms]) of the correctly identified congruent, incongruent and control trials. Lower scores indicate better cognitive function.

Tower of London[38,45,46]

The Tower of London test assesses planning-based cognitive function, with this test assessed using computerized software. In this task, participants are shown three pegs with three different colored balls on them. Participants were shown three colored balls on three pegs and were asked to move them around to create the new pattern that was shown. They were told that they could only move one ball at a time, the balls must always be on a peg if they aren't being

moved, and they were shown a specific number of moves for each task that can be made.[47] This test has been shown to be a valid and reliable assessment of planning-based cognition.[48] The areas of the brain used in this planning task are the dorsolateral prefrontal cortex and lingual cortex.[49]

Data Analysis

Analyses were computed using SPSS (v. 19). To examine the effects of acute exercise on cognitive function, a series of [general linear model] one-way repeated measures ANOVAs were employed. The main effects of condition and time, and the interaction (condition x time) for each dependent variable were examined. Condition (the 16 different groups) served as the between-subject variable while time (visit 1 or 2) served as the within-subject variable. Additionally, to evaluate potential individual differences, a group x time x baseline cognition interaction term was employed. For the baseline interaction term, participants were classified into tertiles based on their cognitive function score from the non-exercise visit (e.g. baseline cognition).

CHAPTER 4

RESULTS

Table 1 displays the demographic characteristics of the analyzed sample. Demographic parameters, including age, gender, race-ethnicity, BMI and VO_{2max}, were similar across the 16 groups.

Table 2 displays the characteristics of the exercise protocol across the 15 experimental exercise groups. Exercise protocol characteristics, including treadmill speed, treadmill incline, average achieved HR during exercise, and RPE at the end of the exercise bout, were similar across the 15 experimental exercise groups. As expected, post-exercise (5 min recovery) heart rate tended to be higher in the exercise groups that had a longer exercise bout (e.g., 60 min exercise vs. 10 min exercise).

As stated in the following paragraph, interaction effects by baseline cognitive function status were evaluated. This was accomplished by including the "baseline cognitive function x group x time" variable in the model. As described elsewhere,[50] evaluating individual differences in an experimental group would be warranted if the SD change is greater in the experimental group compared to the SD change in the control group. Notably, this was observed in the present study. As an example, and for the Trail Making A test, the SD change score for the control group was 0.18, compared to a SD change score of up to 3.62 in one of the experimental groups. Results were similar for the other tests, such as Trail Making B (control group, SD change = -0.04; experimental group, SD change = up to -0.19) and the Stroop test (control group, SD change = 27.7; experimental group, SD change = up to 93.5).

Table 3 displays the cognitive function scores across the 15 experimental groups and 1 control group. For TMA, TMB, memory, planning and Stroop-control, there was no group x time interaction effect, nor was there a group x time x baseline cognition interaction. However, for Stroop-congruent and Stroop-incongruent, there was evidence of a group x time x baseline cognition interaction, which is illustrated in Figure 2A and Figure 2B. Figure 2A demonstrates the Stroop-congruent results for the non-exercise visit compared to after exercise among those in the lowest tertile for baseline Stroop-congruent cognition. Figure 2B is identical to Figure 2A except Figure 2B is among those in the upper tertile for baseline Stroop-congruence. As shown in Figure 2A, Stroop-congruence was generally higher (worse) after exercise among those with higher baseline Stroop-congruence cognition. As shown in Figure 2B, Stroop-congruence was generally lower (better) after exercise among those with lower baseline Stroop-congruence cognition. Results were similar for Stroop-incongruence (not shown in a Figure). Collectively, these findings suggest that, for the majority of the exercise protocols, acute exercise may have a favorable effect on Stroop-congruence and Stroop-incongruence among those with lower baseline cognition.

Results shown in Table 3 and Figures 2A and 2B display the cognition findings for the 2 x 16 (time by group) interaction analyses. Table 4, however, displays the interaction effects (p-values) for each individual exercise group compared to the control group. Results indicated that planning-based cognition (Tower of London) was impaired after exercise for most of the exercise groups that had a 5-minute recovery. As an example, the 2 (group) x 2 (time) interaction p-value for group 13 (60 min exercise bout, 5 min recovery) was 0.01. When referencing the planning-based cognition scores shown in Table 3, planning-based cognition was worse after exercise (32.0) when compared to the visit with no exercise (32.9). These findings suggest that a

short recovery period (e.g., 5 min) may be less favorable for planning-based cognitive function. This finding, however, should be interpreted with caution. Although cognition was worsened after exercise in the experimental group, cognition improved by 1.5 units in the second visit for the control group; thus, this unexpected change in the control group could be partially driving the significant interaction effect.

Similar to the findings shown in Table 3, Table 4 also demonstrates evidence of a group x time x baseline cognition interaction effect when comparing the individual exercise protocols to the control group. Such an interaction effect was observed for memory-based cognition and Stroop-control cognition. The latter is illustrated in Figure 3A and Figure 3B. Figure 3A shows the Stroop-control scores comparing Group 2 (10 min exercise, 15 min rest) vs. Group 16 (control) for non-exercise and after exercise among those in the lower tertile for baseline Stroop-control cognition. Figure 3B is the same as Figure 3A except results are presented for those in the upper tertile for baseline Stroop-control cognition. In contrast to those with higher baseline Stroop-control cognition (Figure 3A), acute exercise was favorably associated with Stroop-control cognition among those with lower baseline Stroop-control cognition (Figure 3B).

The above results (Table 3, Table 4, Figure 2A, Figure 2B, Figure 3A, Figure 3B) suggest that: 1) a short recovery period (i.e., 5 min recovery) *may* have a less favorable effect on planning-based cognition and 2) acute exercise may have a more favorable effect on Stroop-assessed cognition and memory function for those with lower respective cognition. Notably, however, there were several non-statistically significant findings when evaluating the effects of exercise duration and recovery period on various cognitive-related parameters.

