Effects of Varying Cycle Ergometry Intensities on Reaction Time and Cognitive Functioning in Active Collegiates

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Abstract

Purpose: Aerobic activity has been shown to improve cognitive processes, such as the ability to learn, remember, and react. The goal of the current research was to assess college students' reaction time (RT) and cognitive functioning (CF) at baseline, during aerobic exercise of various intensities, and post-recovery.

Methods: Eighteen (10 M, 8 F) physically active students ($\overline{Age}$ = 20.1 years ± SD 2.2) participated. Subjects completed familiarization training for MOΨART choice reaction time and SCAT3 word and number cognitive assessment protocols, and were tested for anthropometrics and Monark bike YMCA submaximal aerobic capacity (VO_2 max). All subjects participated in three testing sessions, each consisting of 20 minutes of cycle ergometer aerobic activity at differing intensities (50-55%, 60-65%, 70-75% HR_{max}). At each intensity, RT and CF word and number memory recall data was collected for baseline, during activity (8:30 and 18:30 minutes), and post-recovery time points.

Results: Within subjects, repeated-measures ANOVA was conducted for the time and intensity of aerobic activity to assess differences in intensity and RT, word CF, and number CF at the specified time points. A significant difference in RT was found when assessing baseline to inter-test RT at the medium intensity, excluding the post-recovery score (p = .035), $\overline{RT}_0$ 1021ms ± SD 148, $\overline{RT}_{8:30}$ 1021 ± SD 146, $\overline{RT}_{18:30}$ 962 ± SD 144. No significant difference in CF was found for word recall at any intensity. A significant difference in CF was found for number recall at the low intensity (p = .03), $\overline{CF}_0$ 6.4 numbers ± SD 1.2, $\overline{CF}_{8:30}$ 5.9 ± SD 1.5, $\overline{CF}_{18:30}$ 6.8 ± SD 1.0. One-way ANOVA to assess differences in average RT at the three intensities provided no significant differences (p = .647).

Conclusion: The results do not show simultaneous significant improvements in RT and CF in active collegiates during acute bouts of aerobic activity at any intensity. Performing at the high intensity appeared too demanding to elicit positive stimulation of RT or CF, while the low intensity was too light to produce significant improvements in RT or word CF, only number CF. The results support that bouts of aerobic activity between 60-65% HR_{max}, lasting at least 18:30 minutes, elicit a physiological arousal most beneficial, in this format, for enhancing RT, and therefore possibly information processing.

Methods

Subjects. Eighteen undergraduate Bethel University students were recruited via posted flyers and recruitment through courses within the Department of Human Kinetics and Applied Health Science. Ten healthy male students (mean ± SD; age = 20.7 years ± 2.8, height = 181.05 cm ± 4.582, body mass = 180.55 lbs ± 17.32, % body fat = 9.89% ± 3.77, VO_2 max = 52.15mL/(kg·min) ± 15.69) and eight healthy female students (mean ± SD; age = 19.8 years ± 1.3, height = 167.47 cm ± 6.36, body mass = 141.44 lbs ± 16.93, % body fat = 23.93% ± 4.02, VO_2 max = 41.39 mL/(kg·min) ± 6.13) voluntarily participated in the study. The participants gave written informed consent to participate in the study, which had been approved by the Institutional Review Board (IRB) Committee at Bethel University. Important inclusion criteria for participation included (a) meeting the American College of Sports Medicine (ACSM) guidelines for a physically active individual (participates in moderate to vigorous aerobic activity for at least thirty minutes, three to five days per week)[1] (b) having met the ACSM guidelines stated above for at least one year, (c) resting heart rate and blood pressure within normal range for young adults.

