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Original Article

Physiology Section

The Acute Effects of a Single Bout of Moderate-intensity Aerobic Exercise on Cognitive Functions in Healthy Adult Males

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ABSTRACT

Introduction: Single acute bouts of moderately-intense aerobic exercise like walking have been found to improve cognitive control of attention in children, but some studies have reported no improvement in cognitive flexibility following acute aerobic exercise. Submaximal aerobic exercise performed for 60 minutes facilitated specific aspects of information processing in adults but extended exercises leading to dehydration compromised both information processing and memory functions. Improvement in executive functions has also been reported during cycling at 70% of Heart Rate Reserve (HRR) across young and older age groups. However, there are studies which have reported no correlation between physical activity and academic performance in children and a recent systematic review of 30 relevant studies reported no significant improvement in cognition with physical activity or exercise in adults. There seems to be lack of consensus on the effect of exercise on cognition, which may be because the exercise protocols used and cognitive functions tested by different researchers were not uniform.

Aim: The primary aim of this study was to investigate the acute effects of aerobic exercise across different cognitive domains in healthy young individuals.

Methods: A homogeneous group of 10 right handed healthy adult males participated in the study and was subjected to 8 cognitive function tests including 2 tests each across the four categories: Memory, Reasoning, Concentration and Planning using a pre-validated web based tool. Following baseline testing, subjects performed 30 minutes' of cycling on a stationary bicycle ergometer at moderate intensity (60-70% of HRR). Post–test scores were recorded when heart rate returned to within 10% of baseline. Pre and post–test scores were compared using the paired t-test.

Results: After exercise, there was significant improvement (Mean ± SD) in the Paired Associates (4.8±1.0 Vs 5.5 ± 1.0), Odd One Out (10.5 ± 3.0 Vs 13 ± 3.1) and Spatial Slider test (30.4 ± 17.8 Vs 40.5 ± 13.9), the tests of Memory, Reasoning and Planning respectively. No significant improvement was found for concentration. Total post-test time was significantly lower than the pre-test time (23.5 ± 2.55 Vs 21.2 ± 1.48 minutes).

Conclusion: A single bout of moderate intensity aerobic exercise for as less as 30 minutes can improve some aspects of cognition, most prominently for memory, reasoning and planning and can shorten the time taken to complete the tests.

Key words: Aerobic exercise, Acute effects, Cognitive functions

INTRODUCTION

Life expectancy in India is steadily increasing, with a large aging population. One problem which is emerging is that of a cognitive decline which affects the quality of life. This is even more of an issue in individuals with neuropsychiatric disorders like Alzheimer's disease and depression. Neuronal loss has been observed as early as in the third decade of life, with a resulting decline in cognitive performance [1]. Single acute bouts of moderately-intense aerobic exercise, like walking have been found to improve the cognitive control of attention in preadolescents [2] and adolescent children, though no improvement in cognitive flexibility was seen following acute aerobic exercise in another group of children [3]. Submaximal aerobic exercise performed for periods of up to 60 min facilitates specific aspects of information processing in adults [4] but extended exercise that leads to dehydration compromises both information processing and memory functions. Reaction time has been shown to improve with light as well as moderate exercise in young and old adults [5]. Executive functions improved during cycling at 70% of Heart Rate Reserve (HRR) across young and older age groups [6]. 30 minutes of walking on the treadmill improved cognitive functions judged by a dual task test in depressed elderly subjects, but showed no improvement in the stroop test or in the digit span test [7].

Then there are other studies that have found no relation between physical activity and academic performance in children [8]. Snowden et al., in a systematic review of 30 relevant studies, reported no significant improvement in cognition with physical activity or exercise in adults [9]. Based on the literature available, it appears that the effect of exercise on cognition is inconsistent. However, the exercise protocols used and the cognitive functions tested by different researchers are not uniform.

Therefore, the primary aim of this study was to investigate the acute effects of aerobic exercise across different cognitive domains in healthy young individuals using standard tests of cognitive functions.

MATERIAL AND METHODS

Subjects

This study was conducted in a homogenous group of 10 healthy adult male medical students who volunteered. The demographic characters were as follows (Mean ± SD): age (in years) 19.5 ± 0.9, height (in cm) 173.8 ± 4.31, and weight (in kg) 70.2 ±13. Informed written consent was obtained from after explaining the procedure and the protocol. The exclusion criteria was subjects with any known cardiac/respiratory disease/physical disability preventing them from being able to comply with the exercise regime (30min of moderate intensity aerobic exercise). We enrolled the first 10 volunteers amongst 2nd year medical students and no student was excluded, as all of them were healthy and were able to complete the exercise protocol.