CHAPTER 5

CONCLUSION

The purpose of this study was to extend our knowledge on the potential dose-response relationship between acute exercise duration and recovery periods on cognitive function. We hypothesized that there would be increased cognition after each of the five durations of exercise that were employed (e.g. 10, 20, 30, 45, and 60 minutes), and that there would be the greatest increases in cognitive function after the 30 and 45 minute bouts of exercise. It was also hypothesized that the largest increase in cognitive function would be seen with a 15 minute recovery period. In contrast to our hypotheses, we did not observe consistent evidence of a group x time interaction effect. As previously stated, our main findings are as follows: 1) a short recovery period (i.e., 5 min recovery) may have a less favorable effect on planning-based cognition and 2) acute exercise may have a more favorable effect on Stroop-assessed cognition and memory function for those with lower respective cognition.

Chang et al.[22] showed that 20 minutes of moderate intensity exercise (65% HR reserve) showed greater cognitive scores on the Stroop test than exercising for 10 or 45 minutes. However, as compared to the methodology from our study, all participants in their study had a 5 minute resting period[22]. Recent research from Basso et al.[23] evaluated the effects of one hour of moderate intensity activity on a cycle ergometer at 60% of the individual's heart rate reserve, having resting periods after exercise of either 30, 60, 90, or 120 minutes before employing the cognitive tests. The battery of cognitive tests employed included the Hopkins Verbal Learning

Test-Revised, the Modified Benton Visual Retention test, the Stroop test, the symbol Digit Modalities test, the Digit Span test, Trail Making test, and the Controlled Oral Word Association test. Their results showed that acute exercise improved prefrontal cortex (planning and decision making), but not hippocampal functioning. They also noted that there was no difference in cognition between the different resting durations. Our results are in partial alignment with theirs as we did not observe evidence of a differential effect of recovery length on the relationship between acute exercise and various cognitive-related parameters.

The majority of previous research on this topic has evaluated group-level differences regarding the relationship between acute exercise and cognitive function. Sibley and Beilock,[28] to our knowledge, is the only study that has evaluated individual differences when examining the relationship between acute exercise and cognitive function. Sibley and Beilock[28] employed a protocol very similar to that of the present study, with a counterbalanced crossover design over two visits to the laboratory consisting of a baseline visit and an exercise session among a college aged population. Their exercise visit consisted of a 30 minute self-paced bout of exercise on the treadmill with the instructions to keep their heart rate between 60-80% of their heart rate reserve (e.g. 220-age), and immediately following exercise completed two cognition tests for working memory. Their cognitive tests included the Operation Span (OPSAN) and Reading Span (RSPAN), and these were also assessed during the baseline visit. Sibley and Beilock observed that individuals in the lowest tertile for baseline cognition, that is, those with the lowest baseline cognition scores, saw the most benefit in their cognition from exercise. Inversely, those individuals who had the highest baseline memory had less of a benefit from exercise[28]. The results from the present study paralleled this observation for inhibition (Stroop) and memory-

based cognitive function. Collectively, these findings suggest that baseline cognition may moderate the relationship between acute exercise and various cognitive-related parameters.

Strengths of the present study include the study's novelty, comprehensive assessment of exercise (i.e. 10, 20, 30, 45, and 60 minutes) and time periods after exercise (i.e. 5, 15, and 30 minutes), the large sample size, comprehensive examination of various cognitive function parameters, and that a counterbalanced, cross-over randomized controlled design was employed. Since participants were college aged students, the results may only be generalizable to the young adult population, though this is an important population to study as this is when cognitive decline could start to occur.

In conclusion, we did not observe consistent evidence of an association between acute exercise and cognitive function. Our findings provide some suggestion that post-exercise recovery period and baseline cognitive function may moderate the relationship between acute exercise and cognition. Future replicative work evaluating these potential moderators is warranted, particularly while also considering a higher-intensity exercise stimulus.

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APPENDIX

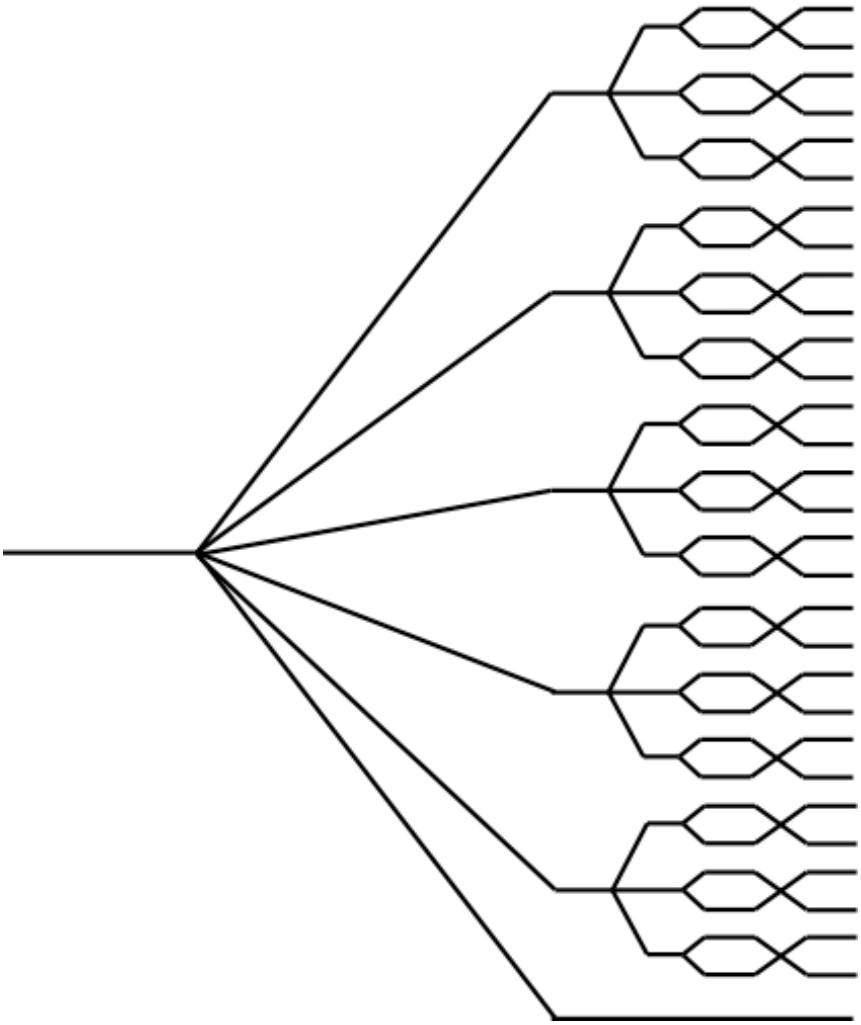

Figure 1A. Schematic of the study design.