Exercise Tests. Each participant completed four testing sessions, lasting approximately forty-five minutes. The first session served as a pre-participation evaluation and familiarization session to acclimate participants to the protocols and equipment being used. During this session, participants signed an informed consent and health history and risk stratification were taken. Anthropometrics such as height, weight, baseline heart rate (serving as a baseline heart rate measurement post recovery for testing), blood pressure, and percent body fat (using a 7-site skinfold protocol) were taken. The researchers then talked the subjects through a practice testing protocol to familiarize them with the testing conditions and protocols. Subjects were seated on the cycle ergometer for all protocols, just as they would be for the testing sessions. A choice reaction time test using the MOΨART reaction board, placed directly in front of the cycle ergometer, and short-term memory recall protocol, using the SCAT3 word and number cognitive assessments, were conducted. Finally, a YMCA submaximal aerobic test was conducted on the Monark cycle ergometer to determine the subject's estimated VO_2 max.

To start the first testing session, subjects put on a polar heart rate monitor and sat on the cycle ergometer. To obtain baseline data, an initial choice reaction time test and baseline memory recall tests were taken prior to beginning the aerobic activity. Subjects then began cycling on the cycle ergometer at a rate of 50 RPMs, which was maintained throughout the entire twenty minutes of cycling. The resistance on the cycle ergometer was adjusted by the researchers in order to keep the participants between 50 and 55% of their maximum heart rate. Maximum heart rate was calculated by taking the average of two reputable equations, shown to accurately reflect the relationship between age and maximum heart rate. The two equations used were: HR_{max} = 206.9 - (0.67 x age) [3] and male: HR_{max} = 202 – (0.55 x age), female: HR_{max} = 216 – (1.09 x age).[9] After eight and a half minutes of cycling at the specified intensity, a choice reaction time test and short-term memory recall tests were conducted while the participant continued cycling. Again after eighteen and a half minutes of cycling, the reaction time and short-term memory recall tests were conducted. As soon as the tests concluded, the resistance on the bike was released and the subject was allowed to continue cycling for a two minute cool-down. The participant was then instructed to sit in a comfortable chair in order to obtain full recovery, bringing their heart rate back to baseline (established during the familiarization session). Once attained, a final reaction time test and short-term memory recall tests were conducted.

For the following two testing sessions, all factors and protocols remained exactly the same except for the aerobic exercise intensities. The second testing session was performed between 60 and 65% of the participant's maximum heart rate. The third and final testing session was performed between 70 and 75% of the participant's maximum heart rate.

Introduction

Exercise elicits acute and chronic physiological, neuromuscular, and neuromotor benefits far beyond cardiovascular fitness and muscular strength. Scientists have discovered that exercise has the effect of enhancing cognition as well as resisting physical shrinkage of the brain.[6] Specifically, cardiovascular exercise has been linked to increased vocabulary learning and reaction time. Other studies show adults' brain-processing speed and memory improved after half an hour of moderate exercise.[5] In conjunction with these physiological and neuromotor benefits, many advocates of exercise report feelings of increased mood and focus, the ability to think more clearly, as well as reductions in psychological conditions such as depression and anxiety.[8] Throughout research it is evident that exercise not only has positive outcomes that relate to improved physical functioning of the kinematic chain, but also to factors that deal with a more disregarded aspect of functioning; cognition.

Physiologically, exercise immediately heightens the blood supply to the brain. This increase in blood being delivered to the brain, in turn, leads to improved cognitive functioning. Not only is aerobic activity related to changes in the brain and enhancement of cerebral blood flow, but also oxygen supply to neurons. Single sessions of physical activity have shown to elevate hippocampal high affinity choline uptake, (HACU) associated with a spatial-learning set task.[7] The hippocampus is a key portion of the brain associated with memory and learning.[7] Starting in the late twenties, most individuals begin to lose about one percent of the volume of the hippocampus, annually. However, exercise has been shown to counteract these detrimental physical effects. In fact, a link has been found between regular aerobic exercise and hippocampus growth after just three months.[6]

Contrary to prior beliefs, researchers have found that the process of neurogenesis, or the creation of new brain cells, is accelerated with both aerobic and anaerobic Exercise.[6,7] For neurogenesis to occur, a protein found in the brain known as BDNF, or brain-derived neurotrophic factor, is essential for supporting the health of existing neurons and coaxing the creation of new brain cells.[6] Research has shown that acute exercise aids in increasing the levels of the BDNF protein in the brain. In addition, exercise induces changes in the neuroplasticity of different brain regions and BDNF signaling, which positively affect learning and memory performance.[4,7] A potential explanation for this advantage is that these brain-specific neuronal adaptations are induced by various levels of intensity or stress elicited by different types of exercise. Since cognitive tasks engage different areas of the brain, it is possible that the cognitive effects of a single bout of acute exercise are based on which part/s of the brain is/are activated at that intensity.

