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The Effects of Aerobic Exercise on Cognition Among Young Indian Adults – An Experimental Study

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Abstract: Aerobic exercise is composed of several modes of exercises that primarily stress up the aerobic energy system & thus producing a number of cardiovascular & respiratory adaptations, and indicated that vital role of exercise training, including enhanced cardiovascular functions, decrease mortality, reduced coronary heart disease, enhanced cognition, decrease fall risk and improve depression. Therefore, the study aim is to investigate the effects of moderate intensity aerobic exercise on cognition among young Indian adults. A total number of 144 students were evaluated, from their 54 students met the inclusion criteria, and were preceded for further study procedure. Stroop test has been used for evaluation where pre and post-Stroop completion time and errors were measured. Comparison of pre and post-Stroop completion time by individuals and significant difference was found (<0.001), hence Stroop completion time and errors were recorded separately. From findings of the study it was concluded that aerobic exercise is beneficial and also responsible for cognitive function enhancement, in all age groups.

Keywords: Aerobic Exercise, Cognition, Stroop Test

1. Introduction

Life will not be life without physical activities. Regular exercise is considered important to develop & maintain optimal health, performance, and appearance [1]. Aerobic exercise (AE) is composed of several modes of exercises that primarily stress up the aerobic energy system & thus producing a number of cardiovascular & respiratory adaptations, after-time increasing endurance. Exercise, especially AE is thought to have a positive impact on cognitive & brain function, involving the acquisition, processing, storage & executive function [2].

Cognitive function is the process of thought to conceptualize, recognize & process stimuli, is considered one of the most important aspects that should be maintained & enhanced for a healthy & disease- free lifestyle [3]. Spirduso et al., suggested 2 mechanisms for cognitive improvement, post-exercise, i.e. the oxygen hypothesis, measuring the blood flow in various brain areas and neurotropic stimulation hypothesis, suggesting the role of neuromuscular activity in promoting higher functioning brain centers [4].

AE increases brain size and hence improves cognitive functions [5, 6]. AE can increase the oxygen hemoglobin concentration in the prefrontal cortex (PFC), activates nerves and thus improves cognitive functions [7, 8].

Executive control process plays a crucial role in sports and occupational settings [9] and executive function can be conceptualized as a set of process that enables one to plan, coordinate, sequence and monitor cognitive operations [10, 11].

Executive control is suggested to be the sum total of three variables: Inhibition, including selective attention, resisting distractions and staying focused; working memory and cognitive flexibility [12, 13].

Hotting K et al, states that physical exercise, apart from promoting cardiovascular, musculoskeletal & endocrine health, also enhances various functions of the brain, including appetite and stress regulation, memory and cognitive functions and mood [14].

Graff Radford indicated vital roles in exercise training, including enhanced cardiovascular functions, decreased mortality, reduced coronary heart disease, enhanced

cognition, decrease fall risk and improve depression [15].

AE has proved to beneficial in healthy individuals; however, it is believed that subjects with psychiatric disorders may exhibit significant changes via performing exercises [16].

Voelcker-Rehage C et al. proposed that different types of exercise exert distinct effects on brain and cognition [17]. Kramer AF et al. suggested that high physical activity is related to high cognitive functions [18].

Hence the aim of the study is to investigate the effects of moderate intensity aerobic exercise on cognition among young Indian adults.

2. Materials and Methods

A total of 144 students, irrespective of their gender, from a convenient sample of Teerthanker Mahaveer Medical College and Research Centre (TMMCRC) were evaluated. Out of 144 students, 54 students met the inclusion criteria, were preceded for further study procedure. Inclusion criteria are based on (i)Body Mass Index (BMI) – 18.5-24.9 kg/m^2, according to World Health Organization (WHO), (ii) Age between 18 years to 25 years, (iii) Both male and female gender are included, (iv) Subjects are included only from nTMMCRC, (v)Subjects who are willing to participate and co-operative. Subjects who are not matched as per inclusion criteria and who are all having musculoskeletal, neurological and other associated health-related issues has been excluded from the study.

Before to participate in the study, all the procedures of the study are fully explained to the subject and assured them that there was no risk involved in the treatment and also informed them that if they fill uncomfortable, they can withdraw from this research at any point of time. As per the research criteria, demographic details and informed consent has been taken from every subject where it was mentioned that their identity will not be disclosed without their permission.

A standardizing questionnaire has been used where the subject's demographic details regarding age, gender, height, weight, alcohol & caffeine intake & average weekly physical activity performance were measured.

The material utilized in this study were recorded or data collection sheet, consent form, stadiometer, weighing machine, static cycle, pulse oximeter, Stroop test mini cards, stopwatch.

