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Original Research Article

The effects of acute aerobic exercise on choice reaction time in young adults

Supriya Komalsingh Patil[1], Umesh Suresh Patkar[2]*, Kshitija Umesh Patkar[2]

[1]Department of Physiology, Shri. Bahusaheb Hire Government Medical College, Dhule, Maharashtra, India
[2]Departement of Physiology, TN Medical College, Mumbai, Maharashtra, India

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***Correspondence:**
Dr. Umesh Suresh Patkar,
E-mail: uspatkar@gmail.com

ABSTRACT

Background: Exercise, especially aerobic exercise thought to have a positive impact on cognitive and brain function which mainly involved in acquisition, processing, storage and executive functions. Executive control processes are important in sport and occupational settings where a person is being asked to make decisions while performing physical work. We have done this study, to determine the effects of acute moderate intensity exercise on cognitive domains and to apply this knowledge in various fields where cognition and executive functions are important. Study and control population each consists of 60 apparently healthy subjects in the age group of 18-30 years.
Methods: The material used for study Cosco Upright Exercise Bike and Reaction Time apparatus. Visual Choice Reaction Time, the examiner presented visual stimuli at random to the subject. The subject saw the light displayed on his side and pressed the appropriate corresponding button as quickly as possible and the reading was noted. The same procedure was repeated for auditory choice reaction time for auditory stimuli. After that each subject from study population underwent acute moderate intensity aerobic exercise on for 10 minutes. Starting within 5 minutes after the exercise, subjects were assessed for the same cognitive test as above, for the second time. Control population rested for 10 minutes and then was assessed again for the same cognitive test.
Results: There was no significant difference between the pre- values of study population and pre- values of control population. There was no significant difference between the pre- values of control population and post values of control population. Thus, there was no improvement in cognitive functions on account of repetition of tests. There was a significant difference between the post values of study population and post values of control population. There was a significant difference between the pre- values of study population and post values of study population.
Conclusions: There was a decrease in reaction time following exercise in the study population, suggests that there was an improvement in the cognitive functions post exercise.

Keywords: Aerobic exercise, Choice reaction time, Cognition, Young adults

INTRODUCTION

Exercise is a physical activity that is planned, structured, repetitive and purposive with the objective of improvement or maintenance of one or more components of physical fitness.[1] Aerobic exercise comprises several modes of activities that primarily stress the aerobic energy system and produce a number of cardiovascular and respiratory adaptations that increase endurance. Aerobic exercise has many health benefits like improvement in cardiovascular and respiratory function.

In addition to this, exercise is thought to have a positive impact on cognitive and brain function as well.[2] Cognition is defined as all mental processes involved in acquisition, processing, storage and retrieval of information. Different cognitive functions include attention, learning and memory, executive functions, language, psychomotor abilities.

Some studies show improvement in cognitive function after acute exercise and others have reported either no change or negative results.[3,4] Executive control processes are important in sport and occupational settings (e.g., for military personnel or in firefighting) where a person is being asked to make decisions while performing physical work.[4] Being very important in various professionals we have done this study, to determine the effects of acute moderate intensity exercise on cognitive domains.

The present study was aimed to study the effects of acute moderate intensity exercise on cognitive functions in healthy adults.

METHODS

Study design

The study was approved by the local ethics committee of the institute and then it was conducted in the Department of Physiology in a reputed medical college.

Sample size

Study and control population each consists of 60 (Total sample size consists of 120) apparently healthy subjects (30 males and 30 females) in the age group of 18-30 years by computer generated randomization table.

Materials

Cosco Upright Exercise Bike -9380 U (cycle ergometer)

Reaction Time apparatus RTM -608 manufactured by Bio - tech, India.

Method

A brief explanation regarding the purpose of study and the cognitive tests was given to the subjects. They were explained in detail about the procedure to be performed in their vernacular language to their satisfaction.

Complete history was obtained and clinical examination was done. Auditory and visual screening was also carried out on the subjects to rule out any auditory or visual impairment. Each subject was asked to be seated for 5 mins and then baseline heart rate and blood pressure were recorded of each subject. Heart rate reserve was calculated using the Karvonen formula:[5]

Heart rate reserve=Heart rate maximum - Basal heart rate.