METHODOLOGY

The cognitive function testing and the exercise were performed in an air-conditioned research lab of the department in the evening hours, between 4 pm and 6 pm.

Day 1: Participants were subjected to a total of 8 cognitive function tests which included 2 tests from each domain – Memory (Spatial Span and Paired Associates), Reasoning (Grammatical Reasoning and Odd one out), Concentration (Feature Match and Polygons) and Planning (Spatial Search and Spatial Slider) using a pre-validated web based tool developed at the Medical Research Council Cognition and Brain Sciences Unit, Cambridge UK. This trial was done to familiarize the participants with the tests and scores and they were not recorded.

Day 2: Cognitive functions were retested and these were noted as baseline scores. Then, the participants were subjected to 30 minutes of aerobic exercise, wherein all the subjects performed 30 minutes of cycling on a stationary bicycle ergometer at moderate intensity at 70% of heart rate reserve (HRR). Continuous heart rate monitoring was done throughout the procedure (Biopac Student Lab, Biopac Systems Inc., Santa Barbara, CA, USA). The post exercise cognitive testing was done once the heart rate fell to within 10% of the basal heart rate [10]. All testing was done by the same examiner at the same time of the day to minimize the effects of observer and circadian variations. All the procedures were carried out in accordance with the ethical standards which were approved by the institutional ethical committee for human experiments following the guidelines of the Helsinki Declaration.

STATISTICAL ANALYSIS

Performances in the pre and post exercise cognitive tests were expressed as mean of all the subjects, with standard deviation as the measure of dispersion and they were compared across all categories of cognition, along with the total time taken to complete the tests. A paired t-test was used to compare the pre- verses and post-exercise scores.

RESULTS AND DISCUSSION

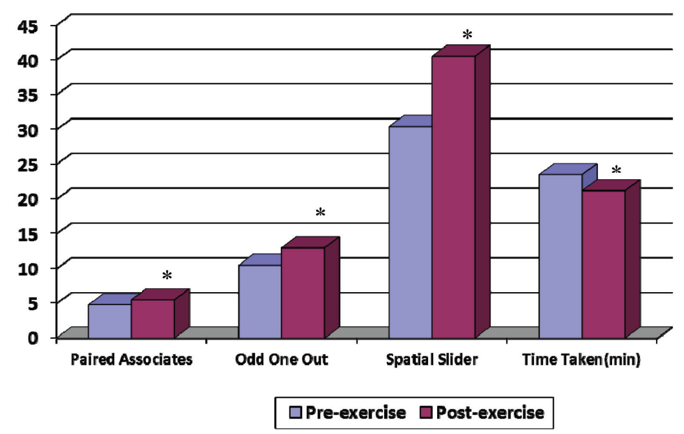
Results

All the volunteers completed the study. The results for different cognitive tests have been shown in [Table/Fig-1].

There was a consistent increase in the mean values of scores of 7 of the 8 tests after the exercise. Among these, there were significant increases in the scores of Paired Associates, Odd One Out and Spatial Slider. There was no significant improvement in the tests of Concentration. There was a significant decrease in the time taken for completing the tests after exercise [Table/Fig-2].

Name of the test	Pre-exercise Score	Post-exercise Score	'p' Value
Spatial Span (memory)	6.1±1.0	6.1±0.7	1.000
Paired Associates (memory)	4.8±1.0	5.5±1.1	0.010
Grammatical Reasoning (reasoning)	14.6±4.6	16.7±4.1	0.142
Odd One Out (reasoning)	10.5±3.0	13±3.1	0.003
Feature Match (concentration)	113±29.8	109.9±26.2	0.836
Polygon (concentration)	39.8±20.1	43.5±25.7	0.728
Spatial Search (planning)	7.9±1.7	8.1±1.3	0.726
Spatial Slider (planning)	30.4±17.8	40.5±13.9	0.043
Time Taken (Seconds)	23.5±2.55	21.2±1.48	0.03

[Table/Fig-1]: Cognitive test scores (Mean ± SD) before and after aerobic exercise



[Table/Fig-2]: Effects of acute aerobic exercise on different cognitive test scores
* p<0.05 compared to baseline

DISCUSSION

A significant improvement was seen after exercise in scores w.r.t "Paired Associates", "Odd One Out" and "Spatial Slider". However, there was no significant change in the mean scores for the other tests. Hence, exercise induced benefits were seen for some tests of memory, reasoning and planning, but no benefits were seen for "concentration". Previous studies have also reported that exercise had selective positive effects on cognition, with benefits being seen in tasks which involved executive control (planning, scheduling and working memory) [11].