Outcome measures are measured by Stroop completion time and errors measurement through Stroop test. Resting heart rate (RHR) was noted and 1st of the 2 separate Stroop tests was done, for pre-evaluation. Then the subject completed the aerobic exercise session of moderate intensity on a stationary bike. Participants performed cycling until their heart rate (HR) reached 50% of their maximum HR (220-Age) and then continued cycling for 3 minutes more (without letting the HR fall below the standard target heart rate).

In post exercise session, subjects took rest for 5 minutes and again HR was recorded & 2nd Stroop test was performed, for post evaluation to find out whether there was any change in Stroop reaction time after post-intervention. Then these 2 readings (pre/post) were compared on the basis of Stroop completion time (SCT), also referred to as motor cognitive response time (MCRT); with the inclusion of errors.

2.1. Procedure

For performing Stroop test required a Stroop mini card listed with 25 words (5 columns,5 rows). The protocol was explained to the subjects, that they had to indicate the ink color of the word (i.e. for blue written in red color, the correct answer is red) and were instructed to proceed for all 25 words as quickly as possible. After the demonstration, the subject was asked to start, with a stopwatch recording the time up to the end. Since Stroop test was performed pre-& post aerobics, SCT was also noted both the times with errors and then compared.

Emily Balton et al. suggested that a number of errors & completion time should be considered independently in future test [19]. Hence, in that study errors are included separately. The Stroop test (ST) to assess cognition and measures executive functions by determining reaction time to color & letters involving prefrontal cortex (PFC) activation.

2.2. Ethical Approval

Before beginning the study approval from the ethical committee of Teerthanker Mahaveer Medical College and Research Centre (TMM CRC), Moradabad was taken.

3. Data Analysis

Data were analyzed and tabulated with SPSS version 22nd (Statistical Package for Social Sciences) for Windows and Microsoft Office Excel-2007. Mean, Standard Deviation (SD), P value and significance were calculated to express the results. Paired "t" test has been used for Intra Group Comparison of SCT (figure 1) and errors (figure 2). Descriptive statistics were calculated for pre-measurement and post-measurement. The significant (Probability-P) has been considered as <.001(Table. 1) in comparison of pre and post exercise mean values of SCT and pre and post error measurement also compared where the significant (Probability-P) has been considered as .005 (Table 2).

4. Results

Total 54 subjects have participated in the study as per inclusion criteria where 16 males and 38 females in the group. On an average mean value of 1st, Stroop completion time was 32.26 seconds, whereas after treatment protocol, on an average mean value of 2nd Stroop completion time was 25.05 seconds (Table. 1).

Average mean values of errors are measured on the basis of before and after the error of times against the completion of the Stroop test (Table. 2).

5. Discussion

The aim of the present study was to investigate the effects of aerobic exercise on cognition among young Indian adults.

Studies with controversial results of AE exists; i.e., some suggesting increase in cognitive function [20, 21, 23], while others suggest that it doesn't alter or may decrease the cognitive functions [23, 24]. Our present study findings support the fact that AE has a positive impact on cognitive functioning.

Hansen Al et al. & Hascelik Z et al., conducted an 8-week training programme of small size and results revealed improved reaction time (of n=20) and executive functions. In our study involved a 5-week session programme of static cycling and reveals improved Stroop completion time, post-exercise as compared to at rest [25, 26].

Also, we have fulfilled the limitation of prior research by Emily Blanton et al., whose future recommendation was to investigate a large sample size, since they examined only 16 young adults. Hence, we investigated 144 individuals stepping down to 54(with inclusion criteria). Also, they incurred a penalty of 1 second per every mistake and recommended that a number of errors should be considered independently in future studies. So, we recorded SCT and errors separately [19].

Recent researchers suggest that the exercise period is directly proportional to the effect i.e. acute exercise seemed to have little effect on memory and cognition; unaltered executive functions and delayed improvement in long-term memory [26, 8] while established slight effect on reaction time in young people with long-term physical exercise [27], whereas present study reveals significant decrease in SCT (Figure 1) & number of errors (Figure 2).

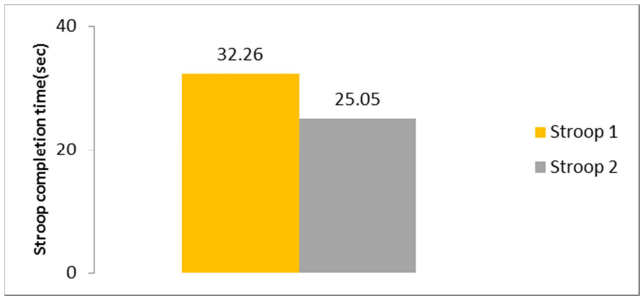

Figure 1. *Comparison of pre exercise(Strrop 1) and post exercise(Stroop 2) mean values.*

