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The Acute Effects of Exercise on Cognitive Performances of Older Adults

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Running Title: Acute Effects of Exercise on Cognitive Performances of Older Adults

Abstract

Accelerating rates of structural decline become evident during the third and fourth decades of human life, with disproportionate degeneration occurring in the frontal, parietal, and temporal brain lobes. As the structure of the brain declines, a broad array of cognitive processes involving memory, decision-making, and selective attention are reduced as well (Raz 2000, Park et al. 2001). Cardiovascular exercise has been associated with improved cognitive functioning in aging humans, suggesting that increased vascular supply enhances availability of oxygen, nutrients, and other physical entities to nourish the brain. Previous experimentation on older adults revealed significant positive effects of exercise on a variety of memory types following participation in a program six or more months in duration (Colcombe 2003, Kramer et al.1999). The primary focus of this study was to test the effects of acute aerobic exercise on cognitive functioning of adults over the age of 60. A second purpose was to determine that the positive neurological effects of exercise can start taking place immediately. The hypothesis is that memory retention, mental processing speed, and selective attention would acutely improve in the participants after they had exercised, in comparison to their cognitive state prior to exercise.

Cognitive performances both before and after exercise were tested using the Stroop test. All participants completed the post-exercise test with improved scores (p=0.000) indicating an increase in cognitive ability, relating exercise and improved cognitive function.

Introduction

The effects of acute exercise on decision-making, mental processing speed, selective attention, and reaction time of participants was studied (Aks 1998, Arcelin et al. 1999, Emery et al. 2001). Reviews of acute exercise literature by Brisswalter and coworkers (2002) and Tomporowski (2003) suggest that acute exercise consistently and positively affects cognitive performance, with intensity (submaximal) and duration (20-60 minutes) being significant factors. In these studies, exercise protocols exceeding 60 minutes and leading to dehydration and fatigue decrease performance on cognitive tasks, suggesting that the optimal level for enhancing acute function involves moderate performance for an hour or less.

The length of delay between exercise and testing appears to be significant. Revelle and Loftus (1992) concluded from an extensive literature survey that higher activity levels immediately before testing may inhibit short-term abilities to think quickly and efficiently, but facilitate cognitive quickness after delays of more than 30 minutes, indicating that moderate-to-intense exercise may not improve information recall and reaction speed if participants are assessed soon after exercise. More recent research by Coles and Tomporowski (2008) supported prior findings and demonstrated that exercise prior to list learning did not facilitate immediate recall, but recall following a 12 minute delay was enhanced by exercise. To further examine this phenomenon we assessed mental processing speeds and mental quickness of participants by testing 30 minutes after exercise. This interval allowed participants to stretch, drink water, experience heart rate recovery, and avoid extreme fatigue.

Numerous studies have shown that exercise can profoundly affect brain functioning and structure. Such structural alterations augment brain interconnections so it becomes more plastic and adaptive to cognitive changes that boost skills such as memory, selective attention, and decision making (Van Praag et al. 1999, Neeper et al. 1995). The brain also changes acutely with exercise because of increased blood flow and oxygenation of the brain. Enhanced oxygenation and blood flow attend increased catecholamine, brain-derived neurotropic factor (BDNF), and serotonin release, and consequent cognitive benefits of acute exercise (Ahmadiasl et al. 2003, McGaugh 1989).

Increasing numbers of adults are surviving to advanced stages, when neurological decline necessitates expensive care. The impression that six months or longer of exercise are necessary to significantly influence cognition is discouraging to participants and may be false. Demonstration of quantifiable benefits soon after exercise initiation almost certainly will increase rates of participation and subsequent quality of life enhancements. Memory retention, mental processing speed, and selective attention both before and after exercise will be evaluated.

Materials and Methods

Participants

Arkansas Tech University's institutional review board approved all protocols pertaining to this study. 30 older adults (13 men, 17 women; median age = 67.8) volunteered from among clients at St. Mary's Wellness Fitness Center in Russellville, Arkansas. Participants consisted of 26 Caucasians, 2 Hispanics, 1 African American and 1 Asian. All provided informed consent to participate in the study. St. Mary's Wellness Fitness Center facility requires all members to complete a Physical Activity Readiness Questionnaire (PAR-Q), ensuring acceptable physical health to safely allow the degree of activity involved. Qualifying participants chose either Pilates or a Silver Sneakers Muscular Strength & Range of Motion (MSROM) exercise of moderate intensity. Nine participants chose to take Pilates (4 male, 5 female, M age= 62.7), and 21 chose to take MSROM Silver Sneakers (9 male, 13 female, M age= 70.39).

Mental speed, Decision-making speed, Reaction Time.