Heart rate maximum = 220 - age.[6]

Then CRT was recorded as follows

Choice reaction time (CRT)

Examiner sat on side of primary control while participant sat on opposite side with secondary control. Subject was instructed at the start of test to press the appropriate corresponding button as quickly as possible. Before taking readings of choice reaction time tests, six to seven practice sessions were given to subjects. Before presenting any stimulus, a warning signal in the form of a verbal instruction

In case of Visual Choice Reaction Time (V-CRT), the examiner presented with any of the three visual stimuli (Red, Green or Yellow Lights) at random to the subject. The reaction timer started immediately and the corresponding light glows on both sides. The subject saw the light (Red, Green or Yellow) displayed on his side and pressed the appropriate corresponding button as quickly as possible. Once subject pressed the button, reaction timer stopped immediately and indicated the reaction time for the subject inseconds. Maximum resolution of time was 0.001 seconds (milliseconds).

In case wrong button was pressed, the timer continued to run and stopped after the appropriate button was pressed. The same procedure was repeated for Auditory Choice reaction time (A-CRT), where the buttons for High, Medium, Low frequencies were used by the examiner and the subject heard corresponding sound through headphone.[7]

In this study, three readings were taken for each visual and auditory choice reaction time test and the average of the three readings was taken as final result. After the participants underwent cognitive function testing for the first time, the method of exercise was as follows,

Method of exercise for study population

Each subject from study population then underwent acute moderate intensity (50% heart rate reserve) aerobic exercise on a cycle ergometer (upright bike) for 10 minutes. If the subject felt discomfort any time during exercise, he was asked to stop doing the exercise. Starting within 5 minutes after the exercise, subjects were once again assessed for the same cognitive test as above, for the second time. Exercise Protocol for Control population: Each subject in this group rested for 10 minutes (did not undergo exercise) and then was assessed again for the same cognitive test as above, for the second time.

RESULTS

Statistical analysis

After data collection, the data entry was done in Microsoft –excel program and statistical analysis was done by Statistical Package for the Social Sciences (SPSS) version 15.0 software. For the analysis, following tests were used: "Unpaired t- test" was used to compare among study group and control group and "Paired t-test" was used to compare between pre- scores and post scores value less than 0.05 was taken as significant level. 60 subjects were included in study group and 60 subjects were included in control group (Table 1).

Table 1: Total no. of subjects.

	Frequency	Percent
Study group	60	50
Control group	60	50
Total	120	100

Table 2: Comparison of mean scores of visual averages (V Avg.) and auditory average (A-Avg.) between study (pre-exercise) and control population (pre- rest).

Parameter	Study group				Control group				Unpaired T-Test	P-value
	Mean	St. deviation	Median	IQR	Mean	St. deviation	Median	IQR		
Pre-V Avg.	0.68	0.11	0.70	0.12	0.68	0.13	0.67	0.12	0.318	0.751
Pre-A Avg.	0.56	0.09	0.56	0.13	0.56	0.10	0.55	0.18	0.077	0.939

Table 2 showed that the mean pre- Visual Average (V Avg) of study group was found to be 0.68 ± 0.11 and that of control group was 0.68 ± 0.13. When the unpaired t-test was applied it was found that no statistically significant difference was present between study group and control groups for pre- V Avg.

The mean pre- Auditory Average (A Avg) of study group was found to be 0.56 ± 0.09 and that of control group was 0.56 ± 0.10. When the unpaired t- test was applied it was found that no statistically significant difference was present between study group and control groups for pre-A Avg.

As per Table 3, the mean post V Avg of study group was found to be 0.63 ± 0.10 and that of control group was 0.67 ± 0.13. When the unpaired t- test was applied it was found that there is a statistically significant difference present between study group and control groups for post V Avg.

The mean post A Avg of study group was found to be 0.51 ± 0.08 and that of control group was 0.57 ± 0.10. When the unpaired t- test was applied it was found that there is a statistically significant difference present between study group and control groups for post A Avg. The mean pre- V Avg of study group was found to be 0.68 ± 0.11 and mean post V Avg of study group was 0.63 ± 0.10. When the paired t-test was applied it was found that there is a statistically significant difference present between pre- scores and post scores of studies populations for V Avg (Table 4).

Table 3: Comparison of mean scores of Visual Average (V Avg.) and Auditory Average (A Avg.) between study (post exercise) and control population (post rest).

