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The Effect of Exercise on Cognitive Function as Measured by Impact Protocol: Aerobic VS. Anaerobic

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Background: Exercise has long played a critical role in the recovery from athletic injuries. Of recent, concussion research has escalated creating new insights into the treatment of and rehabilitation from concussion syndromes. As part of the concussion research, multiple uses of the ImPACT tool have evolved to measure cognitive function. However, combining the variables of cognitive improvement as measured by the ImPACT protocol with aerobic and anaerobic exercise has not been investigated. **Purpose:** The purpose of this investigation was to assess the influence of acute bouts of aerobic versus resistance exercise on cognitive function of college-aged participants as measured by the ImPACT Protocol. **Study Design**: Pre-Test – Post Test Experimental Design. **Methods:** We compared composite scores on two sessions of ImPACT testing (dependent variables) immediately before, immediately after, and 45 minutes after interventions consisting of a randomly assigned aerobic exercise session, resistance exercise session, or seated rest control (independent variables). Twenty college aged participants (11 females, age= 20.1±0.9; 9 males, age= 20.2± 1.6 yrs) completed the study. **Results:** The aerobic group's average (p = 0.07) weight (166±16.8) demonstrated the trend of being higher (p=0.07) than the control (153.9 ±19.0) or resistance group (130±16.1). There was no significant difference (p=0.18) in average height or age between the study groups. Findings indicate a significant change in measures of reaction time (p=0.008), impulse control (p=0.008), and visual motor speed (p = 0.03) across all three groups of participants. No significant change was seen in measures of visual (p=0.08) or verbal memory (p=0.198). **Discussion**: The results cannot be seen as suggesting that exercise has no effect on cognitive function. **Conclusion and Clinical Implications:** These findings may suggest a learning effect previously unaccounted for in the ImPACT testing protocol. **Keywords:** Aerobic, Anaerobic, Cognitive Testing, Exercise

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INTRODUCTION

Recent research has attempted to shift the focus from the physical advantages of exercise to explore possible positive effects of exercise on cognitive function. The result has been a developing body of research that shows that both aerobic and resistance exercise may have a positive effect on cognitive function.[1-10] Several studies have compared the effect of aerobic and resistance exercise on cognition and have demonstrated a potential difference in effect between the two modes of exercise.[11,12] It has been suggested that future research explore the comparison between the two modes of exercise on multiple aspects of cognitive function beyond the single aspect of working memory as an indicator of cognitive function.[13,14] Significant improvements in cognitive function, physical well-being, and behavioral characteristics have been seen in aerobically exercising populations.[7] This work provides strong evidence that aerobic exercise can improve cognitive function in aging individuals. Physiologically, physical evidence of the effect of exercise found through Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) suggests exercise can slow or stop the age-related reduction of brain tissue density.[4] Results specific to this study showed that areas of the brain that were most effected by age were also most effected by exercise.[4] Therefore, the areas of the brain that experienced the most tissue loss due to aging also showed the greatest benefit of exercise in decreasing tissue loss. Additional evidence has indicated that aerobic exercise may slow or stop the depletion of brain tissue as well as increase the plasticity of brain tissue in older individuals.[5] Participants in these studies demonstrated improvements in

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symptoms of depression, self-reported sense of well-being, and overall health.[4,5] Similar improvements have also been reported in other studies employing both aerobic and resistance forms of exercise.[1,2,6,9,10] Potempa et al demonstrated that participants in the exercise group showed an improvement on sensorimotor tasks that was significantly related to the improvement in aerobic capacity.[10] Other researchers found that increases in aerobic capacity have positive effects on both short term and long term effects on psychological outcomes.[6] Similarly, Blumenthal, et al. found that those that completed the aerobic exercise reported self-perceived improvements on psychological and behavioral measures.[1]

In their meta-analysis, McAuley, Kramer and Colcombe concluded that aerobic exercise has a positive effect on cognitive performance and depressive symptomology.[8] Furthermore, they point out that exercise programs that combined strength and flexibility exercises saw a greater improvement in these measures then those that only employed aerobic exercise.[8] One possible explanation for the improvement in cognitive function and decrease in depressive symptoms with exercise is that increased arousal levels immediately following exercise can lead to improved decision making ability and performance as well as an increased ability to focus on target stimuli while ignoring distractors.[2]