Various explanations have been suggested for exercise induced cognitive improvements. Reports have suggested that acute treadmill walking resulted in a enhanced P3 amplitudes in preadolescent children, which most likely represented an increased allocation of attention [2] which could help memory. A probable explanation for the improvement in performance in some of the cognitive tests in our study could be an exercise induced allocation of attention. The decrease in the time taken for completion of all the tests could also be explained by this. The poor performance in the other tests could have been due to poor attention caused by a lack of interest in the specific tests.

Studies have reported that intense stress increases cortisol levels and a decline in the immediate recall performance [12] . Decreasing cortisol levels with Metyrapone has been found to impair delayed recall. In the same study, injecting hydrocortisone at the time of cortisol peak (morning) impaired cognitive functions, whereas injecting it during the trough (evening) had positive effects on memory [13]. A more pronounced cortisol level has been found to be associated with a poorer memory [14]. Stress or cortisol treatment temporarily blocks memory recalls. A functional Magnetic Resonance Imaging (fMRI) study suggested that the neuronal correlate of the cortisol induced retrieval blockade was a reduced activity of the hippocampus and the prefrontal cortex. However, in contrast to its effects on retrieval, cortisol enhances memory consolidation [15]. Adrenal stress hormones which are released in response to acute stress may yield memory-enhancing effects when they are released post-learning, but impair memory if they are released during the process of retrieval [16]. In our study, we used two tests of memory, the spatial span and the paired associates test, among which, a major improvement was seen only with the paired associates test. It is possible that the levels of stress (exercise) which are required for improving performance in different domains of cognition are different and that they may also differ amongst different tests in the same domain. Accordingly, the exercise protocols for the required benefit could be different and this aspect may be looked into in the future.

Different forms of exercise induce changes in the neuroplasticity of different brain regions and exert diverse effects on various forms of learning and memory [17]. Learning and memory performance is affected via BDNF-TrKB signaling and neuroplasticity in different brain regions. The brain region-specific neuronal adaptations are possibly induced by various levels of intensity/stress elicited by different types of exercises [18]. Different cognitive tests engage different parts of the brain and hence, 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 (moderate).

Chronic exercise increases the levels of BDNF and has been found to be associated with an improvement in non-spatial memory [19] in rats. Acute exercise too has been shown to increase BDNF levels in humans, however, BDNF increase was not correlated with the increase in cognitive scores (as measured by spatial memory) post exercise. Moreover, the increase in BDNF in this study was dependent on the level of exercise [20]. It is possible that some of the improvements in cognitive functions seen in our study were caused by a rise in BDNF levels, but we did not measure BDNF levels.

Exercise improves the blood supply to the brain, leading to improved scores in various cognitive tests [21]. Physical activity is related to changes in the brain through overall cardiovascular conditioning and it enhances cerebral blood flow and oxygen supply to neurons [22]. Animal studies have also found positive cholinergic effects in association with chronic exercise and an improvement in spatial memory [23]. Single bouts of exercise elevated Hippocampal High Affinity Choline Uptake (HACU) [23] associated with a spatial-learning set task. It is possible that the intensity or duration of exercise in our study did not bring about the appropriate cholinergic activation. Hence, we saw no improvement in spatial memory with a single bout of exercise.

In any case, it is apparent that even a single bout of moderate intensity exercise can bring about an improvement in cognition and we believe that this is very important, as aerobic exercise could have a dual benefit, both for physical and mental health. It is an already established fact that chronic exercise definitely benefits cognition. However, it is an interesting incentive for the subject to note that there is an improvement in cognition with even a single bout of exercise. Though our sample size was small, it was apparent that in most of the cases, a benefit was seen, albeit being small in some cases. So, we think that the study holds great promise. To the best of our knowledge, there is no publication till date which has reported on the effects of acute exercise on these 4 domains of cognition.

CONCLUSION

A single bout of moderate aerobic exercise for as less as 30 minutes can improve some aspects of cognition, most prominently for memory, reasoning and planning and it definitely decreases the time taken to perform the tests. We believe that among human subjects, this study is the first which has looked at four different cognitive domains together, after a single bout of exercise, and this could be extended and explored further extensively.

LIMITATIONS OF THE STUDY

We are aware that our sample size was small. However, our study gave us important insights into the fact that there was improvement across domains of cognition with a single bout of exercise. Future studies need to look at cognitive effects of exercise extensively across these four domains in a larger number of subjects.

ABBREVIATIONS

BDNF: Brain derived neurotropic factor
TrKB: tropomyosin receptor kinase B

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