However, limited and conflicting empirical research has been done regarding the relationship between specific exercise intensities and cognitive functioning. The results of eleven of the fifteen studies evaluated by Tomporowski, 2003, indicated that submaximal aerobic exercise performed for durations between twenty and sixty minutes aided in multiple cognitive processes that are critical to optimal performance and behavior.[8] In numerous studies conducted since 1990, there has been evidence of a distinct improvement in information processing during sustained ergometer cycling at intensities ranging from 40% to 70% of VO_2 max. Increase in physiological arousal or activation induced by physical activity explains this facilitating effect of information processing observed during or immediately after a bout of exercise.

In preceding research, a general problem in examining the effect of short-term, acute exercise on simple and choice reaction times has been the use of too few intensities, or too small of increments to vary intensities to elicit significant physiological changes.[2] It is important to use an objective means, as opposed to perceived exertion, to determine intensity during aerobic exercise. Therefore, in the present study, the researchers defined the intensities used in terms of the participant's maximum heart rate; low (50-55% HR_{max}), medium (60-65% HR_{max}) and high (70-75% HR_{max}).

Due to lack of convincing and concurring research, the acute effects of exercise on choice reaction time and cognitive functioning, in terms of short-term memory recall, at three different intensities of aerobic exercise was analyzed. The purpose of this research was to assess active collegiate students' reaction time and cognitive functioning at baseline, during aerobic cycling of various intensities, and post-recovery. The effects of central nervous system stimulation and fatigue, in response to differing intensities of exertion, were analyzed to determine any acute benefits or detriments to cognitive processes.