Pennix et al. sought to further examine the effect of exercise on mood and physical well-being while distinguishing differences between the effect of aerobic and resistance forms of exercise, if any existed.[11] Participants in the aerobic group reported significantly lower depression symptom scores over time than those in the control group.[11] Those in the resistance exercise group reported a change in symptoms but it was not significantly different from the change reported by the control group. Evidence that aerobic exercise had a significant effect on working memory while no such result was seen in the resistance exercise group reflects that aerobic and resistance exercise may vary in how they affect cognitive function.[12] This work also suggests that future research should be expanded to focus on assessing various areas of cognition.[12]

Measuring cognitive function is complex and there have been numerous methods utilized across these studies to assess it. One method not previously utilized is the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) protocol. This method uses neuropsychological assessment strategies to detect changes in cognitive function.[13] With a proven sensitivity of 81.9% and a specificity of 89.4% the ImPACT system is recognized as a reliable neurocognitive tool in the identification, evaluation, and care of sports related traumatic brain injuries.

The main purpose of the study was to assess the effect of differing exercise interventions (aerobic, resistance exercise) on cognition versus a control (i.e., no exercise) group in a sample of healthy young adults. As a secondary assessment we then compared the effect of exercise, regardless of modality (i.e., grouping both aerobic and resistance exercise groups together), versus no exercise (i.e., the control group). This was the first such study that we are aware of to utilize the widely-available Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) to assess cognitive function. The ImPACT testing protocol allows for the assessment of five areas of cognitive function – visual memory, visual motor speed, verbal memory, reaction time, and impulse control. Its use would address the suggestion of expanding focus beyond a single aspect of cognitive function. We hypothesized that the ImPACT neurocognitive testing protocol is an appropriate means of measuring cognitive

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function for the design and purpose of this study and that exercise would have a significant positive effect on cognitive function as measured by the ImPACT neurocognitive testing protocol in aerobic and anaerobically exercising groups.

MATERIALS & METHODS

Study Design

This pre-test – post – test experimental study used a two day (day 1, day 2) by three group (aerobic, resistance, control/rest) by three time (pre-exercise, immediate post exercise, 45 minutes post exercise) design. The dependent variables were the five measures of the ImPACT scores (visual memory, visual motor speed, verbal memory, reaction time and impulse control).

Subjects

Twenty undergraduate students (11 females, age= 20.1±0.9; 9 males, age= 20.2± 1.6 yrs, Table 1) who exercised at least three times a week or participated in one or more intramural sports seasons per year were recruited from a northeast Ohio university campus. Individuals who had suffered a self-reported concussion within the past 12 months as well as those on intercollegiate sports teams were excluded from participation. The ImPACT Protocol/Instrument ImPACT testing consists of verbal memory, visual memory, visual motor speed, reaction time, and impulse control measures on a computer setup through the ImPACT Corporation.[14] There are multiple trials of the same tasks within certain tests. These trials result in composite scores reported on the clinical report.

PROCEDURES

Day 1 and 2: Orientation

Participants completed an informed consent form acknowledging that they understood the risks and benefits of participation, as well as a PAR-Q and health screening questionnaire to screen for previous health issues that may have been aggravated by acute exercise.[15,16] Participants completed the forms on the first orientation day prior to engaging in the treadmill portion of orientation. On day one, the target heart rate to be used by the participants in the aerobic exercise was determined using the equation [220-(participants age)] x 70%.[17] Once it had been determined, the participants ran or walked on motor driven treadmills for 30 minutes to allow the participant to become accustomed to the use of the treadmills and the intensity of the exercise. The investigator monitored the volunteers' heart rate, using Polar Heart Rate Monitors, every minute for the first five minutes and every five minutes after that to ensure that they reached and maintained their target heart rate for the remainder of the treadmill session.

