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Effect of High Intensity Aerobic Exercise on Cognitive Functions among Healthcare Students: An Interventional Study

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Abstract
Aim: To study the effect of high intensity aerobic exercise on cognitive functions among healthcare students – An interventional study
Background: High intensity aerobic exercise is a form of cardiovascular training were the body works at 70%to90% of its maximum heart rate (HR max). Exercise benefits cardiovascular health is well known but it also benefits brain performance. Regular exercise promotes neurogenesis particularly in the hippocampus of the brain and also increases the grey matter. Studies have shown that due to less physical exercise among students there's memory and attention deficits that decreases the quality of life. There are certain factors like stress or lack of sleep that may disturb the cognition among medical students. The relationships between exercise and levels of neurotropic factors (i.e. brain- derived neurotropic factor) are seen.
Methodology: An Experimental intervention study was conducted using purposive sampling in which 51participants performed high intensity aerobic exercise for 40 to 45 minutes for 4 week, the digit span test was used to assess memory recall and flankers test for attention both the test were conducted before starting the session and after 4 weeks
Results: Participants elicited significant improvement in reaction time of memory recall and attention when comparing pre/post values.
Conclusion: The findings suggested that high intensity aerobic exercise benefits the reaction time of memory recall and attention.

Keywords: High intensity aerobics, Cognitive functions, Healthcare, Reaction time

1. Introduction

Aerobic fitness is recognized for enhancing aerobic capacity in individuals with no health issues. This capacity reflects how effectively the cardiovascular and respiratory systems—including the heart, lungs, and blood vessels—function, and it indicates the highest volume of oxygen the body can utilize during vigorous physical activity over a specific period [1]. Several factors influence the effectiveness of an exercise program, including frequency, intensity, duration, and type of activity. For the program to be beneficial, the exercise must fall within the individual's tolerance levels. It should exceed the minimum threshold necessary to stimulate adaptation, yet remain below the intensity that might trigger clinical symptoms [2].

Engaging in regular physical activity plays a crucial role in maintaining a healthy body weight, as well as supporting normal levels of blood pressure and blood lipids. But the advantages of exercise are not limited to just physical health—it also contributes significantly to mental well-being. Research has shown that exercise can elevate mood, boost self-esteem and self-confidence, and help alleviate symptoms of depression. Given these wide-ranging benefits, physical activity is frequently prescribed as a preventative and therapeutic tool for numerous health conditions, such as heart disease, metabolic disorders, osteoporosis, certain types of cancer, and mental health disorders [3].

Cognition can be conceived of as the method used by the central nervous system (CNS) to process information. Cognitive processes include knowing, understanding, awareness, judgment, memory and decision making. Executive functions are sometimes included under this heading as well. Executive functions include the capacity to plan, manipulate information, initiate and terminate activities, recognize errors, problem solving, and thinking [4]

The brain possesses the ability to adapt both in function and structure in response to various internal and external challenges, supporting its flexibility, resilience, and wide range of capabilities. Numerous human studies have demonstrated that consistent physical activity over time enhances this neuroplasticity [5]. While the positive effects of physical activity on cardiovascular health are widely recognized, the potential for exercise to enhance brain function has only recently attracted the attention of neuroscientists. A number of observational studies have reported that individuals who engage in regular physical activity tend to exhibit better cognitive performance. Supporting this trend, neuroimaging research has revealed that those who exercise consistently often have greater grey matter volume compared to those with a sedentary lifestyle [6].

In this study we mainly focused on attention and memory, attention is a cognitive process that enables individuals to focus on stimuli while ignoring others. It plays a crucial role in perception, learning and memory allowing to process information effectively in complex environment.

Memory is a fundamental cognitive process that allows individuals to encode, store, and retrieve information, it is essential for learning, decision making and shaping personal identity.

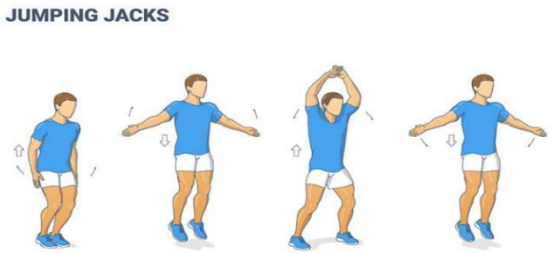
Recent research has shown a strong connection between aerobic fitness and brain function. Studies indicate that regular exercise and improved aerobic capacity are linked to greater brain volume and elevated levels of growth factors that support the development of new neurons (neurogenesis) and blood vessels (angiogenesis) [1]. Exercise plays a significant role in promoting cognitive health [7].