Table 1. *Pre (ST 1) and post (ST 2) demographic data of Stroop completion time. P<0.001 shows a statistically significant result. NS- Non-Significant, S-Significant. Above table shows the pre and post intervention level within the group.*

STROOP TEST	Mean	Mean difference	N	t	df	P value	S/NS
ST 1	32.26	7.20	54	11.67	53	<0.001	S*
ST 2	25.05		54				

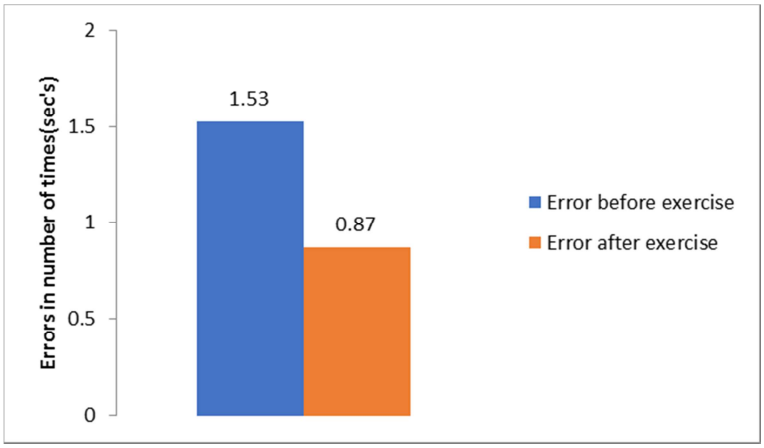

Figure 2. *Comparison of before and after exercise errors mean values.*

Hopkins M. E. stated that neural plasticity is at its peak during adolescence and throughout young adulthood. It is further capitalized by exercises, as it stimulates the brain and hence promotes higher thinking, memory, learning that are important aspects of cognition [28]. Our result revealing the improvement of cognitive function, post aerobic exercise is consistent with prior researches. In accordance with our hypothesis, cognitive function improved post aerobic exercise., Stroop completion time decreased from rest to moderate exercise.

Table 2. *Before and after demographic data of errors against the time of Stroop test.P.005 shows a statistically significant result. NS-Non-Significant, S-Significant. Above table shows the before and after the intervention level within the group.*

Errors	Mean	Mean difference	N	t	df	P value	S/NS
ST 1	1.53	.66667	54	2.912	53	.005	S*
ST 2	.87		54				

Similar results were indicated by various researchers in animal also i.e. cardiovascular exercise has positive influence

on hippocampal angiogenesis [29], neurogenesis [30], and synaptic plasticity [31]. The present study deals with acute exercise session and was still beneficial for cognition. So, as per our sDiamond A. Effects of Physical Exercise on Executive Functions: Going beyond Simply Moving to Move with Thought. Ann Sports Med Res. 2015;2(1):1011. Study short-term aerobic exercise also influences cognition positively.

Cotman CW et al. suggested that in response to aerobic exercise, several potential biochemical mediators are released such as Insulin-like growth factor 1 (IGF1), Brain-derived neurotrophic factor (BDNF), Vascular endothelial growth factor (VEGF) that crosses the blood-brain barrier(BBB); exhibiting a similar or complementary effects in the hippocampus [32]. Also, Asano M et al., Castellano V et al. and Schwarz AJ et al., indicated that circulating levels of these mediators increases in response to exercise [33, 34, 35].

Brown J et al., with various other studies reveals one of the most consistently observed effects of exercise treatment i.e. an increase in cell proliferation and cell survival in the dentate gyrus of the Hippocampus. [36-39] Studies indicate that this effect can occur at any stage of development, including young [40] adulthood and in old age [41] too.

Naylor AS et al., recently proved that voluntary running influenced the system, in restoring the neural stem cell pool, hippocampal neurogenesis and behavioral deficits in [42] Similarly, samples, following the moderate dose of irradiation. the present study reports that static cycling was effective in improving cognitive function hence we can infer that AE, of any type, have a positive influence on the cognition.

Also, Rolland Y et al. indicated that 5-12 weeks intervention of cycling or walking improved mini-mental state examination (MMSE) score from 16.3 at baseline to 19.8, post [43] training.

We used the Stroop test as the determining criteria and found improved mean SCT from 32.262 to 25.058, post-exercise. Spirduso done a systematic examination for assessing the cognition's relation with physical activity, revealed that physically active older adults had faster psychomotor speed, also confined this effect to compared to their counterparts. older adults only, since young adults, haven't established such [44, 45, 40, 27] But, present study of young adulthood improvement. shows improved processing speed and hence we can conclude that the above relation applies to young adults also.

Tomorowski PD et al., stated that the effects of physical activity on cognition is task dependent, among [46] children. Also, Davis CL et al. indicated the evidence of selective facilitation effect of aerobic fitness on executive [47] functions which again correlates with the present study result. Hall & Colleagues proposed that executive functions on special concern were strongly affected by exercise [48]; supported by a meta-analysis of Colcombe & Kramer too. [49].