Day two consisted of strength tests to measure the maximal amount the participant was able to lift for one repetition (1-repetition maximum, 1RM) on triceps press down, bicep curls, bench press, latissimus dorsi pulls, chest fly, single leg curl using the dominant leg, and single leg press using the dominant leg using a multi-station gym or resistance exercise equipment.[12] The participants were given a chance to warm up on each exercise by performing a set of an exercise prior to attempting to lift their 1 repetition maximum. The participants were allowed to continue attempting to lift higher resistances until failure. Each attempt was followed by a 60 second rest period and each exercise followed by a 90 second rest period.[12] The participants were allowed to move from one exercise to the next with no set order given by the researcher. The amount lifted on the last successful attempt was recorded as their 1 repetition maximum (1 RM). This process was repeated on each of the exercises until the session was complete. The 1 RM values were recorded in standard

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units of pounds. Each participant was then randomly assigned to an "aerobic', "anaerobic" or "control" group. After they were placed in a group they scheduled an initial trial session in time slots pre-determined by the researcher.

The first trial session was conducted at least 48 hours after the second day of orientation to allow for proper recovery from the initial evaluations. There was also at least one recovery day between each of the testing sessions. Participants were instructed not to perform any formal exercise activities on the days between the sessions. Participants were ImPACT tested before the exercise session on the days of the trials to determine a baseline reading immediately before they exercised. The volunteers participated in two trials, Day 1 and Day 2. All participants were tested on ImPACT and then proceeded to their assigned tasks as delegated by group. (Table 1)

Table 1. Sample Trial Schedule

Participant 1	Day One	Day Two	Day Three
	Test on ImPACT	Rest	Test on ImPACT
	Exercise		Exercise
	Test on ImPACT		Test on ImPACT
	Wait 15 minutes after ImPact test (total of 45 min. Post Exercise)		Wait 15 minutes after ImPact test (total of 45 min. Post Exercise)
	ImPACT Test		ImPACT Test

Resistance group

Following the baseline ImPACT tests those in the resistance group were led to the faculty weight room where the one repetition maximum (1 RM) tests were conducted. The exercises were conducted at 80% of their 1 repetition maximums on the same machines at the same settings that were used during the orientation session. They were given a 60 second rest period in between sets and a 90 second rest period in between exercises.[12] Following the resistance exercise session, the participants completed another ImPACT test and were given a rest period, long enough to reach 45 minutes post exercise at which time they completed the final ImPACT test of the trial day.

Aerobic exercise group

Those in the aerobic exercise session were fitted with a Polar heart rate monitor and taken to the room with the treadmill. The participants started walking on the treadmill while the investigator increased the speed and adjusted the incline between 0.0 and 1.0 percent to the settings where the target heart rates were reached and maintained during the orientation session. The heart rate was monitored using a Polar Heart Rate Monitor every minute for the first five minutes and every five minutes after that for the remainder of the exercise session to reach and maintain the target heart rate as determined by the equation [(220-participants age)] x 0.70.[17] After 30 minutes of walking or running the speed of the treadmill was decreased to two miles an hour and the participants were allowed to walk at that speed for 1 minute. At the end of that minute the treadmill was slowed by another one mile per hour and the participant walked for another minute to complete a two-minute cool down period. Following the treadmill exercise the participants completed another ImPACT session. After a rest long enough to reach 45 minutes post exercise, the third and final ImPACT test of the trial day was completed.

Rest group

Participants in the rest group completed a baseline ImPACT test. They were required to sit in silence for thirty minutes. Following the 30-minute period, the participants completed another ImPACT test. After another rest period long enough to reach 45 minutes post intervention, the third ImPACT test of that trial day was administered.

STATISTICAL ANALYSIS

One-way analyses of variance (ANOVA) were used to compare participant characteristics (age, height, weight) between the three intervention groups (control, aerobic exercise, resistance-training exercise). Two day (day 1, day 2) by three time point (pre-intervention, immediately post-intervention, 45 minutes post-intervention) by three intervention group ANOVAs with repeated measures on day and time point were conducted to examine differences in: reaction time, impulse control, visual memory, verbal memory and visual motor speed. In an effort to assess the potential effect of exercise, regardless of modality, versus non-exercise additional day (day 1, day 2) by time point (pre-intervention, immediately post-intervention, 45 minutes post-intervention) by group (exercise, no exercise) ANOVAs were performed. In these secondary analyses both the resistance and aerobic exercise groups were combined into a single exercise group and compared to the non-exercise (i.e., control) group. Post-hoc analyses were performed on any significant main or interaction effects using independent and paired-samples T-tests. A-priori significance was set at $\alpha \leq 0.05$ and all analyses were performed using SPSS (version 17.0, SPSS Inc, Evanston, IL)

RESULTS

Participant Characteristics

Participant characteristics are shown in Table 2. There were no significant ($p \geq 0.07$) main effects of group for physical characteristics.

