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Acute Exercise and Academic Achievement in High School Youth

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Abstract

The purpose of this study was to compare the acute effects of Aerobic Exercise (AE), Resistance Exercise (RE), and a nonexercise (NE) control on measures of academic achievement (AA) and cognition in 10th grade males and females. This study utilized a randomized crossover design. Tenth grade males and females performed three exercise trials (AE, RE, NE) separated by 7 days each. Immediately following exercise, participants completed a 10-question mathematics test, followed by the Stroop test. A repeated measures ANOVA revealed small but insignificant differences in mean math test performance between RE and NE, $F(1,86) = 2.81$, $p = .098$, $\eta^2 = .032$, and AE and NE, $F(1,86) = 2.03$, $p = .158$, $\eta^2 = .023$. Significant differences were found between RE and NE in the Stroop dot test, $F(1,86) = 4.31$, $p = .041$, $\eta^2 = .048$, and between AE and NE in the Stroop dot test, $F(1,86) = 10.402$, $p = .002$, $\eta^2 = .108$, and Stroop color test, $F(1,86) = 6.85$, $p = .01$, $\eta^2 = .074$. In conclusion, acute RE and AE did not significantly improve scores on a test of mathematics, but did improve measures of cognition in comparison to an NE control.

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Current research trends in the area of youth physical activity (PA) have highlighted the relationship between students who meet or exceed activity guidelines with improved academic results (Carlson et al., 2008). Numerous studies have established that when maintaining greater levels of PA, students experience improved performance in academic areas over their peers who fail to meet the recommended PA guidelines (Howie & Pate, 2012). Given the high levels of importance currently being placed on academic test results and the rising rates of overweight and obesity among students, it behooves educators, students, and PA proponents to explore the mechanisms that underscore exercise and academic achievement (AA).

The literature linking exercise and AA shows significant relationships between chronic and acute exercise and student improvement in school. Studies of chronic exercise show consistently small, positive associations between exercise and AA (Nelson & Gordon-Larsen, 2006). Acute exercise has demonstrated similarly small, significant effects on measures of cognition and other executive functions across children, adolescents, and adults (Verburgh, Königs, Scherder, & Oosterlaan, 2014). Such findings lend credence to the ability of exercise to influence AA, but a number of questions related to the effect of acute exercise on AA in youth still exist. One important question that deserves exploration is whether a difference in AA exists following bouts of differing types of exercise, specifically resistance and aerobic exercise (AE). AE has been used almost exclusively among youth studies that utilized a measure of executive function or AA as the dependent variable. Among high school–aged students specifically, researchers have targeted AA with AE interventions such as sport and PE participation (Nelson & Gordon-Larsen, 2006), extracurricular PA (Crosnoe, 2002), and traditional AE such as walking or jogging (Wittberg, Northrup, & Cottrell, 2012). Each of the above variations of AE demonstrated positive outcomes on select measures of AA including mathematics, reading ability, and GPA.

Although AE has shown consistently positive effects on AA in high school–aged students, there is a paucity of research examining the effects of resistance exercise (RE) on AA in this age group. Research on senior citizens (Chang & Etnier, 2009), adults (Alves et al., 2012), and high school youth (Harveson et al., 2015) indicates that acute RE may influence cognition positively. Additionally, RE is a mode of exercise that effectively complements AE (Pollock et al., 2000). With the above research in mind, indications are such that acute RE may be an effective intervention to influence AA positively in high school–aged students. As such, the purpose of this study was to compare the acute effects of AE, RE, and a nonexercise (NE) control on measures of AA and cognition in 10th grade males and females. It was hypothesized that AE and RE would improve students' performance on a standardized test of mathematics and a test of cognition, in comparison to the NE control.

Method

Participants and Setting

The participants in this study were 10th grade students sampled from a high school in the southwestern United States. An a priori power analysis (G*power) indicated a minimal sample size of 60 participants. After subject dropout, the total number of participants was 91 (63 males, 28 females), with a mean age of 15.89 ± 0.65 years. Participants provided written assent in conjunction with written consent from a parent or legal guardian. Participants were apparently healthy, as defined by their enrollment in PE class, and able to participate in regular exercise. The study was conducted in accordance with institutional, district, and American College of Sports Medicine (ACSM) ethical guidelines. The university institutional review board provided approval for study procedures.