Aerobic exercise has been shown to boost levels of brain-derived neurotrophic factor (BDNF), insulin-like growth factor, and vascular endothelial growth factor. These biological changes are believed to enhance the formation of new neurons, especially within the hippocampus region of the brain. Additionally, individuals with higher levels of aerobic fitness tend to exhibit increased volumes of both grey and white matter, as seen in MRI scans [7].

Research indicates that the cognitive benefits of exercise vary by age group, with younger adults experiencing minimal improvements, while preadolescents and older adults show more noticeable gains. Moreover, an individual's level of physical fitness plays a significant role in how exercise affects cognition, with those who are more active and fit deriving the greatest advantages from a single session of aerobic activity [5]. Notably, the relationship between exercise intensity and cognitive enhancement follows an inverted U-shape, highlighting that moderate intensity may be optimal for boosting mental performance [8]. The cerebellum plays a crucial role in cognitive functions and has significant connections with the prefrontal cortex. Currently, three main hypotheses, derived from human research, have been proposed to explain how aerobic exercise might enhance cognitive performance:

1. Enhanced oxygen delivery due to increased cerebral blood flow and the formation of new blood vessels (angiogenesis).
2. Elevated levels of neurotransmitters such as serotonin and norepinephrine, which support more efficient information processing.
3. Modulation of neurotrophins, including various growth factors that support brain function and plasticity.

This study will be performed among healthcare students, so to assess cognitive functioning i.e. the digit span test for memory recall and flankers test for attention will be performed before and after the complete session. We are going to use aerobic exercise like as following:



Spot marching

Forward walking

Method and Materials

The following study was An Experimental Interventional type of study. The sampling population was collected by Purposive sampling method. The minimum sample size of the research was 51. The study was conducted in Jalgaon. The duration of study was 6 months.

The sample size was calculated by the following formula.
Formula:

$$n = \frac{Z1^2 S^2}{d^2}$$

The Criteria of selection of participants was done based on Inclusion Criteria which included the participants Voluntary willing to participate, Age group between 19 to 24, Both gender
Participants with an existence of any acute or chronic disease (pulmonary or metabolic), with any injury and chronic smokers were excluded from study
Procedure: Ethical clearance was taken from the institutional ethical committee of prior to the commencement of study. A written consent were taken from all participant. First, the nature and purpose of study was explained to the participants, then the participants were given all the information about the cognitive tests and the aerobic sessions. Before we began the session and after the session two test were performed to check memory recall and attention i.e. the digit span test followed by flankers test respectively. For the intervention, subjects were divided according to the age group. Prior to the session target heart rate was calculated individually for each participant. High intensity aerobics exercise was defined as 70% to 80% of maximum heart rate, which was calculated using the formula 220 – Age = HRmax and 70% or 80% of HRmax is THR. The exercise protocol involved 5 mins of warm-up, 35 to 40mins of aerobic session and 5 to 7 mins of cool-down period. Before starting the session both cognitive tests were assessed. Songs were played on a speaker and participants followed the steps performed by instructor.During the session intensity were maintained from low intensity to high intensity for each step and the steps were:

Spot marching,Side walking,front walking, Front walk with kick, Grape wine, Diamond,Square,Jumping jacks, V walk and V walk with jumping jacks. After 4 weeks of session both cognitive tests were assessed (digit span test and flankers test), General guidelines were given before starting session like, Participants should wear loose and simple clothing, Heavy meal should be avoided before the session, Drinking and smoking should be prevented throughout the session (4 week,) Avoid any strenuous activity before the session.

Cognitive assessment

- To conduct this digit span test, participants were given a random list of numbers and was read them out saying each single digit number in a montone voice, after hearing the digits the subject should place the digits in same order if they pass the first sequence with 3 digits, a second set of numbers will be read out containing more digits and so on. Maximum 2 trails were given and test ended when participant unable to recall the digits in correct order after 2 trails, hence the sequence number of digits were recorded
- To conduct this Flankers test, participants were shown a sequence of same direction arrows (right headed or left headed), only the centrally target arrow was in an opposite direction, participant has to respond by indicating the direction of target stimulus, while performing this test pre and post reaction time was noted.

Results

The entire data of 51 particiapants was entered and cleaned in MSexcel before it was statistically analysed in “GraphPad Instat version 3.05”, Statistical analysis was done with paired T test and on intragroup comparison of pre and post of the participants.

