Cognitive Function During Acute Exercise: A Test of the Transient Hypofrontality Theory

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The purpose of this study was to test the transient hypofrontality theory (Dietrich, 2003) by examining the influence of exercise intensity on executive control processes during and following submaximal exercise. Thirty participants (13 female) exercised for 30 min at ventilatory threshold (VT) or at 75% of VT. The Contingent Continuous Performance Task (CPT) and Wisconsin Card Sorting Test (WCST) were used as measures of executive control. They were administered before, during, immediately following, and 20 min after exercise. An increase in false alarms and unique errors \((p \leq .05)\) occurred during both conditions. False alarms for the CPT and total and perseverative errors for the WCST remained elevated immediately following exercise at VT, but not at exercise below VT \((p \leq .01)\). The decreased executive control function during exercise can be explained by the transient hypofrontality theory. Following VT, executive control performance remained poor possibly owing to an additional amount of time the brain needs to return to homeostasis following intense exercise.

Keywords: executive control, cognitive function, ventilatory threshold, acute exercise, transient hypofrontality

Tomporowski (2003) reviewed the literature exploring the relationship between acute bouts of exercise and cognitive performance and found that most studies demonstrated an improvement in cognitive function following a bout of submaximal exercise with durations up to 60 min. However, a few issues still need to be explored to determine how cognitive function is influenced by acute exercise. The first involves the types of tasks used in many of these studies. They have varied from simple tasks that involve speed (e.g., reaction time) to more complex tasks that involve executive function (e.g., the Stroop test). It is possible that exercise might differently influence tasks of varying complexity. In addition, exercise intensity has been quite varied, making it difficult to draw firm conclusions about the relationship between acute exercise and cognitive function. While most of this research has focused on cognitive function following exercise, little has examined cognition during exercise.

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Complex cognitive processes are important because they relate to daily function and span broad areas, including memory and executive control processes. Generally, short-term memory appears to be resistant to the effects of exercise, as a number of studies have found few or no changes in memory immediately following an exercise bout (Coles & Tomporowski, 2008; Covassin, Weiss, Powell, & Womack, 2007; Sjoberg, 1980; Tomporowski, Ellis, & Stephens, 1987). However, there is some recent support that acute bouts of exercise may positively impact working memory in those with low working memory performance before exercise (Sibley & Beilock, 2007) and in acute aerobic, but not anaerobic exercise (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). In addition, acute exercise has been shown to have some benefits in long-term memory (Coles & Tomporowski, 2008; Potter & Keeling, 2005). Tomporowski and Ganio (2006) observed both memory and executive control processes after 30 min of exercise. Similar to other studies, results showed performance on the memory task was unaffected by exercise. However, the executive control task demonstrated improvement following both the control and exercise conditions, which indicates executive control tasks may be more sensitive to change than memory tasks.

Other studies have found a relationship between exercise and executive control processes. The Stroop test is commonly used as a measure of executive control because it relies on inhibition of interfering cues for successful completion and has been widely used in this line of research. Improvements in performance on this task following exercise have been demonstrated (Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Sibley, Etnier, & LeMasurier, 2006).

The prevailing thought on this topic is that executive control functions improve following exercise. What is less clear is how executive control changes during exercise. Executive control processes are important in sport and occupational settings (e.g., for military personnel or in fire fighting) where a person is being asked to make decisions while performing physical work (Bailey et al., 2008).

Dietrich (2003) proposed the transient hypofrontality theory in an attempt to explain this phenomenon, stating that “altered states of consciousness” can be produced by various stimuli including drug-induced states, hypnosis, and endurance running (p. 237). Dietrich constructed a hierarchy of consciousness in which basic biological functions, such as heart rate, lie at the bottom, and executive processes in the dorsolateral prefrontal cortex are at the top. The theory suggests that events, such as endurance exercise, lead to a deregulation of the highest level of consciousness associated with the prefrontal cortex. When this occurs, the next layer of consciousness takes control over function. Because this effect is transitory, all functioning is restored as soon as the altered state, such as that produced by exercise, has ended. From a behavioral standpoint, this theory suggests a person temporarily experiences impairments in the functions associated with the prefrontal cortex during certain altered states.