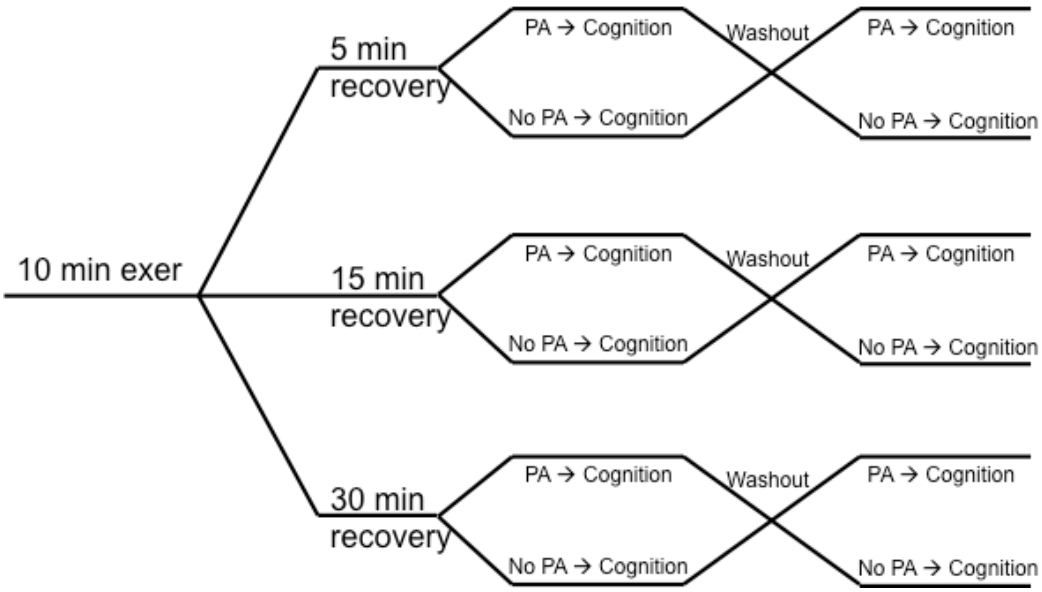

Figure 1B. Schematic pullout of the cross-over study design detailing one of the five exercise duration (e.g. 10, 20, 30, 45, and 60 minutes) with resting periods.

Table 1. Demographic characteristics of the sample.

		Point Estimate (SD)				
Group Assignment	**N**	**Age (y)**	**% Male**	**% White**	**BMI (kg/m^2)**	**Estimated VO_{2max} (mL/kg/min)**
1. 10 min EX, 5 min Rest	22	21.2 (1.8)	22.7	77.3	24.2 (4.9)	42.1 (8.2)
2. 10 min EX, 15 min Rest	22	21.3 (2.5)	31.8	50.0	27.6 (6.8)	39.6 (8.4)
3. 10 min EX, 30 min Rest	22	21.1 (1.3)	40.9	72.7	24.7 (3.9)	43.5 (7.8)
4. 20 min EX, 5 min Rest	22	21.7 (3.2)	36.4	81.8	24.9 (4.9)	43.6 (7.6)
5. 20 min EX, 15 min Rest	22	2.3 (2.4)	45.5	72.7	24.7 (3.7)	43.7 (7.9)
6. 20 min EX, 30 min Rest	22	21.4 (2.1)	31.8	72.7	24.8 (5.2)	41.8 (5.7)
7. 30 min EX, 5 min Rest	22	21.0 (1.3)	18.2	72.7	24.8 (7.1)	39.7 (8.1)
8. 30 min EX, 15 min Rest	22	21.4 (3.1)	22.7	63.6	25.8 (5.0)	41.6 (7.6)
9. 30 min EX, 30 min Rest	22	22.5 (4.1)	31.8	77.3	24.7 (4.4)	41.2 (8.8)
10. 45 min EX, 5 min Rest	22	21.4 (2.1)	22.7	63.6	25.4 (4.2)	39.5 (7.7)
11. 45 min EX, 15 min Rest	22	21.2 (2.5)	22.7	59.1	25.5 (7.1)	40.4 (9.9)
12. 45 min EX, 30 min Rest	22	21.1 (1.4)	27.3	77.3	25.9 (7.2)	40.9 (7.3)
13. 60 min EX, 5 min Rest	22	20.9 (2.9)	27.3	63.6	27.3 (6.1)	40.5 (8.7)
14. 60 min EX, 15 min Rest	22	21.8 (3.6)	13.6	68.2	23.9 (4.7)	41.1 (7.3)
15. 60 min EX, 30 min Rest	22	21.0 (1.8)	18.2	68.1	25.2 (5.2)	38.3 (7.0)
16. Control Group	22	20.9 (1.3)	13.6	72.7	23.9 (3.1)	40.8 (6.2)

BMI, Body mass index
EX, Exercise (treadmill)
VO_{2max}, Volume of maximum oxygen consumption

Table 2. Characteristics of exercise protocol.