Instruments

AA was measured in this study using a battery of four 10-question math tests taken from New York State Testing Program exams used for high schoolers in the last 5 years (http://www.p12.nysed.gov/assessment/). The tests are therefore current, and they come with technical manuals that verify the multiple choice content with Cronbach's alpha coefficient scores. The tests have internal consistency coefficients of $r = .85$ (2012), $r = .84$ (2011), and $r = .86$ (2010). The New York State Testing Program assembled the tests with assistance from high school math teachers to ensure the content had been covered in the current school year. The content of each test covered similar material, but the questions were slightly different, and thus a practice effect was avoided. Students were given 5 min to complete each 10-question test. This mimicked the demands of a classroom setting and allowed the use of the speed-test concept developed by Brown (1970). Cognition was measured using the Stroop test (Victoria version). The Victoria version of the Stroop test is a validated means of assessing selective attention and cognitive flexibility over the course of three increasingly demanding tasks (Spreen, 1998) and has been utilized frequently in research with children, high school youth, and adults (Bub, Masson, & Lalonde, 2006; Comalli, Wapner, & Werner, 1962). Participants identified stimulus flash cards beginning with colored dots, progressing to common words printed in the same color as dots, and ending with color words printed in noncorresponding colors. Each task contained 24 items and challenged participants to deal with an interference effect, which is marked by significantly slower reaction time.

Procedures

This study utilized a randomized crossover design. Participants were required to perform one familiarization session on the mathematics test and exercise protocols. Seven days after the familiarization session, participants performed one of three experimental sessions (AE, RE, NE) in a randomized order, completing all three interventions over 3 weeks. The math test was initiated 5 min after the exercise intervention. Upon completion of the math test, the Stroop tests were administered in sequence (dot, color, word), no later than 20 min after completion of each exercise intervention, in accordance with prior research (Hillman, Pontifex, Raine, Castelli, & Kramer, 2009). The author and trained research assistants performed data collection.

The AE and RE protocols were based on previous work by Alves et al. (2012). The RE protocol involved two sets of 15 repetitions in the following exercises: leg press, bench press, lat pull down, cable row, back extension, and biceps curl. If participants were not able to complete 15 repetitions/set, a 5% reduction in weight was allowed (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). A 1-min rest interval was assigned between sets. The RE intervention was 30 min in length. The AE protocol was matched for time and consisted of 30 min of walking/jogging at an intensity of 50% to 60%

age-predicted heart rate max. In the NE control, participants sat quietly for 30 min while viewing a sports-related DVD. Participants were monitored to ensure they did not fall asleep or move around (Pontifex et al., 2009). Participants were also monitored via heart rate telemetry during both exercise interventions using Polar E600 heart rate monitors, which are designed and recommended for classroom PE use. Participants were also assessed with Borg's original rating of perceived exertion scale, which was used to monitor exercise intensity more closely across experimental interventions (Borg, 1970).

Data Analysis

A repeated measures analysis of variance (ANOVA) was used to determine whether differences existed among the treatments (AE, RE, NE). Statistical significance was determined with an alpha of .05. All analyses were completed using SPSS 22.0.

Results

Table 1 displays mean values for all variables across exercise interventions. A repeated measures ANOVA revealed no significant difference in mean math test performance between RE and NE, $F(1, 86) = 2.81$, $p = .098$, $\eta^2 = .032$; AE and NE, $F(1, 86) = 2.03$, $p = .158$, $\eta^2 = .023$; and AE and RE, $F(1, 86) = 0.04$, $p = .837$, $\eta^2 < .001$. No differences were found between male and female participants in mean math test performance following any exercise intervention. Figure 1 illustrates the results.

Table 1
Mean (SD) Values for Stroop Test Performance, Math Test Performance, Heart Rate, Rating of Perceived Exertion

Exercise type	Stroop dot *M* (*SD*)	Stroop word *M* (*SD*)	Stroop color *M* (*SD*)	Math scores *M* (*SD*)	Heart rate *M* (*SD*)	RPE *M* (*SD*)
Aerobic	9.810 (1.78)	11.205 (2.58)	15.885 (4.23)	3.3862 (2.01)	125.86 (18.04)	2.72 (0.75)
Resistance	10.08 (1.83)	11.40 (2.33)	16.368 (4.69)	3.389 (2.2)	119.58 (12.62)	3.4 (0.78)
Nonexercise	10.44 (2.05)	11.55 (2.26)	16.93 (4.31)	2.954 (2.1)		

Note. RPE = rating of perceived exertion.

