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RESEARCH ARTICLE

Effect of cardiovascular fitness on cognitive functions among male medical students of South Kerala

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ABSTRACT

Background: Cardiovascular fitness has a beneficial effect on cognition and brain function in children. However, due to conflicting results in relationship between acute exercise and cognitive function in young adults, the data remain unknown. Hence, the present study is aimed to assess the effect of cardiovascular fitness on cognitive functions in healthy young adults. **Aims and Objectives:** The aims of the study were as follows: (1) To assess the cardiovascular fitness among male medical students using Harvard step test, (2) to study the audiovisual reaction time and critical flicker-fusion frequency (CFFF) among male medical students, and (3) to study the correlation between cardiovascular fitness and cognitive functions. **Materials and Methods:** A comparative study was conducted among 100 male medical students of the age group of 18–25 years and they were randomly chosen into the study and control group. All were subjected to cognitive function tests such as visual reaction time (VRT), auditory reaction time (ART), and CFFF and pre-scores were recorded. Each subject from the study group underwent Harvard step test at a rate of 22/min for 5 min or until exhaustion for which fitness index was calculated. Cognitive tests were repeated within 5 min after exercise and post-exercise values were also recorded. The same cognitive tests were assessed in the control group after resting for 10 min. **Results:** The pre-values and post-exercise values of the study group showed a significant difference in cognitive functions. The pre-values and post rest values of the control group had no significant difference. The pre-values of the study group and control group had no significant difference. The post-values of the study group and control group had significant difference. There was also a correlation between the fitness index and some cognitive function tests such as VRT and CFFF in the study group. **Conclusion:** There was a decrease in VRT and ART and increase in CFFF after exercise in the study group, which suggests that there was a positive influence of acute moderate exercise on cognitive functions.

KEY WORDS: Cardiovascular Fitness; Cognitive Function Tests; Young Adults; Fitness Index

INTRODUCTION

Aerobic exercise is essential for the maintenance of cardiovascular fitness and good health. Aerobic exercise produces a number of cardiovascular and respiratory adaptations that increase endurance by primarily stressing the aerobic energy system. It is linked to reduction in blood pressure, reduced incidence of developing coronary heart disease, diabetes, strokes, lower fat mass, and increased bone mass. Along with these benefits, exercise also had a positive effect on cognitive performance in humans.

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Cognition is defined as all mental processes involved in acquisition, processing, storage, and retrieval of information. Cognition process uses existing knowledge and generates new knowledge. Attention, learning and memory, executive functions, language, and psychomotor abilities are different types of cognitive functions.[1] Reaction time and critical flicker-fusion frequency (CFFF) are used to assess cognitive function.

Reaction time is a non-invasive ideal tool for measuring sensory motor association that gives the length of time to respond to a given stimulus such as light and sound with appropriate voluntary response in a subject. CFFF is the frequency at which an intermittent light stimulus that appears to be steady. Both are a part of automated psychomotor test battery along with continuous attention test.[2,3]

Some studies show that physical activity during midlife appears to decrease the incidence of dementia and improve cognitive performance in older adults.[4,5] A positive correlation was achieved between physical activities and academic achievements among school children. However, the data related to relationship between acute exercise and cognitive function in young adults remain unknown due to conflicting results.[6-9]

Hence, the present study is aimed to assess the effect of cardiovascular fitness on cognitive functions in healthy young adults.

MATERIALS AND METHODS

Study Design

This was an observational study.

Sample Size

The study and control group each comprising 50 male students (total sample size of 100) in the age group of 18–25 years were randomly selected from their batch register.

Study Tool

PC 1000 Hz reaction timer device, indigenously built CFFF instrument, and a personal computer with audacity software were used.

Method

The subjects were briefed regarding the purpose of the study and cognitive tests. They were explained in detail about the procedure to be performed in their vernacular language, after which informed consent was taken from all the participants.