- Age group distribution of the study shows 27.45 % subjects belongs to 19-20 age group, 37.25 belongs to 21-22 age group and 35.29 age group

Table 1: Age group distribution of the study

Sr. No.	Variable	Groups	Frequency	Percentage
1	Age (in years)	19-20	14	27.45
		21-22	19	37.25
		23-24	18	35.29

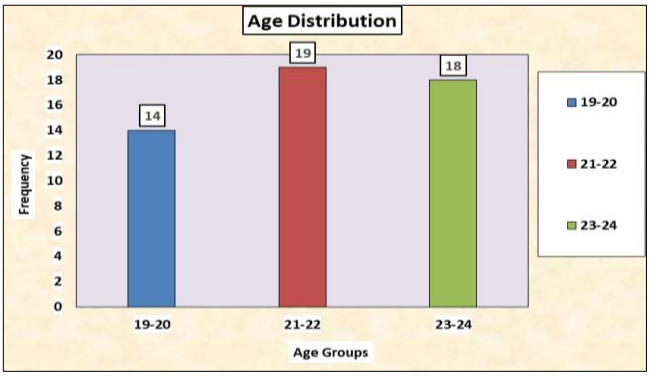


Fig 1: Age Distribution

- Gender wise distribution shows 22 (43.14%) of male and 29 (56.86) of female.

Table 2: Gender wise distribution

Sr. No.	Variable	Groups	Frequency	Percentage
2	Gender	Male	22	43.14
		Female	29	56.86

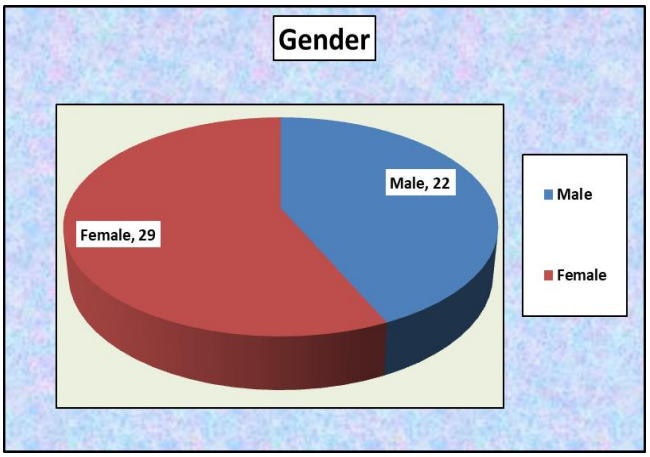


Fig 2: Gender

- Intragroup pre and post comparison of Flankers test:

Table 3: Intragroup pre and post comparison

Variable	City	N	Mean	SD	t value	p value
Flankers Test	Pre Test	51	30.41	5.61	4.12	0.000
	Post Test	51	25.07	7.00		

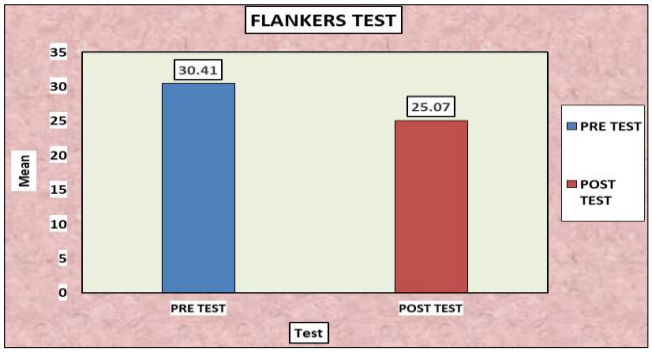


Fig 3: Flanker test

The comparison of pre and post time were done by paired T test. The average pre test time time was 30.41 with standard deviation of 5.61. The average post time was 25.07 with standard deviation of 7.00. The test statistics value of paired t test was 4.12 with P value 0.00, the P value is less than 0.05, that means there is significant difference in average time

- Intragroup pre and post comparison of digit span test

Table 4: Intragroup pre and post comparison

Variable	Groups	PRE TEST		POST TEST	
		Frequency	Percentage	Frequency	Percentage
Digit Span Test	1st	0	0.00	0	0.00
	2nd	13	25.49	9	17.65
	3rd	9	17.65	11	21.57
	4th	15	29.41	8	15.69
	5th	11	21.57	2	3.92
	6th	3	5.88	6	11.76
	7th	0	0.00	6	11.76
	8th	0	0.00	9	17.65