Studies have considered AE, to be beneficial for cognitive functions, but at the same time indicate that these benefits are dependent on the exercise intensity. Also, Kashihara K et al., have shown an inverted U relationship, as high-intensity AE beyond the optimal the optimal intensity is known to attenuate the enhanced effects.

Intensity is thought to modulate the effect of exercise on cognition. Various studies consider moderate intensity to be the most effective in improving cognition. [50, 51, 52]Controversial studies have shown insignificant differences in inhibitory control between moderate intensity acute aerobic exercise task and a passive task. [53] Also, it has been shown that vigorous intensities and different combinations of intensities can improve inhibitory control tasks.[54, 55] Schmit et al. implied an insignificant decline in inhibitory control after a linear increase in the intensity of an acute bout of exercise. [56] Also, indicated to avoid the point of exhaustion during exercise.

Tsukamoto et al. also showed similar results with 12 healthy male subjects involved in 2 different acute exercise protocols. Inhibitory Control was seen to improve via both intensities, with high interval session emphasizing better results. Protocol – 40-minute continuous exercise at 60% VO_2 max peak and high interval intensity protocol with 4 repetitions of 4 minutes at 90% $VO_{2\,max}$ peak with 3 minutes of active recovery at 60% VO2. max. [55] But we could not include the high-intensity exercise protocol, indeed followed moderate intensity exercise protocol, i.e., continuous cycling for 3 minutes more as he/she reaches the standardized heart rate, without letting the heart rate decline below standardized HR.

On the other hand, Etnier JL et al. and Tomprowski PD et al., stated that frequent or strenuous exercise performed by young adults can deteriorate the cognitive achievement during adolescence. [57, 8]

Zervas et al. indicated that, in addition to fitness, acute bouts of exercise, may have enhanced effects on cognitive performance, regardless of prior exercise regimes.[58]Also, researchers by Tuckman and Hinkle Davis et al. reveals improved executive functioning in children & adolescents, after undergoing an exercise programme for several weeks.[59, 60, 47] Chang et al., suggested the optimum duration of an acute bout of exercise i.e. ‘not less than 20 minutes & no more than 40 minutes ’ such that to produce significant improvements in cognitive performance. [66]

Hawkes, Manselle & Woollacott established AE protocol of 30 minute/session, 3 times/weeks, showing enhanced cognitive functions, in relation to sedentary lifestyle population, through increased switch reaction time, percent local switch costs & P3b switch amplitude. [67] In contrast, our study was based on 3 min static cycling, post reaching 50% of max HR(220-age), but still, it proved to have a positive effect & enhance the cognition.

Acyl et al., investigated 30 schizophrenia patients, mean age between 21-45 years, antipsychotics abusers for about 10 years. They were divided into a control group and experimental group, who were subjected to aerobic exercise for 10 weeks, 3 days a week & 40 minutes per day. Results indicated improved symptoms while suppressing the negative

ones. Also, a significant reduction in hallucination and delusions were reported [68]. Another study conducted by Oertel et al find out a similar result [69] where our present study results also showed that short-term aerobic exercise also influences cognition levels.

Anderson Hanley et al. examined the effect of stationary cycling with virtual reality tours ("cyber cycling") on cognition and revealed improved executive functions and enhanced brain-derived neurotrophic factor (BDNF), compared to traditional exercises. [61]

Finkel D et al., along established the importance of genetic effects on intelligence [62-64] as well as on physical activity [65, 66]. Various researches have indicated that physical activity either has an enhanced effect or isn't associated with academic performance. The results may alter according to the techniques used for assessing behavior &/or criteria for scholastic aptitude chosen (e.g. achievement testing, grade point average & academic records) [70, 71, 23]. Also, the relationship between cognition and physical activity gets influenced by programme duration, age, gender [72] and type [49].

Hence, studies conclude the Myriad beneficial effects of moderate intensity aerobic exercise over various aspects of health (also, at the mean time considering the protocol needed for the effect), including enhanced cardiopulmonary capacity fitness, reduced body fat & improved cognitive functions too [5, 73-77]. Due to this fact, moderate-intensity aerobic exercise (MIAE) is being recommended & preferred to the existing population.

6. Conclusions

As per the present study findings, aerobic exercise has a positive impact on cognition and it is concluded that aerobic exercise is beneficial and is responsible for cognitive function enhancement, in all age groups. Also, in comparison, the number of times error has been reduced before and after the performance of SCT. This effect is highly dependent on the FIT principle, i.e. the frequency, intensity and duration/time of aerobic exercise performed.

For as future recommendations, further studies should emphasize on different types of exercises on different intensity, to know the effectiveness variations of different exercises.

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