Dietrich (2006) refined the theory to specifically explain why executive control processes would be adversely affected by exercise. The basis of the theory exists on the assumption that the brain operates on a fixed amount of metabolic resources during exercise. Because an increase in the amount of brain activation is required to perform dynamic movements of the body, activation of the motor cortices of the brain come at the expense of other regions. According to the theory, the prefrontal cortex is most affected by the reallocation of resources leading to a temporary
deregulation which can be observed behaviorally as decrements in cognitive function during exercise. Because the motor cortex activation would cease when exercise ended, metabolic resources in the brain would be restored almost immediately and the decrements in cognitive function would not necessarily follow into recovery.

Dietrich and Sparling (2004) performed a study to determine whether exercise is specific in targeting functions associated with the prefrontal cortex. As part of their first experiment, they separated participants into three groups: running, cycling, and a sedentary control. Each group completed two cognitive tasks, the Wisconsin Card Sorting Test (WCST) and an intelligence task. The WCST has been shown to target the prefrontal cortex whereas the intelligence task does not rely heavily on the prefrontal cortex. Their results found decreases in performance only on the WCST in both the cycling and running groups indicating that the prefrontal cortex was disrupted during exercise. The study was repeated using the Paced Auditory Serial Addition Test, a test that uses the prefrontal cortex and the Peabody Picture Vocabulary Test, which does not rely on the prefrontal cortex. Their results, once again, showed decrements in performance were only observed during exercise in the task that was prefrontal dependent. These results provided initial support for the transient hypofrontality theory.

Recent studies have shown support for the transient hypofrontality theory by demonstrating impaired executive function during exercise. Pontifex and Hillman (2007) found a decrease in response accuracy in the incongruent condition (the more difficult condition) of the flankers test, which demonstrated a debilitative effect on executive control during exercise. In addition, they examined event-related potentials elicited by an executive control task during exercise and found evidence for more attentional resource allocation and slower processing speed as indexed by P3 amplitude and latency, respectively. Davranche and McMorris (2009) found response inhibition to be compromised during exercise. In addition, several other studies have shown executive function to be impaired during exercise (Adam, Teeken, Ypelaar, Verstappen, & Paas, 1997; Audiffren, Tomporowski, & Zagrodnik, 2008; Mahoney, Hirsch, Hasselquist, Lesher, & Lieberman, 2007; Paas & Adam, 1991).

Considering the small number of studies that have examined cognition during exercise, more research is needed to determine how executive processes change during exercise and how exercise intensity may influence executive function during exercise. Therefore, the purpose of this study was to test the transient hypofrontality theory by examining executive control processes during and following submaximal exercise below and at ventilatory threshold (VT). It was hypothesized that executive control tasks would be impaired during exercise, with the greatest impairment seen during the exercise bout at VT. In accordance with previous research, it was also hypothesized that executive control functions would improve immediately following exercise and then return to baseline values following 20 min of recovery.

**Methods**

**Participants**

Thirty college students (17 male, 13 female) participated in this study (see Table 1 for descriptive information). The participants in this study were considered to be above average in fitness as determined by norms established for their age and
gender on percent body fat and $\text{VO}_{2\text{peak}}$ (American College of Sports Medicine, 2006). In addition, as would be expected, males had lower percent body fat ($F(1, 28) = 40.9, p < .001$) and greater $\text{VO}_{2\text{peak}}$ ($F(1, 28) = 8.8, p = .006$).

All participants completed a written informed consent and Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading, & Shephard, 1992) before taking part in the study. The completion of the PAR-Q insured that participants had no known medical condition that could influence their ability to exercise. This study was approved by the university’s Institutional Review Board.

**Measures**

The Contingent Continuous Performance Task and the Wisconsin Card Sorting Test were administered using STIM2 software (Compumedics Neuroscan; Charlotte, NC). The tests were projected onto a large screen in front of the participant. A wireless keyboard and mouse served as the response devices for each of the tasks. The tests were randomized and counterbalanced each time they were administered. The participants needed between 3 and 4 min to complete the cognitive tasks; the Contingent Continuous Performance Task took 2 min, whereas the Wisconsin Card Sorting Test was completed in approximately 1–2 min.