	Mean (SD)						
Group Assignment	**Treadmill Speed (MPH)**	**Treadmill Incline (%)**	**Estimated HR at 40% of HRR**	**Estimated HR at 59% of HRR**	**Average Achieved HR during Exercise**	**RPE at End of Exercise**	**HR at 5 min Post-Exercise (recovery)**
1. 10 min EX, 5 min Rest	3.6 (0.2)	2.9 (1.9)	120.6 (4.0)	143.8 (2.9)	123.9 (9.0)	10.1 (2.1)	76.4 (7.9)
2. 10 min EX, 15 min Rest	3.4 (0.4)	2.8 (2.1)	123.8 (8.0)	146.1 (5.5)	128.4 (11.4)	11.1 (2.2)	82.5 (15.3)
3. 10 min EX, 30 min Rest	3.5 (0.3)	2.6 (2.0)	120.4 (5.8)	143.7 (4.0)	124.7 (7.7)	9.7 (2.4)	80.5 (11.0)
4. 20 min EX, 5 min Rest	3.5 (0.3)	2.9 (1.6)	122.3 (7.3)	144.9 (5.2)	127.5 (8.1)	11.7 (1.7)	84.3 (11.3)
5. 20 min EX, 15 min Rest	3.5 (0.2)	2.4 (2.2)	123.2 (7.2)	145.6 (5.2)	127.1 (8.1)	11.1 (1.2)	82.3 (10.6)
6. 20 min EX, 30 min Rest	3.3 (0.2)	3.2 (1.9)	121.4 (8.4)	144.3 (6.0)	124.2 (12.1)	10.9 (2.5)	78.7 (12.7)
7. 30 min EX, 5 min Rest	3.3 (0.3)	2.7 (1.4)	122.4 (7.7)	145.1 (5.3)	125.5 (10.2)	11.2 (2.0)	83.9 (14.4)
8. 30 min EX, 15 min Rest	3.4 (0.4)	2.7 (1.7)	121.8 (9.4)	144.6 (6.8)	123.4 (11.7)	11.1 (2.2)	82.6 (15.3)
9. 30 min EX, 30 min Rest	3.4 (0.3)	2.7 (1.8)	122.1 (6.6)	144.5 (4.8)	126.7 (9.0)	11.5 (1.9)	87.1 (14.5)
10. 45 min EX, 5 min Rest	3.4 (0.3)	1.9 (1.8)	125.8 (12.8)	147.4 (8.9)	134.1 (10.5)	10.9 (1.7)	97.1 (12.8)
11. 45 min EX, 15 min Rest	3.3 (0.3)	3.2 (2.0)	124.2 (6.4)	146.3 (4.4)	129.0 (8.5)	11.2 (2.2)	89.2 (12.0)
12. 45 min EX, 30 min Rest	3.4 (0.2)	3.0 (2.7)	122.2 (7.6)	145.0 (5.2)	126.9 (11.7)	11.0 (1.7)	86.1 (16.0)
13. 60 min EX, 5 min Rest	3.4 (0.2)	2.5 (1.9)	123.5 (7.1)	145.9 (4.9)	128.8 (9.0)	10.7 (2.4)	87.5 (13.7)
14. 60 min EX, 15 min Rest	3.4 (0.2)	2.6 (2.2)	121.5 (6.2)	144.3 (4.3)	128.5 (9.5)	11.3 (2.5)	83.8 (13.4)
15. 60 min EX, 30 min Rest	3.2 (0.3)	2.3 (1.4)	125.9 (7.2)	147.6 (5.1)	132.1 (7.9)	11.9 (2.1)	90.1 (9.5)
16. Control Group	-	-	-	-	-	-	-

EX, Exercise (treadmill)
HR, Heart rate
HRR, Heart rate reserve
MPH, Miles per hour

Table 3. Cognitive function scores across the exercise protocols (mean/sd).