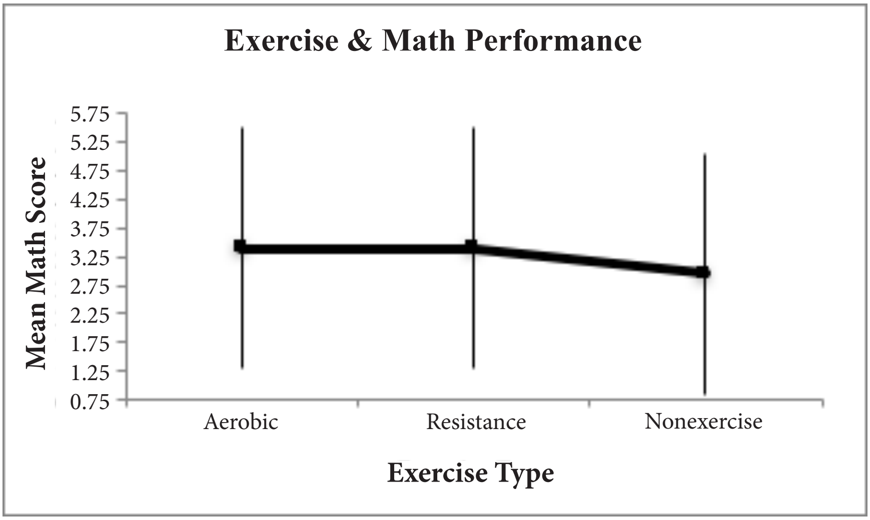

Figure 1. Mean math scores following various exercise types.

Results of separate repeated measures ANOVAs revealed significant differences between RE and NE in the Stroop dot test, $F(1, 86) = 4.31$, $p = .041$, $\eta^2 = .048$, and approached statistical significance in the Stroop word test, $F(1, 86) = 3.66$, $p = .059$, $\eta^2 = .041$. Significant differences were also found between AE and NE in the Stroop dot test, $F(1, 86) = 10.402$, $p = .002$, $\eta^2 = .108$, and Stroop color test, $F(1, 86) = 6.85$, $p = .01$, $\eta^2 = .074$. Differences between AE and NE approached statistical significance in the Stroop word test, $F(1, 86) = 3.63$, $p = .06$, $\eta^2 = .040$. No differences were found between male and female participants in Stroop test performance following any exercise intervention. Figure 2 illustrates the results.

Discussion

Contrary to the primary hypothesis, acute AE and RE did not demonstrate statistically significant improvements in mean math test performance in comparison to NE. Practical significance as measured by effect size greater than $\eta^2 = .04$ (Ferguson, 2009) was not achieved statistically, but both exercise interventions resulted in greater mean performance than the NE control by nearly 5%. As such, the author believes an argument could be made for the findings being practically significant for day-to-day classroom achievement. Such findings are in agreement with prior literature, which has consistently indicated that acute exercise exhibits small, positive changes in AA and cog-

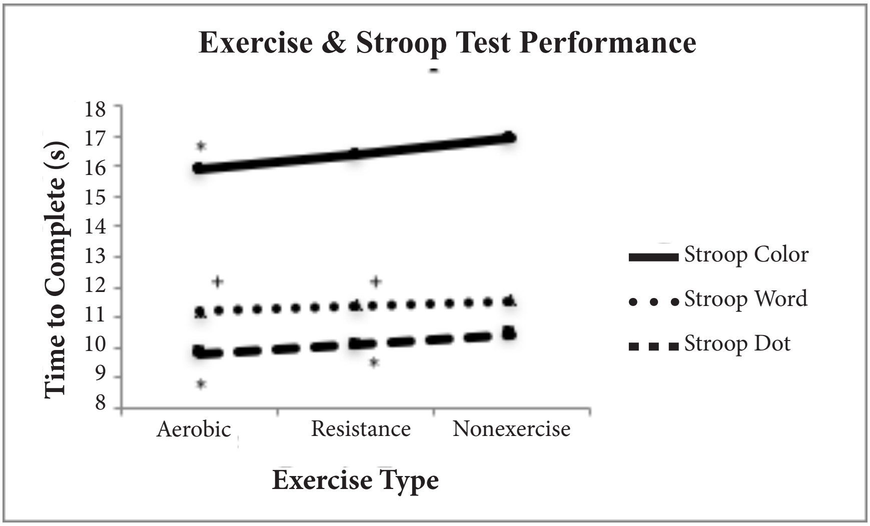

Figure 2. Time to complete Stroop dot, word, and color tests following various exercise types. $^{*}p < .05$. $^{+}\eta^2 > .04$.