**Contingent Continuous Performance Task.** The Contingent Continuous Performance Task (CPT) is an attentional task that has an executive control component. The participant was presented with a series of letters that flashed on the screen for 200 ms with 1000 ms between each letter. The task instructions were to click the mouse whenever the target letter “T” was shown. The letter “S” would always precede the letter “T” but did not always indicate that the target letter would follow. Twenty target letters and 10 lures were presented in the task. A lure occurred when the letter “S” was shown and the letter “T” did not follow. A false alarm was recorded anytime the participant clicked the mouse when a letter “T” was not shown. Because preventing these mistakes requires inhibitory processing, the number of false alarms was recorded as an executive control variable. Attentional abilities, part of executive control processes, are crucial for successful completion of the CPT test (Smid, de Witte, Homminga, & van den Bosch, 2006).
Wisconsin Card Sorting Test. A modified version of the WCST was used in the current study. The computer program presented four cardlike stimuli at the top of the screen with a different pattern on each: one red triangle, two yellow stars, three green crosses, and four blue circles. The participant was then required to match the probe stimulus, which appeared in the bottom right-hand corner of the screen. The probe stimuli had one of four shapes (triangle, star, cross, or square), colors (red, yellow, green, or blue), and number of objects (one, two, three, or four). The participant was told to match the probe stimulus to one of the four cardlike stimuli by color, shape, or number. They pressed buttons on a wireless keyboard that corresponded to one of the cardlike stimuli. Feedback was given as to whether the card placement was correct by a tone and the appearance of the word “CORRECT” or “INCORRECT” at the top, middle portion, of the screen. As soon as 10 cards were matched correctly, the computer would change the rule and the participant would be required to adapt and match cards according to the new rule. Though the participants were unaware, the computer changed the rule after 10 cumulative correct placements of the cards. The test was completed after the participant successfully sorted 60 cards.

Total errors, perseverative errors, and unique errors were recorded as executive control variables since an increase in any of these variables suggests executive control impairment. Total errors were calculated as the number of times a card was matched incorrectly. Perseverative errors are a type of error that occurred when the participant continued to follow the previous set’s rule. For example, following a rule change from color to number, the participant would make a perseverative error by continuing to match cards by the color. Unique errors occurred when a card was matched by neither color, shape, nor number. An example of this could be if the participant matched three green triangles to four blue squares. The WCST is considered to be one of the most accurate measures of executive control (Royall et al., 2002).

Procedures

Participants came into the laboratory for three sessions. During the first session, participants completed the informed consent and PAR-Q. Height and weight were assessed and body composition was measured by bioelectrical impedance using an HBF-306C body fat analyzer (Omron Health Care Inc., Vernon Hills, IL). The participant was fitted with a heart rate monitor (Polar, Lake Success, NY) and asked to sit on the recumbent bike to begin the test. The participant was given written and verbal instructions on how to complete the cognitive tasks. The participant practiced each cognitive task until he or she reported confidence in understanding how to complete the task. The researcher confirmed this by examining the results of the task. Baseline measures for the tests were taken, and then the protocol for the graded exercise test (GXT) began.

The GXT protocol began with the participant seated on the bike for 2 min to obtain resting expired gases. Male participants began the protocol at 50 W and increased 25 W every 2 min until exhaustion. Female participants began the protocol at 30 W and increased 20 W every 2 min until exhaustion. The test was slightly different for each gender to account for body size and muscle mass so that the GXT time was similar regardless of gender. Borg’s 6–20 Ratings of
Perceived Exertion (RPE; Borg, 1998) and heart rate were taken at the end of every stage of the GXT. The analysis of expired gases occurred using the True-One 2400 Metabolic Measurement System (ParvoMedics Inc., Sandy, UT). The expired gas data were used to determine \( \text{VO}_{2\text{peak}} \), as indicated by the greatest value of 30-s averages, as well as ventilatory threshold (VT). Ventilatory threshold was graphically determined by plotting the ventilatory equivalents for oxygen (\( V_{E}/\text{VO}_2 \)) and carbon dioxide (\( V_{E}/\text{VCO}_2 \)) across work rates and identifying the point at which there was a systematic increase in \( V_{E}/\text{VO}_2 \) without a corresponding increase in \( V_{E}/\text{VCO}_2 \) (Davis, Frank, Whipp, & Wasserman, 1979). The point of divergence between the two lines was identified visually and agreed upon by two raters. The intensities for the second and third sessions were based on the determination of VT.