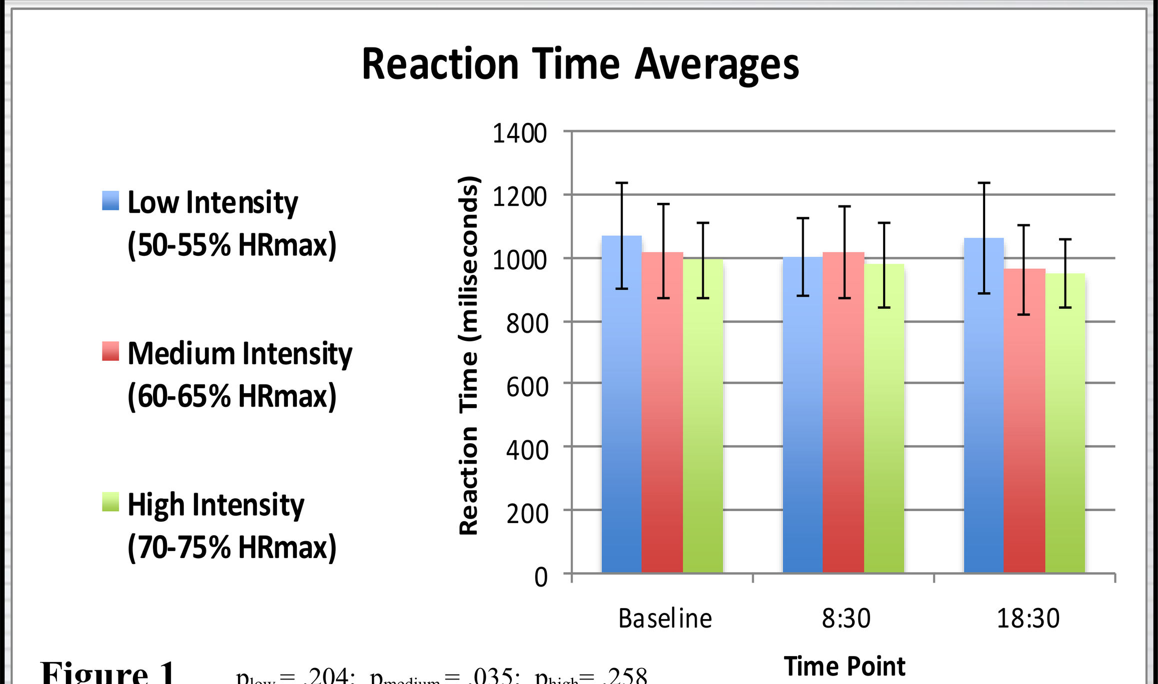

Figure 1 p_{low} = .204; p_{medium} = .035; p_{high} = .258

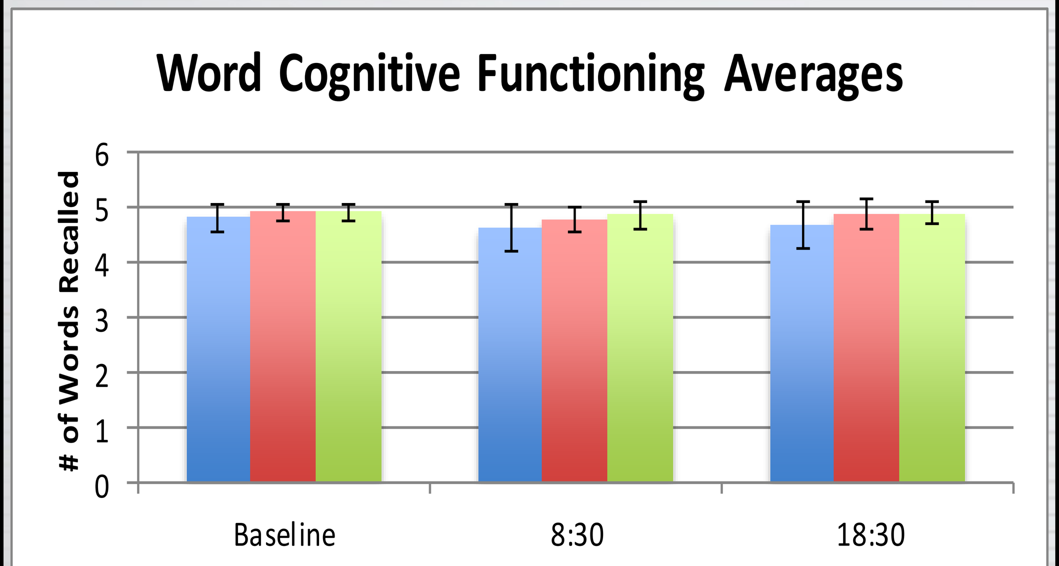

Figure 2 p_{low} = .141; p_{medium} = .102; p_{high} = .472

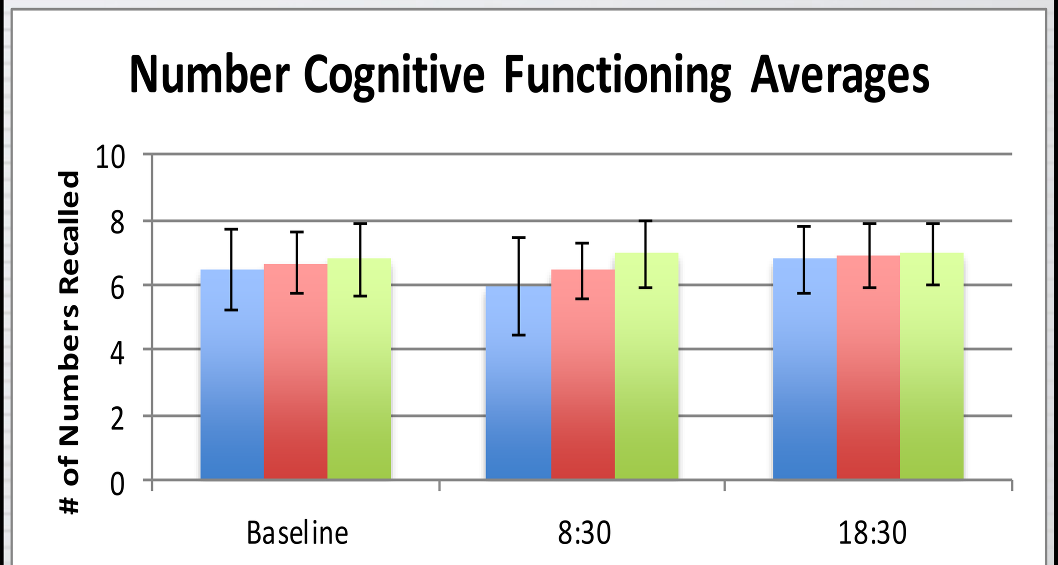

Figure 3 p_{low} = .03; p_{medium} = .123; p_{high} = .562

Results

Statistical Analysis. Within subjects, repeated-measures analysis of variance (ANOVA) was conducted. The analysis was factored for the time and intensity of aerobic activity to assess differences in intensity and reaction time, word cognitive functioning, and number cognitive functioning at the specific time points throughout the activity. In addition, a one-way ANOVA was conducted to determine differences in average reaction time of baseline and inter-test reaction time between the three intensities. The level of significance was set at .05 for both the repeated-measures ANOVA and the one-way ANOVA analyses.

Findings. A significant difference in reaction time was found at 18:30 when assessing baseline to the inter-test reaction times at the medium intensity, excluding the post-recovery score (p = .035), $\overline{RT}_0$ 1021ms ± SD 148, $\overline{RT}_{8:30}$ 1021 ± SD 146, $\overline{RT}_{18:30}$ 962 ± SD 144 (*Figure 1*). However, no significant difference was found at the low intensity (p = .204) or high intensity (p = .258). No significant differences in cognitive functioning were found when assessing baseline to inter-test word recall at the low intensity (p = .141), medium intensity (p = .102), or high intensity (p = .472, *Figure 2*). A significant difference in cognitive functioning was found at 18:30 when assessing baseline to inter-test number recall at the low intensity (p = .03), $\overline{CF}_0$ 6.4 numbers ± SD 1.2, $\overline{CF}_{8:30}$ 5.9 ± SD 1.5, $\overline{CF}_{18:30}$ 6.8 ± SD 1.0 (*Figure 