	TMA		TMB		Memory		Planning		Stroop-Congruent		Stroop-Incongruent		Stroop-Control	
Group Assignment	No EX	EX	No EX	EX	No EX	EX	No EX	EX	No EX	EX	No EX	EX	No EX	EX
1. 10 min EX, 5 min Rest	20.7 (13.1)	17.1 (4.0)	43.9 (12.1)	42.7 (14.4)	5.8 (0.9)	6.0 (0.8)	31.6 (2.6)	32.5 (2.8)	991 (217)	991 (290)	1243 (264)	1178 (279)	989 (171)	1023 (280)
2. 10 min EX, 15 min Rest	18.2 (6.5)	19.1 (5.6)	45.3 (19.8)	47.2 (19.7)	5.7 (1.0)	5.7 (1.1)	31.5 (3.2)	31.4 (3.6)	903 (253)	947 (256)	1099 (315)	1069 (431)	859 (289)	901 (250)
3. 10 min EX, 30 min Rest	17.7 (5.1)	18.9 (6.3)	42.6 (15.5)	38.7 (13.2)	5.3 (1.0)	5.7 (1.1)	31.6 (2.8)	31.7 (3.0)	1012 (311)	1028 (248)	1260 (541)	1278 (418)	982 (360)	987 (326)
4. 20 min EX, 5 min Rest	15.1 (3.1)	16.2 (4.4)	41.9 (21.5)	38.7 (12.4)	6.0 (1.0)	5.7 (1.0)	32.2 (2.4)	31.6 (2.5)	853 (268)	867 (195)	1092 (239)	1097 (360)	870 (149)	890 (238)
5. 20 min EX, 15 min Rest	18.6 (7.4)	18.6 (8.6)	41.3 (11.3)	43.6 (19.9)	5.6 (1.0)	5.9 (1.3)	31.8 (3.9)	31.5 (4.9)	899 (262)	891 (217)	1160 (327)	1131 (312)	875 (269)	924 (196)
6. 20 min EX, 30 min Rest	19.7 (6.1)	17.3 (5.9)	42.2 (16.6)	38.0 (10.6)	5.3 (0.9)	5.6 (0.9)	30.0 (3.8)	31.6 (3.0)	1024 (363)	974 (269)	1245 (468)	1226 (373)	996 (346)	991 (284)
7. 30 min EX, 5 min Rest	18.7 (7.3)	19.3 (9.5)	39.4 (15.4)	44.6 (16.8)	6.0 (0.7)	5.7 (0.8)	33.0 (2.4)	31.8 (3.7)	969 (358)	967 (356)	1198 (493)	1210 (454)	914 (270)	1010 (295)
8. 30 min EX, 15 min Rest	18.3 (4.6)	19.9 (8.1)	45.3 (22.2)	38.7 (13.6)	5.9 (1.1)	5.5 (1.1)	31.2 (3.4)	31.2 (3.7)	975 (313)	994 (319)	1226 (381)	1187 (399)	951 (212)	1030 (327)
9. 30 min EX, 30 min Rest	15.2 (4.6)	16.7 (6.8)	36.8 (21.0)	41.8 (31.6)	6.0 (0.8)	5.7 (0.9)	31.8 (2.8)	31.0 (3.7)	951 (208)	988 (293)	1102 (322)	1190 (354)	972 (266)	969 (300)
10. 45 min EX, 5 min Rest	18.6 (5.7)	17.2 (4.9)	42.4 (12.9)	43.7 (34.0)	5.5 (1.2)	5.8 (0.7)	32.9 (2.2)	31.8 (5.6)	996 (236)	923 (267)	1225 (402)	1201 (418)	977 (312)	942 (235)
11. 45 min EX, 15 min Rest	17.7 (8.6)	17.6 (6.4)	43.4 (19.9)	42.0 (20.9)	6.1 (0.7)	5.8 (0.9)	31.5 (3.0)	32.0 (3.0)	879 (171)	973 (412)	1068 (258)	1076 (480)	930 (242)	899 (278)
12. 45 min EX, 30 min Rest	17.4 (5.2)	15.9 (3.5)	50.1 (22.5)	40.9 (17.4)	5.9 (0.9)	5.9 (1.1)	31.6 (3.8)	32.9 (3.4)	990 (306)	943 (251)	1195 (430)	1184 (474)	989 (284)	976 (284)
13. 60 min EX, 5 min Rest	17.1 (5.8)	18.2 (7.6)	39.9 (12.7)	42.0 (15.4)	5.5 (0.6)	6.0 (0.8)	32.9 (2.0)	32.0 (2.9)	953 (270)	995 (264)	1186 (354)	1142 (320)	928 (197)	967 (308)
14. 60 min EX, 15 min Rest	17.8 (6.2)	17.3 (4.9)	36.7 (7.6)	38.6 (10.4)	6.0 (0.8)	5.8 (0.9)	32.2 (3.5)	30.8 (4.0)	916 (211)	915 (267)	1071 (232)	1166 (412)	874 (166)	905 (213)
15. 60 min EX, 30 min Rest	19.1 (5.8)	20.5 (9.3)	47.5 (16.1)	45.7 (18.6)	5.7 (0.7)	5.6 (1.0)	31.2 (4.2)	31.1 (3.8)	1035 (305)	1003 (263)	1330 (455)	1313 (443)	990 (224)	1010 (301)
16. Control Group	17.2 (5.1)	17.0 (6.0)	45.9 (30.4)	40.3 (16.4)	5.7 (0.8)	5.8 (1.0)	30.9 (2.6)	32.4 (2.7)	1005 (275)	977 (294)	1207 (394)	1180 (352)	966 (228)	972 (275)
P-Value 1 †	F=1.10, P=0.35		F=1.31, P=0.19		F=1.29, P=0.16		F=0.71, P=0.76		F=0.99, P=0.45		F=0.61, P=0.86		F=0.58, P=0.88	
P-Value 2 †	F=0.96, P=0.52		F=0.85, P=0.64		F=1.29, P=0.14		F=0.91, P=0.60		F=1.52, P=0.04		F=1.88, P=0.004		F=1.08, P=0.35	

† P1 = The P-value for the group x time (2 x 16) interaction
† P2 = The P-value for the group x cognition tertile (baseline, non-exercise) x time (3 x 16) interaction

EX = Exercise (treadmill). That is, the exercise bout occurred before the cognition assessment
No Ex = No exercise before the cognition assessment.

Table 4. Statistical comparison (p-values displayed) between the individual experimental groups and the control group.

	TMA		TMB		Memory		Planning		S-Congruent		S-Incongruent		S-Control	
Group Assignment	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
1. 10 min EX, 5 min Rest vs. Control	0.22	0.58	0.56	0.96	0.68	0.08	0.52	0.96	0.70	0.82	0.70	0.73	0.71	0.82
2. 10 min EX, 15 min Rest vs. Control	0.54	0.69	0.36	0.92	0.99	0.66	0.14	0.62	0.35	0.44	0.98	0.85	0.69	**0.006**
3. 10 min EX, 30 min Rest vs. Control	0.41	0.95	0.81	0.68	0.24	0.47	0.14	0.76	0.50	0.11	0.65	0.45	0.99	0.82
4. 20 min EX, 5 min Rest vs. Control	0.35	0.83	0.77	0.54	0.42	**0.04**	**0.04**	0.33	0.53	0.64	0.72	0.59	0.81	0.37
5. 20 min EX, 15 min Rest vs. Control	0.91	0.09	0.31	0.76	0.33	0.22	0.18	0.43	0.78	0.24	0.99	0.70	0.54	0.37
6. 20 min EX, 30 min Rest vs. Control	0.12	0.27	0.85	0.98	0.52	0.83	0.91	0.33	0.79	0.23	0.92	0.97	0.89	0.24
7. 30 min EX, 5 min Rest vs. Control	0.70	0.93	0.16	0.95	0.21	0.34	**0.01**	0.92	0.75	0.81	0.75	0.11	0.19	0.71
8. 30 min EX, 15 min Rest vs. Control	0.41	0.23	0.89	0.66	0.19	**0.002**	0.19	0.48	0.44	0.91	0.89	0.95	0.29	0.78
9. 30 min EX, 30 min Rest vs. Control	0.25	0.91	0.18	0.51	0.28	**0.03**	**0.01**	0.33	0.26	0.43	0.20	0.85	0.91	0.97
10. 45 min EX, 5 min Rest vs. Control	0.39	0.85	0.44	0.53	0.28	**0.02**	0.06	0.49	0.42	0.87	0.96	0.98	0.48	0.73
11. 45 min EX, 15 min Rest vs. Control	0.96	0.78	0.62	0.89	0.35	0.54	0.29	0.76	0.17	0.26	0.75	0.29	0.62	0.76
12. 45 min EX, 30 min Rest vs. Control	0.33	0.47	0.63	0.86	0.88	0.47	0.83	0.89	0.77	0.50	0.85	0.47	0.81	0.94
13. 60 min EX, 5 min Rest vs. Control	0.36	0.53	0.29	0.71	0.17	0.76	**0.01**	0.54	0.31	0.44	0.85	0.85	0.57	0.69
14. 60 min EX, 15 min Rest vs. Control	0.82	0.35	0.30	0.98	0.37	0.17	**0.005**	0.88	0.69	0.20	0.18	0.06	0.64	0.83
15. 60 min EX, 30 min Rest vs. Control	0.41	0.79	0.63	0.79	0.59	**0.05**	0.24	0.66	0.96	0.21	0.87	0.09	0.76	0.59
16. Control Group	-	-	-	-	-	-	-	-	-	-	-	-	-	-