Table 2. Participant Average Demographics and Fitness Values

Measure	All	Resistance	Aerobic	Control
N	20	9	4	7
Age	20.2±1.3	19.7±0.9	21.3±1.1	20.1±1.5
Height (in)	66.4±3.1	65.2±3	66.8±4.3	67.7±1.5
Weight (lb)	145.6±22.1	130±15.1	166±14.6	153.9±19

Table 2. Participant Average Demographics and Fitness Values. Average age (years), height (inches), and weight(lbs.) of study participants.

Reaction Time

There was a significant main effect (p = 0.001) of time for reaction time. Post-hoc analysis revealed that reaction time was significantly (p ≤ 0.008) faster immediately post (M ± SE = 0.52 ± 0.05 seconds) and 45 minutes' post-intervention (M ± SE = 0.52 ± 0.05 seconds) than pre-intervention (0.54 ± 0.04 seconds). There was a trend (p = 0.06) towards a significant main effect of day as reaction time was faster on day two (0.52 ± 0.05 seconds) versus day one (0.54 ± 0.05 seconds). There were no additional significant (p ≥ 0.09) main or interaction effects for time, day or intervention group. The average scores for the three groups across all time points and on each day are in shown Table 3.

Table 3. Reaction Time (seconds)

	Day 1			Day 2		
	Baseline	Immediately post	45 minutes post	Baseline	Immediately post	45 minutes post
Resistance exercise	0.55±0.05	0.52±0.03	0.51±0.03	0.51±0.03	0.49±0.04	0.50±0.03
Aerobic exercise	0.55±0.03	0.52±0.02	0.53±0.02	0.55±0.03	0.52±0.02	0.51±0.05
Control	0.56±0.06	0.56±0.07	0.55±0.08	0.55±0.08	0.54±0.07	0.54±0.07
Total	0.55±0.05	0.53±0.05	0.53±0.06	0.53±0.04	0.52±0.05	0.51±0.

Table 3. Reaction time (seconds) at baseline, immediately post exercise and 45 minutes post exercise on day 1 and day 2 for the resistance training, aerobic exercise and control groups. Reaction time was significantly (*p* = 0.001) faster immediately post and 45 minutes post exercise relative to baseline.

In the secondary ANOVA comparing the effect of exercise (resistance and aerobic exercise groups combined) versus non exercise (control group) there was again a significant (p = 0.006) main effect of time for reaction time and the main effect of day was now significant (p = 0.026). There were no additional significant (p ≥ 0.09) main or interaction effects for time, day or intervention group.

Impulse Control

There was a significant (p = 0.04) main effect of day for impulse control. Impulse control measures were greater, meaning impulse control was improved during day two (6.8 ± 4.6) versus day one (5.18 ± 3.0). There were no additional main or interaction effects (p ≥ 0.07). The average scores for the three groups across all time points and on each day are in shown Table 4.

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Table 4. Impulse Control (score)

	Day 1			Day 2		
	Baseline	Immediately post	45 minutes post	Baseline	Immediately post	45 minutes post
Resistance exercise	5.4±2.9	6.4±4.7	6.1±4.0	7.0±5.1	5.9±4.0	6.6±3.6
Aerobic exercise	4.5±2.1	5.5±4.7	6.5±5.5	8.8±6.2	11.8±8.0	10.8±7.4
Control	3.9±3.7	4.1±1.9	3.9±2.5	4.3±2.0	5.9±4.7	5.4±2.9
Total	4.7±3.0	5.5±3.5	5.4±3.8	6.4±4.6	7.1±5.5	7.0±4.6

Table 4. **Impulse Control (score)** at baseline, immediately post exercise and 45 minutes post exercise on day 1 and day 2 for the resistance training, aerobic exercise and control groups. Impulse control was significantly ($p = 0.04$) greater during day two than day one.