Sessions 2 and 3 measured cognitive function before, during, and following exercise at 75% VT or at VT. Intensity was randomly assigned and counterbalanced so each participant exercised at both intensities on different days. Sessions 2 and 3 occurred at the same time of day. Upon arrival at the laboratory, the participant was asked to review each cognitive task and practice until he or she felt confident in their ability to complete the task. Baseline measures of heart rate and cognitive tasks were taken before beginning the exercise bout. The exercise bout began with a 5-min warm-up in which the participant reached the desired intensity (e.g., 75% VT or VT). Participants began the warm-up at the same wattage as they started the GXT and wattage was increased to the desired workload as determined from the GXT. Including warm-up the total duration of the exercise session was 30 min. Exercise intensity was monitored by recording heart rate and RPE for the participant every 5 min throughout the exercise to ensure the desired intensity was maintained. If heart rate was below or above the desired level, the intensity was titrated until the heart rate reached the predetermined value. The cognitive tests were repeated at 20 min following the onset of exercise (while the participant was still cycling), immediately following exercise (post 0), and 20 min into recovery (post 20). All cognitive tasks were completed while the participant was seated on the recumbent cycle.

In an effort to ensure that no lingering effects from preceding exercise bouts influenced cognitive performance on subsequent sessions, trials were scheduled no less than 48 hr apart. Subsequently, there were 4.8 ± 2.8 days between the GXT and Session 2 and 5.7 ± 6.2 days between Sessions 2 and 3.

**Data Analysis**

A Condition (2: 75%VT, VT) × Time (4: baseline, 20 min, post 0, post 20) repeated measures general linear model (RM GLM) was used to determine main and interaction effects of condition and time (within-subjects repeated measure) for each of the cognitive function variables. Partial eta squared (partial \( \eta^2 \)) values were reported as estimates of effect size. A least-significant difference test was performed for all post hoc analyses. To determine differences between conditions, a paired-samples \( t \) test was used when appropriate. Cohen’s effect sizes were calculated to examine main effects for time and condition as suggested by the American Psychological Association (2001) and Andersen, McCullagh, & Wilson, (2007).
Results

As a manipulation check, a RM GLM was conducted for heart rate and RPE at 20 min during exercise to verify that the two intensities were different from one another. There was a significant difference in heart rate ($F(1, 28) = 7.42, p < .001$, partial $\eta^2 = 0.96$) and RPE ($F(1, 28) = 170.9, p < .001$, partial $\eta^2 = 0.86$). See Table 1 for heart rate and RPE values.

Table 2 provides descriptive information and effect sizes for all cognitive variables. A 2 (Condition) $\times$ 4 (Time) RM GLM for false alarms revealed a significant time effect ($F(3, 27) = 4.40, p < .01$, partial $\eta^2 = 0.33$) and a significant condition effect ($F(3, 27) = 5.88, p < .05$, partial $\eta^2 = 0.17$). There was a nonsignificant time $\times$ condition interaction ($F(3, 27) = 2.28, p > .05$, partial $\eta^2 = 0.20$). The time effect was due to an increase in false alarms from baseline to during exercise (LSD post hoc < .05) and a decrease in false alarms immediately following exercise compared with during exercise (LSD post hoc < .01). The condition effect was due to more false alarms in the VT condition.

A 2 (Condition) $\times$ 4 (Time) RM GLM revealed a significant time $\times$ condition effect ($F(3, 27) = 3.17, p < .05$, partial $\eta^2 = 0.26$) for the total number of errors for the WCST, but not an effect for time ($F(3, 27) = 1.43, p > .05$, partial $\eta^2 = 0.14$) or condition ($F(1, 29) = 3.27, p > .05$, partial $\eta^2 = 0.10$). A paired samples $t$ test revealed that the number of errors immediately following exercise at the 75% VT condition was dramatically decreased compared with the total errors made following the VT condition, which remained elevated ($t(29) = 3.11, p < .01$). There were no other significant differences between the two conditions.

A 2 (Condition) $\times$ 4 (Time) RM GLM revealed a significant time $\times$ condition effect for perseverative errors ($F(3, 27) = 4.75, p < .01$, partial $\eta^2 = 0.35$), but not an effect for time ($F(3, 27) = 1.30, p > .05$, partial $\eta^2 = 0.13$) or condition ($F(1, 29) = 0.75, p > .05$, partial $\eta^2 = 0.03$). Paired samples $t$ test revealed that the number of perseverative errors made following the VT condition were significantly greater than the perseverative errors immediately following the 75% VT condition ($t(29) = 3.30, p < .01$). There were no other significant differences between the two conditions.