Complete history of all the participants was obtained. Clinical examination was done along with auditory and visual screening to rule out any impairment. Each participant was asked to take rest for 5 min and then, resting heart rate and blood pressure of each participant were recorded. All the participants underwent cognitive function tests for the 1st time. After which, Harvard step test was performed by the study group.

Cognitive Function Tests

Auditory reaction time (ART), Visual reaction time (VRT), and critical flicker-fusion frequency (CFFF) were measured using the PC 1000 Hz reaction timer. ART and VRT were measured in the control and study groups in a quiet secluded room whose ambient temperature was about 27°C with their right upper limb, from 10 am to 12 noon.

Reaction Timer

The ART and VRT were measured using PC 1000 Hz reaction timer with 1000 Hz square wave oscillator which has a soft key for “start” and “stop” function. It has two components, A and B which are connected to each other. Component (A) has a start button and it is handled by the examiner only. Component (B) handled by the participant, which has a stop button containing a small red light-emitting diode (LED) since red light persists for a long time in retina and headphone (1000 Hz tone) which receives the visual and auditory stimulus, respectively. Personal computer which has audacity software installed in it connected to these two components which records the reaction time in 0.001 s accuracy in wave format.

VRT Measurement

The “Start” button in component (A) was pressed by the examiner which was out of the view of the participant. The participant as soon as he sees the red light, he was instructed to press the “Stop” button in component (B) with the right index finger. Audacity software in the personal computer records the reaction time.

Auditory Reaction Time (ART) Measurement

When the “start” button which was out of the view of the participant was pressed, he was instructed to press the stop button with the right index finger as soon as he hears the sound (1000 Hz tone) for the 1st time through the headphone connected to it. Audacity software in the personal computer records the reaction time.[2]

CFFF Instrument

CFFF measuring instrument is a portable device, indigenous LED-based instrument. Monochromatic red light LED light of wavelength 630 nm fixed on white background is used as flickering light source. As the red light is perceived for longer time in retina, it is used as a light source in this instrument. Frequency adjustment done by software-based variable frequency square oscillator (10–50 Hz). Frequency is measured from the recorded data using audacity software.

Procedure

Subject was asked to relax and tested in a minimally illuminated room, with CFFF measuring device kept at a distance of 30 cm. Subject was properly instructed, asked to respond by lifting the hand, and tested by increasing and decreasing the frequencies. When the frequency was increased, at one point, the flickering stops and light is perceived as a steady source. If the frequency was decreased from higher level the flickering at one point reappears. Both ascending and descending frequencies were recorded and the mean of the two is taken as CFFF.[3]

Exercise Protocol

Each subject from the study group underwent Harvard step test at a rate of 22/min for 5 min or until exhaustion. A metronome is used to ensure the right stepping rate. Exhaustion is the point at which the subject cannot maintain the stepping rate for 15 s. Immediately, after the completion of exercise, the participant was asked to sit down, and the heartbeats are counted for 1–1.5, 2–2.5, and 3–3.5 min. Fitness index was calculated by plotting the time of exhaustion in seconds (t_e) and the heartbeats (h_b) using the following equation:

$$\text{Fitness index} = t_e \times 100/h_b \times 2$$

where, t_e is time until exhaustion in seconds and h_b is total heartbeats counted.[10]

Participants were subjected to the same cognitive tests, for the 2nd time, starting within 5 min after the exercise. The same cognitive tests were assessed for the 2nd time in the control group after resting them for 10 min. The average of three readings of VRT and ART was taken as final result.

Statistical Analysis

Statistical analysis was done after collecting and entering the data into Microsoft Excel sheet using Statistical Package for the Social Sciences (SPSS) version 16.0 software. For the analysis, to compare among the study group and control group, "unpaired *t*-test" was used and to compare between pre-values and post-values, "paired *t*-test" was used, $P < 0.05$ were taken as significant level. Fitness index was correlated with cognitive function test values using Pearson's correlation.

RESULTS

The findings of the present study are depicted in Tables 1-6.