† P1 = The P-value for the group x time interaction

† P2 = The P-value for the group x cognition tertile (baseline, non-exercise) x time interaction

EX = Exercise (treadmill). That is, the exercise bout occurred before the cognition assessment

No Ex = No exercise before the cognition assessment

S = Stroop test

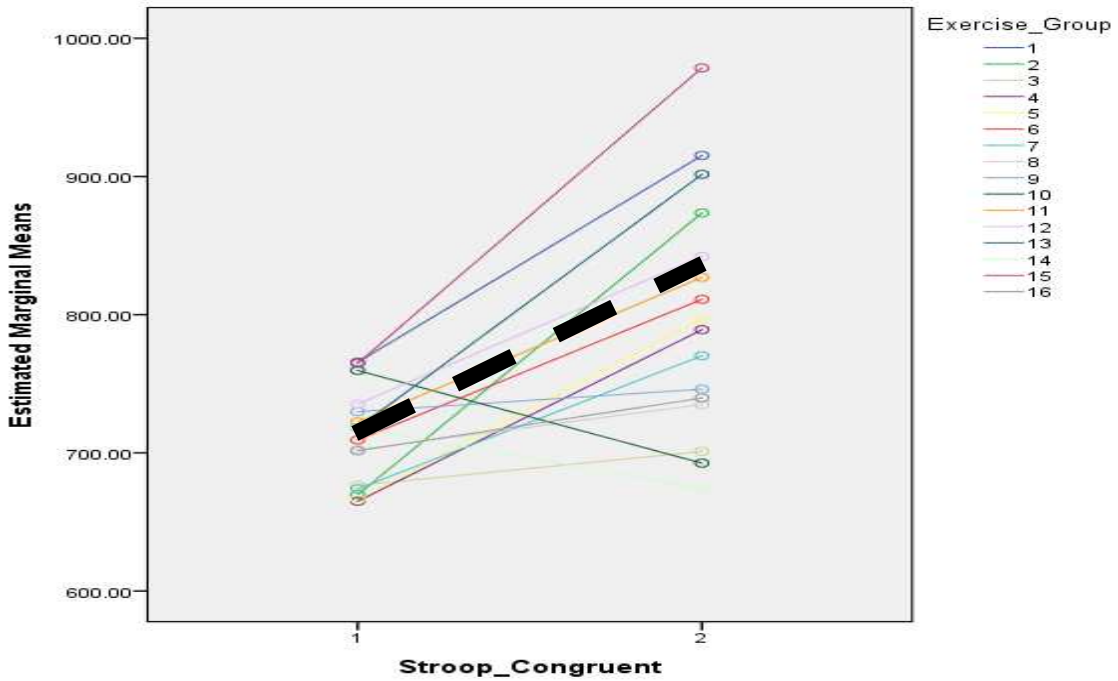

Figure 2A. Stroop congruent results for the non-exercise visit (1) compared to after exercise (2) among those in the lowest tertile for baseline Stroop congruent cognition. Bolded dashed line is the average across the groups.