In the secondary ANOVA comparing the effect of exercise versus non exercise there was a trend ($p = 0.06$) towards a main effect of day which was similar to the initial ANOVA which included all three groups (aerobic exercise, resistance exercise, control). There were no additional significant ($p \geq 0.19$) main or interaction effects for any of the independent variables.

Visual Motor Composite

There was a significant ($p = 0.05$) main effect of day for differences in visual motor composite scores. Visual motor composite scores were significantly improved on day two (44.7 ± 8.9) versus day one (43.3± 8.8). There were no additional main or interaction effects ($p \geq 0.16$) for any of the independent variables. The averages for the three groups for the three test sessions on each day are in Table 5.

Table 5. Visual Motor Composite (score)

	Day 1			Day 2		
	Baseline	Immediately post	45 minutes post	Baseline	Immediately post	45 minutes post
Resistance exercise	43.3±2.8	46.2±3.9	46.7±3.0	45.4±5.3	47.5±3.7	46.3±4.8
Aerobic exercise	42.6±18.6	42.2±18.6	40.5±18.1	42.1±19.1	41.4±18.6	42.1±18.7
Control	39.6±5.7	41.3±6.7	42.4±8.0	42.9±7.6	43.5±6.8	45.6±4.1
Total	41.9±8.4	43.7±9.0	44.0±9.1	43.9±9.5	44.9±9.0	45.2±8.5

Table 5. **Visual Motor Control (score)** at baseline, immediately post exercise and 45 minutes post exercise on day 1 and day 2 for the resistance training, aerobic exercise and control groups. Visual Motor Composite scores were significantly ($p = 0.05$) greater during day two than day one.

In the secondary ANOVA comparing the effect of exercise versus non exercise there was a trend ($p = 0.06$) towards a main effect of day which was similar to the initial ANOVA which included all three groups (aerobic exercise, resistance exercise, control). There

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were no additional significant ($p \geq 0.19$) main or interaction effects for any of the independent variables.

Visual Memory Composites

There was a significant ($p = 0.004$) main effect of day for differences in visual memory composite scores. Visual memory composite scores were significantly improved on day two (83.5 ± 12.2) versus day one (77.1 ± 12.6). There were no additional main or interaction effects ($p \geq 0.16$) for any of the independent variables. The averages for the three groups for the three test sessions on each day are in Table 6.

Table 6. Visual Memory Composite (score)

	Day 1			Day 2		
	Baseline	Immediately post	45 minutes post	Baseline	Immediately post	45 minutes post
Resistance exercise	76.0±9.9	69.6±18.3	76.6±12.5	84.2±12.4	83.3±11.3	74.6±13.2
Aerobic exercise	79.0±13.1	84.0±7.8	79.3±10.6	89.5±6.6	81.0±6.6	89.0±3.6
Control	79.4±11.2	78.4±11.2	78.4±14.2	85.3±10.9	84.1±18.4	86.3±12.4
Total	75.6±10.5	75.6±15.0	77.8±12.2	85.7±10.6	83.2±13.0	81.6±12.9

Table 6. **Visual Memory Composite (score)** at baseline, immediately post exercise and 45 minutes post exercise on day 1 and day 2 for the resistance training, aerobic exercise and control groups. Visual Memory Composite scores were significantly ($p = 0.004$) greater during day two than day one.

In the secondary ANOVA comparing the effect of exercise versus non exercise there was also a significant ($p = 0.06$) main effect of day for differences in visual memory composite scores. This was similar to the initial ANOVA which included all three groups. There were no additional significant ($p \geq 0.27$) main or interaction effects for any of the independent variables

Verbal Memory Composite

There were no significant ($p \geq 0.13$) main or interaction effects on verbal memory composite scores in either the primary ANOVA (aerobic exercise, resistance exercise, control) or the secondary ANOVA (exercise, non-exercise controls). The averages for the three groups for the three test sessions on each day are in Table 7.