Table 1: Comparison of age and BMI between the study and control group

Variable	Group	*n*	Mean	SD	*t* value	*P* value
Age (years)	Study	50	20.54	1.092	1.208	0.230
	Control	50	20.84	1.376		
BMI (Kg/m^2)	Study	50	22.619	2.7752	0.686	0.495
	Control	50	22.970	2.3301		

Independent sample *t*-test, BMI: Body mass index

Table 2: Comparison of mean pre- and post-exercise scores of VRT, ART (ms), and CFFF (Hz) in the study group

Variable	*n*	Mean	SD	*t* value	*P* value
Pre-VRT	50	192.180	15.3205	3.480	0.001*
Post-VRT	50	183.380	10.8841		
Pre-ART	50	169.273	9.3216	4.230	0.001*
Post-ART	50	160.860	11.5106		
Pre-CFFF	50	45.140	2.2925	3.195	0.002*
Post-CFFF	50	43.140	3.7294		

*Statistically significant (dependent sample *t*-test), CFFF: Critical flicker-fusion frequency, VRT: Visual reaction time, ART: Auditory reaction time

Table 3: Comparison of mean pre and post rest scores of VRT, ART (ms), and CFFF (Hz) in the control group

Variable	*n*	Mean	SD	*t* value	*P* value
Pre-VRT	50	192.360	22.3462	0.646	0.522
Post-VRT	50	193.880	23.8815		
Pre-ART	50	169.953	12.9851	0.016	0.987
Post-ART	50	169.987	11.9280		
Pre-CFFF	50	45.640	3.4583	1.260	0.214
Post-CFFF	50	45.100	2.3013		

Dependent sample *t*-test, CFFF: Critical flicker-fusion frequency, VRT: Visual reaction time, ART: Auditory reaction time

Table 4: Comparison of mean pre-exercise scores of VRT, ART (ms), and CFFF (Hz) between the study group and control group

Variable	Group	*n*	Mean	SD	*t* value	*P* value
Pre-VRT	Study	50	192.180	15.3205	0.047	0.963
	Control	50	192.360	22.3462		
Pre-ART	Study	50	169.273	9.3216	0.301	0.764
	Control	50	169.953	12.9851		
Pre-CFFF	Study	50	45.140	2.2925	0.852	0.396
	Control	50	45.640	3.4583		

*Statistically significant (independent sample *t*-test), CFFF: Critical flicker-fusion frequency, VRT: Visual reaction time, ART: Auditory reaction time

DISCUSSION

This study was aimed to study the effect of acute moderate-intensity exercise on cognitive functions and correlate them with fitness index in young adults. A comparison of mean values of VRT, ART, and CFFF was done between the study group and control group.

The following observations were made from our study:

- The pre-values and post-exercise values of the study group had a significant difference, as shown in Table 2
- The pre-values and post rest values of the control group had no significant difference, as shown in Table 3

- The pre-values of the study group and pre-values of the control group had no significant difference, as shown in Table 4
- The post-values of the study group and post-values of the control group had a significant difference, as shown in Table 5
- Table 6 shows a correlation between the fitness index and post-exercise values of VRT and CFFF but not ART in the study group
- All these observations demonstrated that in the study group, there was a decrease in reaction time and increase in CFFF following exercise, which suggested that cognitive performance was improved post-exercise.

Our results are similar to the study done by Ellenberg,[11] in which they studied the effect of acute exercise on cognitive function by assessing simple reaction and choice response time. Each of them was tested before and after the exercise. The children in exercise group showed a significant improvement in both tasks when compare to the control group, indicated that physical exercise has a positive influence on cognitive functions.[10]

Similarly, Lambourne *et al*. studied the effect of a single bout of steady-state aerobic exercise on young adult's sensory sensitivity (critical fusion frequency [CFF]) and executive functions. In this study, CFF scores revealed that the participant's sensory discrimination increased during exercise.[12]