3*), however, no significant difference in cognitive functioning was found at the medium intensity (p = .123), or high intensity (p = .562). The one-way ANOVA conducted to assess differences in average reaction time of baseline and inter-test scores between the three intensities provided no significant differences (p = .647).

Conclusion

Overall, the results do not show simultaneous significant improvements in both reaction time and cognitive functioning in active collegiate students during acute bouts of cycle ergometer aerobic activity at any intensity. Performing at a high intensity of 70-75% HR_{max} appeared too demanding to elicit positive stimulation of either reaction time or cognitive functioning. The inability to enhance these processes may be due to task complexities inherent in the reaction time motor task and the memory recall cognitive tasks requiring heightened awareness, attention, and physiological demands already exhausted by the energetic demands of high intensity exercise. In contrast, the low intensity of 50-55% HR_{max} was too light to elicit enough arousal to stimulate significant improvements in reaction time or word cognitive functioning, only number cognitive functioning.

In conclusion, the results support that bouts of aerobic activity between 60-65% HR_{max}, lasting at least 18:30 minutes elicit a physiological arousal most beneficial, in this format, for enhancing reaction time, and therefore possibly information processing. Further research is necessary to explicate the neurophysiological mechanisms that support the dynamics of the arousing effect of moderate intensity aerobic activity. Focusing on different forms of full kinetic chain aerobic activity, such as running, that stress different areas of the body may facilitate interesting comparative results.

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