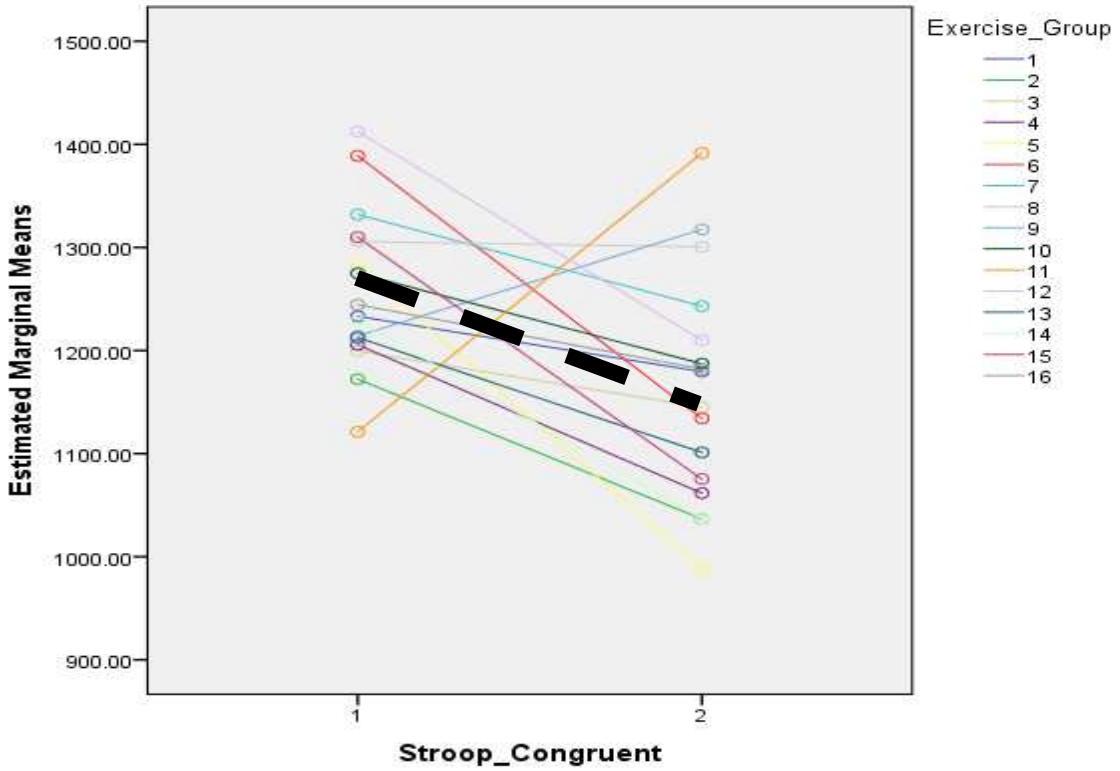

Figure 2B. Stroop congruent results for the non-exercise visit (1) compared to after exercise (2) among those in the top tertile for baseline Stroop congruent cognition. Bolded dashed line is the average across the groups.

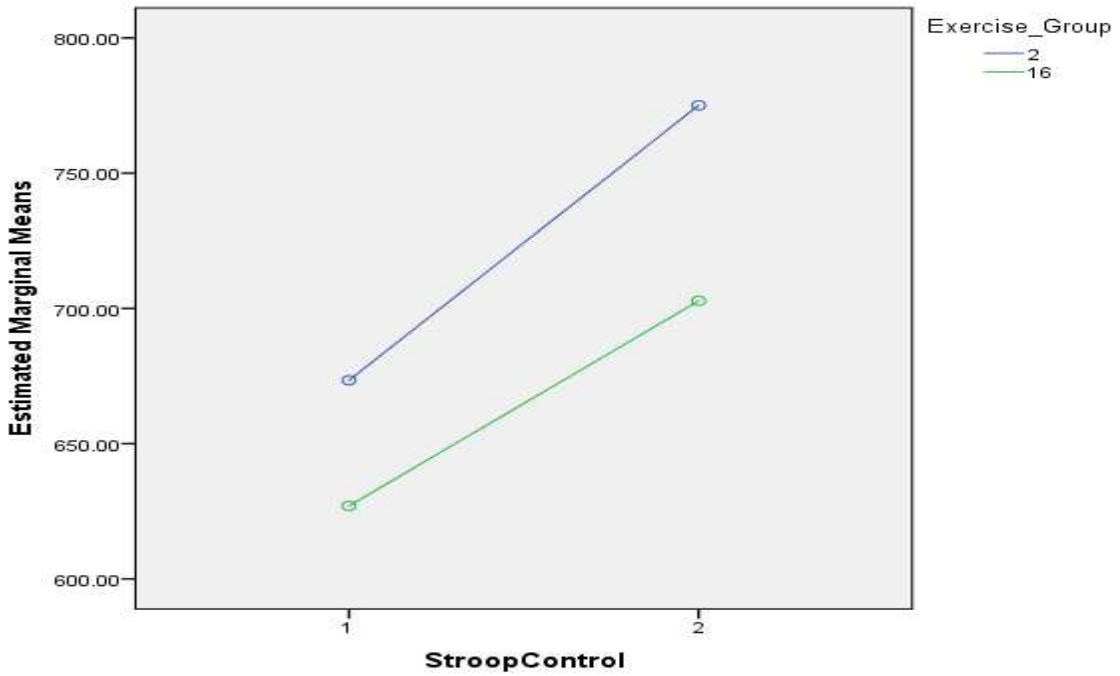

Figure 3A. Stroop control scores comparing Group 2 vs. Group 16 for non-exercise (1) and after exercise (2) among those in the lower tertile for baseline Stroop control cognition.

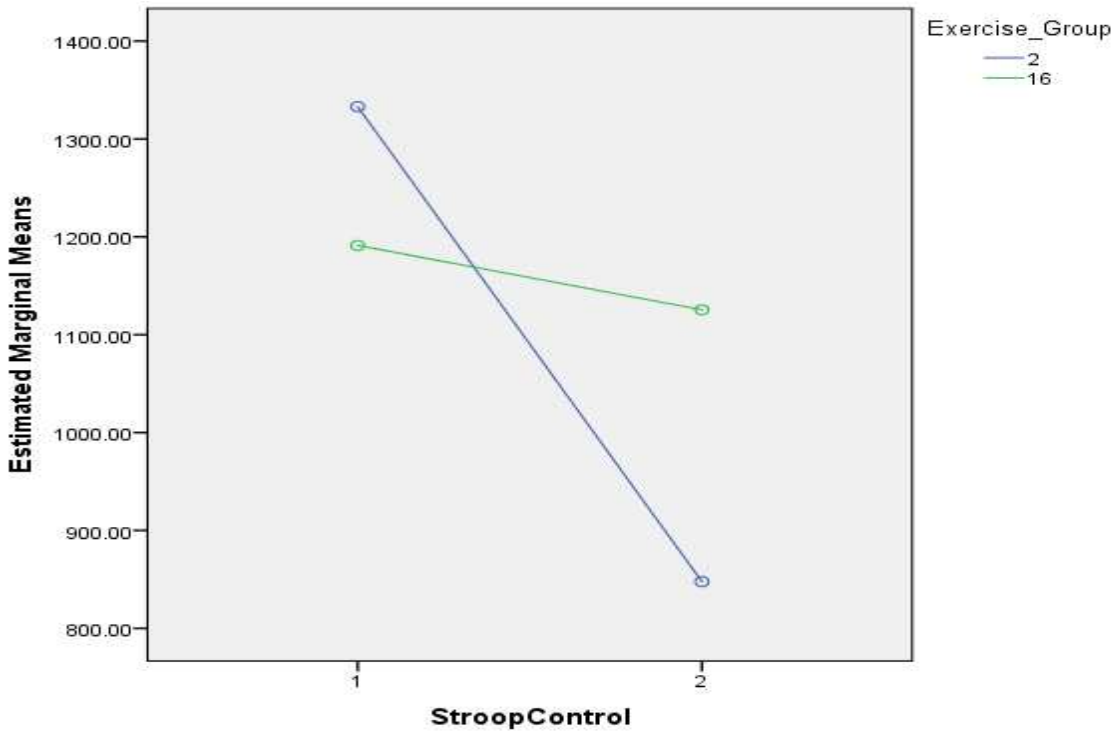

Figure 3B. Stroop control scores comparing Group 2 vs. Group 16 for non-exercise (1) and after exercise (2) among those in the upper tertile for baseline Stroop control cognition.