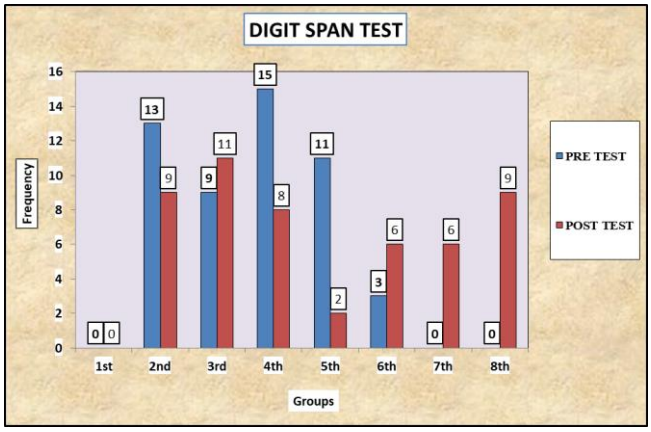


Fig 4: Digit span test

In the table pre, post frequency and percentage is given according to the sequence of the digits and In the graph, there is improvement seen when compared with pre to post evaluation

Discussion

The objective of the study was to see the effect of high intensity aerobic exercise on cognitive functions (memory and attention) among healthcare students

The present study was conducted on total 51 participants with age group 19 to 24 among healthcare students. Students were given intervention according to the age group, the session was given for about 35 to 40 mins for 4 weeks (3days per week), after the session both cognitive tests were evaluated for memory and attention.

1) Effect of high intensity aerobic exercise on attention

Our study found that high intensity aerobic sessions were effective in improving attention among students, to assess attention flankers test was used, on intragroup comparison using paired T test, the mean pre value was 30.41 $\pm$ 5.61 and the mean post value was 25.07$\pm$7.00 and p value was 0.000 respectively. Similar results were found in the study of Sebastian et.al has conducted a study on younger adults in higher education to see the effect of aerobic exercise on cognitive functions showed that participants in RUN compared to CON showed shorter reaction time on flankers task, F(1, 50) = 5.59, p =.022, η2 =.101.This can be explained by aerobic exercise elevates the neurotransmitters such a dopamine, norepinephrine and serotonin, which are crucial for attention and mood regulation. Exercise also activates the prefrontal cortex which is responsible for executive functions and attention control.

2) Effect of high intensity aerobic on memory recall :-

In our study we used digit span test for memory recall which also showed improvements after aerobic session. The results are shown on the basis of frequency and percentage according to the sequences from 1st to 8th sequence. Participants showed improvements in recalling the digits in pre post comparison. Similar results were found in Holy Rose *et al*. conducted a study on the positive effect of Zumba (i.e high intensity aerobics) on memory recall in middle aged to older population which included 15 participants. The results showed Zumba participation elicited significant improvements in MR (p =.026) and a medium effect size of (d=.671) when comparing pre/post values. The improvement in memory following aerobic exercise, may be attributed to mechanism such as cerebral hypoxia increase production of reactive oxygen species lactate irisin and cathepsin. These

factor contributes to elevated level of BDNF. Another possible reason for improvement of memory is that cortisol accumulation can lead to memory deterioration exercise may help to prevent cortisol build up potentially resulting in improved memory function.

Study done by Roig *et al*. indicated that from a neurobiological perspective exercise induce increases catecholamines and neurotrophins may be key mechanism underlying temporary improvements in cognitive functions

In current study it has been seen that greater improvement in the individual who were regular throughout the session of 4 weeks program. Some participants showed irregularity throughout the session and had less cognitive performance when compared to the regular participants. study done by Francesco Riganello *et al* study on sedentary young adults, in which they included 23 participants were assigned in two groups results found that memory, reasoning and verbal abilities improved throughout the aerobic session but not through resistance program and the study concluded lack of physical can be a major threat to cognitive health.

During aerobic exercises, the cardiorespiratory system supplies oxygen that the skeletal muscle system utilizes. In contrast, during resistance exercises, without the use of oxygen, the cells revert to the formation of ATP via glycolysis and fermentation. Physical exercises improve hemodynamic, hormonal, metabolic, neurological, and respiratory function.

It remains probable that factors such as perceived stress, intelligence or sleep, moderated the relationship between exercise and executive functions in present study.

Conclusions

From this research, the study concluded that high intensity aerobic exercise improves memory and attention among healthcare students.

Future Scope

In future scope, Conducting follow ups to assess sustained effects of regular high intensity exercise on cognitive function and academic performance over the course of healthcare education, Implementing apps and tools that measure cognitive function in real time can provide immediate feedback on how exercise affects cognitive abilities

Clinical Implication

The study needs to reflect importance and awareness of doing aerobic exercise in day to day life, which will improve quality of life among younger population and will also relive them from mental illness

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