To assess the speed of thought, decision making, and reaction time we used the Stroop Test, which is a widely used and accepted assessment tool for testing cognitive quickness and executive function (Levine et al. 1995). The Stroop Test places demands on cognitive flexibility by requiring shifting of perceptual set in accordance with changing external demands, as well as the inhibition of a habitual response in favor of a novel one. The Stroop Test yields highly reliable measures of individual differences in cognitive function based off the participants speed of reading color names, naming color patches, and naming colors printed in incongruous colors. In the diverse fields of cognitive function—perception, learning, reaction time, executive function, etc.—significant relationships have been found by using the Stroop test (Jensen et al. 1966, Stroop 1935), making it a reliable and accepted source for testing participants in this study. The Stroop Test was used to evaluate cognitive performances in the participants both before and after exercise in this study. The Stroop test employed was created by the Center for Sensorimotor Neural Engineering in Seattle, Washington and is taken online. Previous studies employing a computerized Stroop test show that results generated by group testing are both reproducible and acceptable (Campbell et al. 1999). Participants were tested both before and after exercise, and times required for completion were monitored. On the tests we administered, the words listed are colored differently than the color described. The format was 25 word units arranged in a 5 by 5 table. The units were read from left to right. The response times of the participants to the test was recorded before and after exercise. The post-exercise tests were taken after a 30-minute delay, and the pre-exercise tests were taken immediately before the exercise protocol. Comparison of pre- and post- exercise results indicate that acute exercise increases mental processing speeds and decreases average reaction times of test subjects.

Ratings of Perceived Exertion.

Since detrimental effects from fatigue can mask the beneficial effects of exercise on cognitive performance (Tomporowski 2003, Tomporowski et al. 1986), each individual exercised at what he or she considered a moderate intensity to ensure the exercise was non-fatiguing. Participants exercised at a self-determined moderate intensity level using the Borg scale of perceived exertion (ratings of perceived exertion; RPE) with ratings of 13-15 as the desired range. This scale has been shown to be psychometrically sound, with reliability coefficients above 0.90 and validity coefficients at 0.77 and higher (Borg 1998). RPE measures were taken every 10 minutes throughout the exercise protocol.

Acute Exercise Protocol.

Participants chose either a standard Pilates or an MSROM Silver Sneakers class of moderate intensity and duration. Based on a One-Way ANOVA test, these two classes were determined to have similar cardiovascular effects. The Pilates class involved a single bout of aerobic exercises in a group workout setting, with a floor mat as the single piece of exercise equipment. The protocol began with a 5 minute warm-up and stretch, followed by a series of upper-body and lower-body movements that included movements such as squats, lunges, abdominal work, light cardio, and full range of motion arm movements. These exercises produced RPE ratings within the prescribed 13-15 range. Participants exercised at a moderate intensity for 40 minutes. To minimize the effects of factors associated with bouts of high intensity and long duration exercise (e.g., fatigue and dehydration) that may also influence cognition. The Pilates class concluded with a 5 minute cool-down period. The MSROM Silver Sneakers class also involved a single bout of aerobic exercises in a group fitness setting, following a similar 5 minute warmup/stretching protocol. Equipment used during this class included a chair, 2-3 lb hand weights, and a resistance band with handles. Following the warm-up, participants were instructed to mimic the motions of an instructor and complete muscular range of motion exercises coupled with light cardio that produces RPE ratings within the desired 13-15 range. Participants exercised at a moderate intensity for 40 minutes, concluding with a 5-min cool-down period.

Procedure

People in either the Pilates or MSROM Silver Sneakers groups began by taking the Stroop test immediately before exercising. The test facilitator sat by each participant as they took the tests and monitored each participant as they read the color of the word out loud, making sure the test was fully completed before stopping the timer. Statistical analyses of Stroop Test results determined mean scores both before and after exercising. One-Way ANOVA analysis was performed to determine whether the types of exercises affected the results. Paired samples T-Tests were examined to further analyze pre- and post-exercise Stroop Testing.

Results

Comparison of Class Types

One-way ANOVA (Table 1) testing compared average RPE in the Pilates and Silver Sneakers MSROM classes. No significant difference between the Pilates group and Silver Sneakers group in their cognitive functioning could be discerned, with p= 0.531 before exercise and p= 0.614 after exercise.

Cognitive Function Performance

Descriptive statistics revealed a mean score of 20.33 on Stroop Testing before exercise, and a mean score of 16.31967 after exercise (Table 2). One standard deviation for the Stroop test before exercise was 6.173912, and 5.819248 after exercise. A Paired Samples T-Test and Paired Samples Correlations Test revealed a significant association between exercise and memory retention, mental processing speed, and selective attention, p=0.000 (Table 3, Table 4).

Table 1. A One-Way ANOVA Comparing Pilates and Silver Sneakers MSROM. This table is a comparison of the average rate of perceived exertion of participants in both the Pilates and Silver Sneakers Programs. This shows that even though the two classes did not follow the exact same exercise format, the exertion rate of participants was similar enough that they could be tested equally by the same format.