VITA

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Curriculum Vitae

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Education

2017- Doctorate in Health Promotion: University of Mississippi
Intended Graduation: May 2020

2015 - 2017 Masters in Exercise Science: University of Mississippi
Graduation: May 2017

2011 - 2015 Bachelors in Exercise Science: Bellarmine University
Graduation: May 2015

Research Experience

2015- **Masters Thesis** – *University of Mississippi*

Designed and coordinated *Dose-Response Association Between Acute Exercise Duration, Exercise Recovery, and Cognitive Function*

I designed this research question and built this study to be a comprehensive study of this association. Participant recruitment, commitment, and participation, analyzing data, and writing manuscripts are all involved.

2014-2015 **Undergraduate Research Thesis** – *Bellarmine University*

Designed and coordinated *Objectively Assessed Physical Activity and Personality Factors in College-Aged Students*

I designed this research question and built this study from the ground up; writing the IRB, getting participant commitment, coordinating participation, using SPSS, analyzing the data, and writing the manuscripts.

2014 **Undergraduate Research Presentation** – Exercise Science – *Bellarmine University*

Working under Dr. Paul Loprinzi with the study Association of physical education frequency, duration and school sports participation with U.S. adolescent physical activity, muscular fitness, and exercise-related beliefs.

With a partner, I analyzed the data and created a poster to present at the undergraduate research poster event and presented the data to judges during the event.

Peer-Reviewed Publications

Loprinzi PD, Edwards MK, **Crush E**, Ikuta T, Arco AD. Dose–Response Association Between Physical Activity and Cognitive Function in a National Sample of Older Adults. *American Journal of Health Promotion.*

Crush, E., & Loprinzi, P. D. (2016). The Association Between Demographic and Lifestyle Characteristics on Patient Cholesterol Profile. *Journal of Behavioral Health*.

Loprinzi. P.D., **Crush, E.** (in press). Physical activity and cognitive function among older adults with congestive heart failure patients. *Journal of Molecular Pathophysiology.*

Crush, E. & Loprinzi, P.D. (in press). Lifestyle characteristic and patient cholesterol profile. *Journal of Behavioral Health*.

Loprinzi, P.D. & **Crush, E**. (in press). Source and size of social support network on sedentary behavior among older adults. *American Journal of Health Promotion*.

Loprinzi, P.D. & **Crush, E**. (in press). Sensory impairment, functional balance and physical activity with all-cause mortality. *Journal of Physical Activity & Health*.

Edwards, M.K., **Crush, E**., & Loprinzi, P.D. (in press). Dietary behavior and predicted 10-yr risk of a first atherosclerotic cardiovascular disease (ASCVD) event using the Pooled Cohort Equations among US adults. American Journal of Health Promotion.

Loprinzi, P.D., **Crush, E**., & Joyner, C. (in press). Cardiovascular disease biomarkers on cognitive function in older adults: Joint effects of cardiovascular disease biomarkers and cognitive function on mortality risk. *Preventive Medicine.*

Peer-Reviewed Publications (Under Review)

Loprinzi, P.D., Joyner, C., & **Crush, E**. (under review). Multiple health characteristics on cognitive function in older adults. *AGE*.

Professional Presentations

Frith, E., **Crush, E.**, & Loprinzi, P. (2014). Association of physical education frequency, duration and school sports participation with U.S. adolescent physical activity, muscular fitness, and exercise-related beliefs. *Poster presentation at the undergraduate research poster event at Bellarmine University.*

Instructor

EL 129: Body Contouring and Conditioning

A body contouring and conditioning course that deals with muscular development, cardiovascular fitness, flexibility training, and the individual. Students are introduced to various strength training and cardiovascular programs and instructed to apply them to his/her personal fitness goals. The course covered learning proper technique, body weight circuit training, and yoga.
Fall 2015, Spring 2016, Fall 2016, Spring 2017

EL 153: Sports Conditioning

A sports conditioning course that deals with muscular development, cardiovascular fitness, flexibility training, and the individual. Students are introduced to various strength training and cardiovascular programs and instructed to apply them to his/her personal fitness goals. The course covered learning proper technique, body weight circuit training, and yoga.
Spring 2016, Spring 2017

EL 156: Jogging

An introduction to jogging course. The course covered jogging as well as other cardio activities associated with jogging.
Fall 2015

EL 158: Low Impact Aerobics

A low impact aerobics course that deals with muscular development, cardiovascular fitness, flexibility training, and the individual. Students are introduced to various strength training and cardiovascular programs and instructed to apply them to his/her personal fitness goals. The course covered low impact aerobic activities such as fitness walking, swimming, and yoga.
Fall 2015, Fall 2016

Awards

Bellarmine University Student Government Association Undergraduate Research Award, 2014-2015, $500

Certifications

American Red Cross: Certified Instructor

American Heart Association: CPR Certified

Professional Societies/Organizations

Bellarmine University Exercise Science Association, Member (2011-2015); Secretary (2013-2014)

Service

University of Mississippi
Judge at the Elementary/Middle School Science Fair (Spring 2017)

Bellarmine University
Women's Tennis Team; Member (2011- 2015); Captain (2013-2014)
Student Ambassador (2011-2015)
Student Athletic Advisory Committee, Member (2011-2015); Vice President (2013-2015)

Community
Tennis Instructor, Rising Stars (2007-2015)