Parameter	Study group				Control group				Unpaired t-test	P-value
	Mean	St. Deviation	Median	IQR	Mean	St. Deviation	Median	IQR		
post-V Avg.	0.63	0.10	0.63	0.17	0.67	0.13	0.67	0.13	-2.227	0.028*
Post-A Avg.	0.51	0.08	0.48	0.12	0.57	0.10	0.56	0.19	-3.632	0.000*

*P –value < 0.05 is significant

Table 4: Comparison of mean scores of choices reaction time visual average (V Avg.) and auditory average (A Avg.) between study pre and post exercise

Parameter	Pre- scores				Post scores				Unpaired t-test	P-value
	Mean	St. Deviation	Median	IQR	Mean	St. Deviation	Median	IQR		
Pre-v avg.	0.68	0.11	0.70	0.12	0.63	0.10	0.63	0.17	6.561	0.000*
Pre-a avg.	0.56	0.09	0.56	0.13	0.51	0.08	0.48	0.12	6.828	0.000*

*P –value < 0.05 is significant

The mean pre- A Avg of study group was found to be 0.56 ± 0.09 and mean post A Avg of study group was 0.51± 0.08. When the paired t-test was applied it was found that there is a statistically significant difference present between pre- scores and post scores of studies populations for A Avg (Table 4). The mean pre- V AVG of control group was found to be 0.68 ± 0.13 and mean post V Avg of control group was 0.67 ± 0.13. When the paired t- test was applied it was found that there is no statistically significant difference present between pre- scores and post scores of controls population for V Avg (Table 5).

Table 5: Comparison of mean scores of choice reaction time visual average (V Avg.) and auditory average (A Avg.) between control pre and post exercise.

Parameter	Pre- scores				Post scores				Unpaired T-Test	P-value
	Mean	St. Deviation	Median	IQR	Mean	St. Deviation	Median	IQR		
Pre-V Avg.	0.68	0.13	0.67	0.12	0.67	0.13	0.67	0.13	0.800	0.427
Pre-A Avg.	0.56	0.10	0.55	0.18	0.57	0.10	0.56	0.19	-0.711	0.480

The mean pre- A Avg of control group was found to be 0.56 ± 0.10 and mean post A Avg of control group was 0.57 ± 0.10. When the paired t- test was applied it was found that there is no statistically significant difference present between pre- scores and post scores of controls population for A Avg Table 5).

DISCUSSION

The present study was carried out with an aim of studying the effects of acute moderate intensity exercise on cognitive functions in healthy adults. A comparison of mean scores of Choice Reaction Time Visual (V Avg) and Auditory (A Avg) was done between study population and control population.

From our study it was clear that,

- There was no significant difference between the pre- values of study population and pre- values of control population as shown in Table 2,
- There was a significant difference between the post values of study population and post values of control population as shown in Table 3,
- There was a significant difference between the pre- values of study population and post values of study population as shown in Table 4,
- There was no significant difference between the pre- values of control population and post values of control population. Thus, there was no improvement in cognitive functions on account of repetition of tests. As shown in table no.5.
- All these findings indicate that there was a decrease in reaction time following exercise in the study population, which suggests that there was an improvement in the following cognitive functions post exercise: processing speed, attention, psychomotor abilities, response inhibition and stimulus categorization.

In 1997 Arcelin et al examined the effect of 60% VO_2 max cycling exercise on a choice reaction time task and found that reaction time was not only significantly faster in the two exercise conditions, but was also faster than in the rest condition.[8] This finding is similar to our study.

Similarly, in 2009 Dave Ellemberg studied the effects of acute exercise on cognition during development.[9] Compared to the control group, the children in the exercise condition showed a significant improvement on both tasks, with a better outcome for the choice compared to the simple task.

The possible mechanisms could be interplay of the following factors

Arousal is the most commonly cited potential mechanism for the explanation of the relationship between acute

exercise and cognitive performance.[10] The optimal level of arousal seems to be at moderate intensity exercise.[11]

It seems that moderate steady-state exercise, like other agents e.g., psycho stimulant drugs that increase central nervous system arousal, enhances performance by making the individual more receptive to sensory stimulation and by increasing the speed of late motor processes.[12]

Recent advances in methods of assessing the structure and function of the brain have provided researchers the means to identify more precisely the neurophysiological components of arousal and activation. The reticular activating system has for e.g. been shown to consist of several interrelated arousal systems that are differentiated by specific neurotransmitters.

Three main systems of neuromodulators have been distinguished: The noradrenergic, the dopaminergic and the serotonergic systems.[10] The noradrenergic system originates from the locus coeruleus in the pons. An increase in brain noradrenergic transmission improve the signal to noise ratio of evoked responses to environmental stimuli, either by enhancing evoked responses, by suppressing "background activity" or by a combination of these two effects in several cortical terminal regions, whatever the sensory modality.[10]

The dopaminergic system originates from cell bodies located in the substantia nigra pars compacta and from the ventral tegmentum. projections from these areas modulate neural activity in (a.) the dorsal and ventral striatum, which, in turn, affect the supplementary motor area, premotor area and primary motor cortex and (b) the frontal lobe, and more particularly the medial prefrontal cortex, that underlies executive functions. These pathways affect the activation or energization of behavior and account for the vigour and frequency of behavioural outputs.