A 2 (Condition) $\times$ 4 (Time) repeated measures GLM for unique errors revealed a significant time effect ($F(3, 27) = 5.45, p < .01$, partial $\eta^2 = 0.38$), but not a condition ($F(1, 29) = 3.57, p > .05$, partial $\eta^2 = 0.11$) or time $\times$ condition interaction ($F(3, 27) = 1.34, p > .05$, partial $\eta^2 = 0.13$). The time effect was due to an increase in unique errors from baseline to during exercise (LSD post hoc < .01), which then decrease from during exercise to immediately following exercise (LSD post hoc < .001) and post 20 (LSD post hoc < .01).

Discussion

The purpose of this study was to observe the influence of acute exercise on executive control processes during and following submaximal exercise. Participants completed two different cognitive tasks before, during, immediately following exercise, and 20 min into recovery. Executive control performance decreased during exercise at both intensities and carried over into the minutes immediately following exercise for the VT condition only.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Time</th>
<th>Pre-</th>
<th>During</th>
<th>Post-0</th>
<th>Post-20</th>
<th>Pre-</th>
<th>During</th>
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<td>Pre-</td>
<td>1.0 ± 1.1</td>
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<td>During</td>
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<td>Total Errors</td>
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<td>Pre-</td>
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<td>11.5 ± 3.2</td>
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<td>−.07</td>
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<td>11.1 ± 3.4</td>
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<td>−.25</td>
<td>.17</td>
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<td>.57</td>
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<td></td>
<td>Pre-</td>
<td>0.7 ± 1.2</td>
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<td>−.25</td>
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<td>−.59</td>
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<td>1.4 ± 1.2</td>
<td>−.51</td>
<td>−.62</td>
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*Note.* Effect sizes comparing time points were calculated (e.g., \((M_{\text{During}} - M_{\text{Pre}})/SD_{\text{pooled}}\)); thus, positive effect sizes reflect greater errors at the later time point. Effect sizes (ES<sub>cond</sub>) comparing conditions were calculated as \((M_{\text{VT}} - M_{\text{75%VT}})/SD_{\text{pooled}}\); thus, positive effect sizes reflect greater errors in the VT condition.
The transient hypofrontality theory was proposed to explain how higher level cognition, executive control, is altered as a function of exercise. The increase in false alarms in the CPT lends support to this theory since false alarms correspond to a lack of inhibition, which is a component of executive control. Since increases in false alarms were observed only during exercise this could be an indication of the deregulation of the prefrontal cortex associated with exercise.

Results from the WCST provide support for this hypothesis, as well, since the ability to maintain a set of rules—sort cards according to those rules and adapt when new information is presented—is a core part of executive control processing (Royall et al., 2002). The increase in unique errors made on the WCST during exercise was perhaps most indicative of executive control impairment since these errors represented a lack of focus on the participant’s part to sort the cards. It is also worth noting there were nonsignificant increases in the number of total errors and perseverative errors made during exercise at both intensities. Dietrich and Sparling (2004) have reported similar results in favor of their theory when they showed cognitive decrements during exercise in the WCST and another test using primarily executive control. Therefore, this study provides additional support for the transient hypofrontality theory and previous research that has shown decrements in cognitive function during exercise (Adam et al., 1997; Audiffren et al., 2008; Davranche & McMorris, 2009; Mahoney et al., 2007; Paas & Adam, 1991; Pontifex & Hillman, 2007). Previous research has shown it is unlikely these findings are a result of the participants having their attention and effort divided between exercise and the cognitive task (Dietrich & Sparling, 2004). In their studies, Dietrich and Sparling found no differences in performance on the Kaufman Brief Intelligence Test and the Peabody Picture Vocabulary Test between the exercise and control conditions. If the differences were due to simply dividing the attention between exercise and cognitive task, differences should have been found on these tasks as well.