nition (Chang, Labban, Gapin, & Etnier, 2012; Hillman, Kamijo, & Scudder, 2011; Travlos et al., 2010). Considering the test-centered approach that exists in today's educational environment, such findings should be of interest to parents, educators, administrators, and legislators. In partial agreement with the secondary hypothesis, RE significantly improved performance in the Stroop dot test compared to NE and approached statistically significant improvement in the Stroop word test compared to NE. Significant differences were also found between AE and NE in the Stroop dot and color tests, and the results approached statistical significance in the Stroop word test. Although findings related to AE agree with results in prior literature, this study marks the first instance of researchers utilizing acute RE to effect improvement in AA in a high school–aged sample. Although AA and cognitive performance increases were modest following both exercise interventions, the author hopes that such results will further strengthen the argument supporting increased PA, be it RE or AE, in the typical school day among high school–aged students.

Although the literature has demonstrated consistently small, positive changes in AA and cognition following acute exercise, the mechanisms underlying such changes are still being explored. Given that AE and RE resulted in modest increases in AA and cognition in this study, it appears that exercise type may not play a selective role in boosting higher-order brain processes. Rather, a wide variety of PA types can likely produce increases in executive functions. Hillman, Buck, Themanson, Pontifex, and Castelli (2009) may have inadvertently established support for such an idea by introducing the neurotrophic-stimulation hypothesis. This hypothesis states that neuromuscular activity stimulates areas of the brain that control executive function, resource allocation, and speed of processing. The hypothesis was developed based on studies of AE, but it has logical application to RE as well, given the nature of RE and its development of the neuromuscular system (Häkkinen et al., 2003). Similarly, acute RE and AE have been shown to elevate brain-derived neurotrophic factor (Seifert et al., 2010; Yarrow, White, McCoy, & Borst, 2010). Brain-derived neurotrophic factor has been shown to protect against neurodegeneration, enhance neural plasticity, and improve learning and memory (Yarrow et al., 2010), which make it a prime candidate for label as a causative agent behind the increase in AA and cognition following acute exercise. Finally, one of the more documented hypotheses related to acute exercise and its ability to enhance executive functions is the cerebral blood-flow hypothesis. This hypothesis states that during moderate exercise up to 60% VO_2 max, blood flow to the brain increases, delivering additional oxygen and nutrients that appear to optimize the physiologic state of the brain and benefit cognition and AA (Guiney, Lucas, Cotter, & Machado, 2015). Given the greater oxygen uptake levels associated with AE as compared to RE, this hypothesis has frequently been cited in the literature as a primary mechanism underlying the small, positive changes in cognition and AA in research. It is also possible that increased cerebral blood flow worked synergistically with mechanisms such as brain-derived neurotrophic factor to produce the increased performance in AA and cognition in this study. Additional research should be directed at isolating the precise mechanisms that drive the changes in executive function throughout the literature.

The results of this study bolster the current literature, but one limitation must be addressed. Specifically, student motivation appeared to be an issue, especially during mathematics testing. Motivation was not directly measured in this study, but it was apparent to the author that many of the students were not overly concerned with doing their best on the math tests, because they knew there were no academic repercussions for poor performance. Castelli, Hillman, Buck, and Erwin (2007) also discussed motivation, noting that students who typically enjoy academics may perform better on tests of AA than their peers who are less academically inclined. Thus, the construct of motivation could explain some of the variance credited to the individual exercise protocols utilized in this study. Future research would be wise to measure or control for student motivation to eliminate as much variance as possible.

In conclusion, the results of this study demonstrate that acute AE and RE can lead to small, positive changes in AA and cognition in a high school youth sample. These results are novel in that they mark the first example of researchers using acute RE to enhance AA among a high school–aged sample. Additionally, the findings expand youth school-based PA recommendations to include RE as a means to influence AA and cognition. These findings may be valuable for PE teachers, educators, and administrators who are involved in daily programming to maximize student effectiveness in the classroom. Given that equipment and available space are often primary considerations in school PA settings, the option of utilizing RE or AE could be valuable for physical educators seeking to influence their students' academic success while improving students' health.

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