A several mechanisms have shown the exercise-induced cognition improvements. In these, most commonly cited mechanism is arousal, which relates exercise with cognitive performance.[13] Like psychostimulant drugs, moderate exercise also increases arousal of central nervous system, which improves the individual's receptive ability to sensory stimulation and increases the speed of late motor processes.[12]

Table 5: Comparison of mean post-exercise scores of VRT, ART (ms), and CFFF (Hz) between the study group and control group

Variable	Group	*n*	Mean	SD	*t* value	*P* value
Post-VRT	Study	50	183.380	10.8841	2.829	0.006*
	Control	50	193.880	23.8815		
Post-ART	Study	50	160.860	11.5106	3.893	0.001*
	Control	50	169.987	11.9280		
Post-CFFF	Study	50	43.140	3.7294	3.163	0.002*
	Control	50	45.100	2.3013		

*statistically significant (independent sample *t*-test), CFFF: Critical flicker-fusion frequency, VRT: Visual reaction time, ART: Auditory reaction time

From structural and functional magnetic resonance imaging of brain have shown that several interrelated arousal systems that are differentiated by specific neurotransmitters are present in reticular activating system. Three main systems of neuromodulators are the noradrenergic system originating from locus ceruleus in the pons, the dopaminergic from substantia nigra, and the serotonergic system from raphe nucleus. Evoked responses in several cortical terminal regions are enhanced by increasing brain noradrenergic transmission, whatever the sensory modality.[13]

Motor cortex and prefrontal cortex that are involved in executive functions are modulated by neuronal activity in the dopaminergic system. The vigor and frequency of behavioral outputs are also energized by these pathways.[13]

The behavioral inhibition and cortical deactivation done by serotonergic system originating from raphe nucleus dampen the actions of each of the two preceding systems.[13]

Exercise-induced attention is another probable cause for the improvement in performance in some of the cognitive test.[14,15] Consistent results have indicated that dual task effect was strongly related to energetic limitation of the task when the cognitive performance was performed during exercise. When there is an increased energy demand, more attention is used to control the movements.[16]

It is also observed that aerobic exercise improves scores in various cognitive tests due to the enhancement of the blood flow and oxygen supply to brain and neurons, which improves neurotransmitter function and cerebral vascularization.[13] Many potential biochemical mediators of exercise such as insulin-like growth factor-1, brain-derived neurotrophic factor (BDNF), and vascular endothelial growth factor affect the brain which exhibit similar or complementary effects in the hippocampus mechanistically that improves the cognitive functions.[6] During acute exercise, BDNF levels are increased which are required for cognitive function.[17] Immediately, after exercise higher levels of BDNF may enhance neurogenesis, neuronal plasticity, learning abilities, memory, and mood.[18]

Immediately, after 15 min of exercise improvements in attention and inhibitory control is associated with activated

Table 6: Correlation between fitness index and mean scores of VRT, ART, and CFFF in the study group

Variables		Pre-VRT	Post-VRT	Pre-ART	Post-ART	Pre-CFFF	Post-CFFF
Fitness index	Pearson correlation	0.176	−0.473	0.082	0.102	0.163	−0.674
	P value	0.223	0.001*	0.572	0.483	0.257	0.001*
	n	50	50	50	50	50	50

CFFF: Critical flicker-fusion frequency, VRT: Visual reaction time, ART: Auditory reaction time brain area like anterior cingulate. Exercise-induced activation of reticular formation results in modulation of attention and arousal.[18] By increasing the levels of BDNF and/or BDNF mRNA expression in hypothalamus, psychomotor abilities are improved with acute exercise. Following acute exercise, the dopaminergic pathway in basal ganglia, frontal cortex, cingulate cortex, and olfactory tubercle is activated.[19]

CONCLUSION

Acute moderate exercise improves cognitive functions in male medical students. The present study also found that there is a correlation between cardiovascular fitness and cognitive functions by calculating the fitness index in the study population. Hence, we can conclude that exercise plays a major role in improving the quality of life by having a positive effect on physical and mental health.

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