The present study did not show improvements in cognitive function following exercise as has previously been seen by other researchers (Hogervorst et al., 1996; Sibley et al., 2006; Tomporowski, 2003). One explanation for why improvements were not seen following exercise was due to insufficient statistical power stemming from relatively low participant numbers. It should be noted that compared with baseline levels, there were improvements in executive function immediately following exercise at the 75% VT condition as can be seen in false alarms, total errors, perseverative errors, and unique errors, but these returned to baseline levels at 20 min following exercise.

The results of the current study suggest that hypofrontality may continue following exercise at VT. False alarms for the CPT and total errors for the WCST immediately following exercise at VT remained elevated whereas both dropped immediately following exercise at 75%VT. This trend was also observed with perseverative errors, which is indicative of executive control impairment. Perseverative errors reflect an inability to inhibit responding to a previously learned rule. The transient hypofrontality theory, as it applies to exercise, does not attempt to explain how executive control processes might change immediately following exercise because “a delay of even a few minutes would be sufficient enough to normalize any exercise-induced changes in neural activities” (Dietrich, 2006, p. 82). However, this trend immediately following exercise for false alarms in the CPT and total and perseverative errors on the WCST indicate the transient hypofrontality theory might
still be a valid explanation for what is occurring immediately following intense exercise. Assuming performance is related to the reallocation of resources in the brain, there appears to be a time lag between the end of exercise and when the brain returns to the baseline homeostatic state. This may be more pronounced following higher intensity exercise because of the increased metabolic demands associated with it and the longer time required to return to homeostasis.

In a recent review, Dalsgaard (2006) discussed the cerebral metabolic ratio, which demonstrates similar effects with intense exercise. The ratio is described as the relationship of oxygen in the brain to the amount of substrate available. During exercise this ratio is affected by sensory input from skeletal muscle as well as the mental effort required to control the body’s motions. During light exercise, this ratio is believed to remain stable but has been shown to be reduced at higher intensities of exercise. In the current study, the cerebral metabolic ratio is likely to have been reduced in the VT condition and may not have had enough time to return to baseline levels immediately following exercise. This may account for the decrements in performance when compared with the below-VT condition.

Interestingly, few differences were observed in the executive control variables during exercise between intensities which is suggested by the transient hypofrontality theory. It could be that an increase in exercise intensity does not result in a proportional increase in the utilization of additional brain volume or that the intensities used did not require a significant increase in recruitment of brain resources. However, previous research observing blood flow to the brain in both animals and humans suggests that there are at least changes in blood flow that correspond to exercise intensity, but perhaps these changes do not produce significant behavioral responses (Delp et al., 2001).

This research may have practical applications because numerous occupations (e.g., fire fighters and rescue workers) require individuals to make informed decisions while being physically active. Understanding how different exercise intensities affect executive control functions associated with making these decisions is important in terms of knowing when physical activity compromises cognitive function. The same can be said of acute exercise’s application to the military, where planning and decision-making tasks are performed simultaneously sometimes with very intense or long duration aerobic exercise (Bailey et al., 2008).

Potential limitations of the study could be the sample and intensity selection. A limitation of this sample was that it consisted of individuals possessing average to above-average fitness and this may have influenced the results. For example, having a higher fitness level may have corresponded to better coping with the dual task of exercising while performing the cognitive tasks. In addition, the number of participants may have been a limitation in that there may not have been enough statistical power to show differences from pre- to postexercise and between the exercise intensities. Another limitation may be due to the exercise intensities that were chosen. Selecting an intensity level greater than VT may have elicited a more dramatic change in executive control due to allocation of more resources according to the transient hypofrontality theory. However, the decision to select an intensity level at VT was made so that the participants could engage in a bout of exercise at a prolonged period of time, in this case 30 min.

Perhaps one of the most interesting avenues for future research may be the examination of event-related potentials in the brain as they relate to the cognitive
tests. Observing event-related potentials during and immediately following exercise would provide information about brain processing as opposed to behavioral responses. Replication of the work by Pontifex and Hillman (2007) is warranted to see how changes in P3 may occur at different intensities during exercise. Overall, additional ERP research combined with behavioral measures at different intensities may provide further insight into both the electrophysiological and behavioral changes that occur with cognitive tests during exercise.

In conclusion, the current study demonstrated that specific changes occur in executive control tasks during and immediately following exercise. The decrease in executive control during exercise provides some support for the transient hypofrontality theory. Following VT, executive control performance remained poor possibly due to an additional amount of time the brain needs to return to homeostasis following intense exercise.

References


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