	Sum of Squares	Degree of Freedom	Mean Square	F	Significance
Before Exercise: Between Groups	15.629	1	15.629	0.402	0.531
Within Groups	1089.770	28	38.920		
Total	1105.398	29			
After Exercise: Between Groups	9.046	1	9.046	0.260	0.614
Within Groups	973.000	28	34.750		
Total	982.046	29			

Table 2. Total Mean Test Scores Before and After Exercise. This table shows a comparison of the average amount of seconds it took participants to complete the Stroop test both before and after exercise, and their standard deviation.

	Before Exercise	After Exercise
Mean	20.33297	16.31967
Number of Participants	30	30
Std. Deviation	6.173912	5.819248

Table 3. Paired Samples Correlation Test linking Exercise and Cognitive Function. This table shows the statistical relationship between the effects of exercise and cognitive function, which suggests that the increase in cognitive ability was due to the physiological effects caused by the exercise protocol.

	Number of Participants	Correlation	Significance (p-value)
Test Before and After	30	0.870	0.000

Table 4. Confidence Intervals for Paired Samples Test. This table shows the amount of reliability of the numerical results in the paired samples correlation test shown in Table 3.

	Paired Differences		T-Value	Degrees of Freedom	Significance (2-tailed)
	95% Confidence Interval of the Difference				
	Lower	Upper			
Test Before-Test After	2.865192	5.161408	7.149	29	0.000

Discussion

The primary purpose of this study was to quantify acute effects of exercise on cognitive function in adults over the age of 60. A second purpose was to evaluate how quickly neuropsychological effects are measurable. Positive neurological effects of exercise are discernible immediately after one workout, and strenuous 6-month programs clearly are not the only way to provoke benefits. The participants kept their RPEs within the desired range, exercise bouts were at moderate intensity levels, and the different exercise groups completed bouts comparable statistically in intensity.

Memory retention, mental processing speed, and selective attention improved in participants following exercise. Both exercise groups completed the post-exercise test faster than the pre-exercise test. All 30 test subjects improved their test scores post-exercise, at a p=0.000 significance level. These results are very encouraging, and show that there is a safe and healthy way to immediately improve cognitive functioning. This shows that the benefits of exercise can start taking place immediately and promote mental health and well-being. Our results are consistent with empirical research measuring effects of acute exercise on executive processing and short-term memory (Coles and Tomporowski 2008).

The Inverted-U hypothesis attributes exercise-induced cognitive performance enhancements to arousal (Davey 1973), but research has not consistently supported this notion (Chang and Etnier 2009, McMorris and Graydon 2000). Processes related to physiological arousal such as increases in catecholamines or neurotrophins (Neeper et al. 1995, Vaynman and Gomez-Pinilla 2005), may drive improvements in cognitive performance. Although neurochemical levels were not studied in the present project, significant increases in concentrations of neurochemical modulators have been measured following exercise of mild-to-moderate intensity and moderate duration (Hartley et al. 1972, Zouhal et al., 2008).

Physical fitness was not assessed prior to initiation of our studies to set and determine exercise intensity. Instead, we asked participants to exercise at an intensity that maintained an RPE range of 13-15 to ensure a moderate exercise level. RPE is a reliable tool for monitoring exercise intensity, but individual differences can influence RPE, so future research should include more thorough evaluation of subjects prior to analysis of the effects of exercise on cognition.

In summary, participation in exercise has a strong, positive, acute effect on the cognitive function in adults over the age of 60. These results show that exercise can lead to a more plastic and adaptive brain that can boost memory retention, mental processing speed, and selective attention skills. These studies further show that the effects of exercise can be seen immediately and not only for a long period of time before seeing any results. Another factor that appears to be important is the intensity and duration of the exercise protocol. Prior research indicated that intense, exhausting exercise resulting in fatigue and dehydration (Brisswalter et al. 2002), and light brief activity (Varner and Ellis 1998) may have detrimental effects on cognitive performance. This and other studies (Coles and Tomporowski 2008, Potter and Keeling 2005) show that exercise of moderate intensity and duration facilitates cognitive function. While the term "moderate exercise" has been applied to a broad range of protocols, the moderate exercise most likely to produce beneficial effects on cognitive performance has been identified as an intensity range of 40%-80% of maximal oxygen uptake (Brisswalter et al. 2002) with durations of 20-60 minutes (Tomporowski 2003). We designed the exercise protocol in the current study (intensity= 13-15 RPE, duration=40 minutes) to be consistent with the ranges of moderate exercise identified in reviews of acute exercise protocols. This study shows that exercise may be very important factor in maintaining a healthy, aging brain; a finding of increasing importance to the aging population of the U.S. and many other countries.

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