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Table 7. Verbal Memory Composite (score)

	Day 1			Day 2		
	Baseline	Immediately post	45 minutes post	Baseline	Immediately post	45 minutes post
Resistance exercise	91.2±7.7	88.2±8.7	90.4±11.1	92.6±6.8	90.3±5.3	89.0±6.9
Aerobic exercise	88.5±9.0	89.0±9.8	87.0±8.9	92.8±3.1	86.8±5.7	79.5±18.8
Control	92.3±6.4	92.0±9.2	89.9±8.4	95.6±7.2	91.9±11.5	96.0±3.6
Total	91.1±7.3	89.7±8.7	89.6±9.4	93.7±6.3	90.2±7.9	89.6±10.8

Table 7. **Verbal Memory Composite (score)** at baseline, immediately post exercise and 45 minutes post exercise on day 1 and day 2 for the resistance training, aerobic training, and control groups.

DISCUSSION

The findings of the current investigation show significant improvements in reaction time across the time independent variable. Participants' reaction time improved by 3.7% both immediately after and 45 minutes post-exercise relative to baseline. There were also significant improvements in reaction time, impulse control, visual motor speed, and visual memory from day one to day two.

Relative to day one, during day two, participants decreased reaction time by 3.7%, and increased impulse control, visual motor speed and visual memory scores by 31.3%, 3.3%, and 8.3%, respectively. There were no significant differences found for the visual memory composite scores.

A previous study employing similar exercise routines, but testing only working memory, showed that aerobic exercise improved reaction time on tasks of working memory while no such effect was seen in those that underwent a resistance exercise routine.[14] Similar findings appear to have occurred in the current study. However, the change in performance on the reaction time composite, as well as the visual motor speed and impulse control composites, are more likely the result of a learning effect as there was no significant difference in improvement between the exercise groups or the exercise groups and the rest group. The producers of ImPACT suggest that there was no observable learning effect in repeated testing over a short period of time. However, the study that derived this conclusion tested the participants once per day at 36 hours, four, and seven days after initial testing if in the uninjured group or after suffering a head injury if in the injured group.[13] In the current study the participants underwent six tests in a period of two days with at least one day, and no more than three, between testing sessions. It is possible that multiple tests over a shorter period of time would amplify a learning effect that was not evident in previous studies. The fact that the learning effect expressed itself over two days of testing would argue that daily testing using ImPACT as a way of monitoring signs and symptoms of concussion and for monitoring the acute fluctuations in cognition for those without concussion is inappropriate and perhaps the 36 hour, 4, and 7 day spacing used by the developers is most appropriate.

A main goal of this study was to add to the body of literature on acute exercise and investigations comparing resistance exercise to aerobic exercise. Use of ImPACT for this study sought to address suggestions made by previous researchers that future research on the effect of acute exercise on cognition should be expanded to include more than one aspect of cognitive function in the investigation. This is the first known study to use ImPACT to investigate the effect of exercise on healthy individuals. The results indicate that caution should be used when considering ImPACT as a tool to measure cognitive improvement over time with aerobic and resistance exercise as the control/rest group improved as much as the experimental groups reflecting a potential learning curve with this instrument.

A direction for future research would be to test the effect of exercise on populations of those who have suffered head injuries to investigate if exercise has an effect on the rate at which they improve in areas of cognitive function measured by the ImPACT test battery. Further investigation narrowing the focus to specifically test the effect of different modes of acute exercise on each aspect of cognitive function would also prove beneficial in adding to the body of literature on the effects of acute exercise on cognition. This study focused on the effect of acute exercise but future research may benefit from examining the effects of sustained exercise regimens on the outcome of ImPACT testing in either injured or uninjured populations. In addition to receiving potentially greater benefit from sustained exercise, increasing the time between the ImPACT testing sessions may result in a decreased learning effect.

CONCLUSION AND CLINICAL RELEVANCE

In summary, improvements in cognitive performance occurred on three out of five composite scores measured by the ImPACT test battery. Improvement on these composite scores; reaction time, impulse control, and visual motor control may be attributed to a learning effect as there was no significant difference in the effect between groups. Perhaps conducting similar research employing the changes suggested above (e.g., sustained exercise or increased time between sessions) would yield different results pointing to differences or similarities between the effects of the aerobic and resistance exercise on cognitive function.

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