Table 6: Characteristics of noradrenergic and dopaminergic neuromodulator mechanisms are summarized in the table below.

Energetical Mechanism	Neurotransmitter system	Brain localization	Main function	ERP index
Arousal	Noradrenaline	Locus	Filtering	P300
Activation	Dopamine	Substantia nigra, pars compata	Energizing inputs	CNV

Note-ERP: Event related potential; P300: Positive cortical wave observed 300 milliseconds after the occurrence of response signal in a reaction time task; CNV: contingent negative variation.[10]

The serotonergic system originates from cell bodies located in the raphe nucleus. Neurons from this system dampen the actions of each of the two preceding systems and promote behavioural inhibition and cortical deactivation.[10]

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.[13,14] The mediating role of resource allocation has been suggested to explain improvement in cognitive performance during exercise. This effect highlights the importance of motivational factors in such tasks. Finally, when the cognitive performance was performed during exercise, consistent results have indicated that the dual task effect was strongly related to energetic constraints of the task. The greater the energy demand, the more attention is used to control movements.[15]

Cerebral blood flow –It is surmised that aerobic exercise promotes increased cerebral blood flow and draw from animal models, which have indicated that exercise improved neurotransmitter function and cerebral vascularization among other neurobiological changes.[16] Exercise improves the blood supply to the brain, leading to improved scores in various cognitive tests.[17] Physical activity is related to changes in the brain through overall cardiovascular conditioning and it enhances cerebral blood flow and oxygen supply to neurons.[10]

BDNF (Brain-Derived Neurotrophic Factor)- Adequate BDNF levels are essential for cognitive function.[18] BDNF is one of the growth factors and is mainly found in the pre-frontal cortex, basal forebrain and hippocampus where decision making takes place (i.e. priority is given to important information and distraction is eliminated). Thus, attention, stimulus selection, and decision making are improved.[19]

The probable mechanism of improvement of learning and memory performance is affected via BDNF-TrKB (Tyrosine receptor kinase B) signaling 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. Different cognitive tests engage different part 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).[20]

Higher levels of BDNF immediately after exercise may enhance neurogenesis, neuronal plasticity, learning abilities, memory and mood.[21]

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. In conjunction with this, many participants after exercise reported feelings of increased mood and focus, the ability to think more clearly, as well as reductions in psychological conditions such as depression and anxiety. The specific improvements in the cognitive functions may also be due to the reasons given below: Attention: In this study, we assessed auditory Choice reaction time. We found an improvement in attention in the study population following exercise.

The improvements in attention and inhibitory control immediately after and 15 minutes after exercise can be associated with activated brain areas such as the anterior cingulate. Moreover, exercise may promote the activation of the reticular formation that is responsible for the modulation of attention and arousal.[21] Psychomotor abilities: We assessed participants for psychomotor abilities using Choice reaction time and found an improvement in the performance. Acute exercise induces increased BDNF and/or BDNF-mRNA expression in the brain, in the hypothalamus. Also, the dopaminergic pathway, which is activated following acute exercise mainly serves the basal ganglia, frontal cortex, cingulated cortex and olfactory tubercle. Thus, these areas which are important to bring about psychomotor abilities are benefitted following acute exercise.[22]

CONCLUSION

The present study was done to determine the effects of acute moderate intensity aerobic exercise on cognitive functions in healthy adults. Cognitive functions were assessed using the choice reaction time. There was a decrease in reaction time (i.e. responses were quick) following exercise in the study population, which suggests that there was an improvement in the following cognitive functions post exercise: processing speed, attention, psychomotor abilities, response inhibition and stimulus categorization.

Also, there was no improvement in the cognitive functions in the control population, thus eliminating repetition (exposure to the tests) as a cause of improvement in the study population. The mechanisms which may be responsible are: An increased arousal level after exercise, exercise induced allocation of attention (increased P3 amplitude), increased cerebral blood flow and increased BDNF levels.

In the light of present study, following important conclusions can be drawn. Acute moderate intensity aerobic exercise improves the reaction time function in healthy adults.

Thus, it is evident that even acute exercise of lasting for short duration (10 minutes) can bring about an improvement in the cognition. The use of exercise as an alternative to improve the cognitive function shows to be relevant, especially due to its applicability, as it is a relatively cheap method that can be applicable and practiced by a major part of the population. It can improve our quality of life by promoting both physical and mental health. It can help coaches and athletes in assembling strategies that involve attention and decision, thus reinforcing a good sportive performance. It may be valuable for personnel like soldiers, fire fighters, miners where a person is being asked to make decisions while performing physical work.

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