ECRONICON OPEN ACCESS

EC PSYCHOLOGY AND PSYCHIATRY

Research Article

An Experimental Study on the Effects of Acute Bouts of Exercise on Neurocognitive Performance in Athletes and Non-Athletes

Keni Gowsi[1]*, Vivek Kumar Sharma[2], Gopal Krushna Pal[3], Praveen Aaramban[4] and Karthick Subramanian[5]

[1]Senior Resident, Department of Physiology, Jawaharlal Institute of Post Graduate Medical Education and Research, Puducherry, India

[2]Dean, Professor and Head, Department of Physiology, Government Institute of Medical Sciences, KASNA, Greater Noida, Uttar Pradesh, India

[3]Dean, Senior Professor, Department of Physiology, Jawaharlal Institute of Post Graduate Medical Education and Research, Karaikal, India

[4]Assistant Professor, Department of Physical Education and Sports, School of Humanities, Pondicherry University, Puducherry, India

[5]Assistant Professor, Department of Psychiatry, Mahatma Gandhi Medical College and Research Institute, Puducherry, India

***Corresponding Author:** Keni Gowsi, Senior Resident, Department of Physiology, Jawaharlal Institute of Post Graduate Medical Education and Research, Puducherry, India.

Received: July 26, 2018; **Published:** August 21, 2018

Abstract

Background: Physical inactivity and obesity are highly prevalent in the contemporary world. This has its impact on various aspects of health domain including cognition. Global reviews reveal that even an acute bout of physical exercise can improve the cognitive functioning of an individual. This improvement in the cognitive domain of a person can be assessed by a neurocognitive test battery which includes a series of paper and pencil tests.

Materials and Methods: The study is a single-blind randomized controlled study. Eighty healthy male volunteers participated in the study which included 40 athletes and 40 age and BMI-matched non-athletes. All the participants underwent Letter Cancellation Test (LCT), Trail Making Test (TMT-A and TMT-B), Digit Span Test (FDS and RDS) at baseline and after an acute bout of treadmill exercise. These tests assesses the executive functions of the subjects particularly attention, concentration, processing speed and short term memory.

Results: All the cognitive tests showed improvement following the intervention in both the study and the control group. There was a significant post-exercise reduction in the time taken to complete the Letter Cancellation Test and Trail Making Test A and B ($p < 0.001$). And also the number of digit sequences recalled improved following the exercise ($p < 0.001$) in both the groups. Sub-analyses revealed no group-based differences.

Conclusion: Acute bouts of physical exercise can enhance the cognitive functions irrespective of one being the athlete or non-athlete. Even milder forms of exercise can bring about significant improvement in cognitive functioning.

Keywords: *Acute exercise; Athletes; Non-Athletes; Neurocognitive Tests*

Abbreviations

BDNF: Brain Derived Neurotrophic Factor; BMI: Body Mass Index; FDS: Forward Digit Span; HR_{max}: Maximum Heart Rate; LCT: Letter Cancellation Test; NCT: Neuro Cognitive Test; RDS: Reverse Digit Span; TMT-A: Trail Making Test-A; TMT-B: Trail Making Test-B; VEGF-1: Vascular Endothelial Growth Factor-1

Introduction

There is a global increase in the trend of physical inactivity and obesity in the general population. Sedentary behaviour and physical inactivity are recognised as significant determinants of cognitive decline [1,2]. Accruing evidence reveal that interventions improving the cardiorespiratory fitness may protect the people from cognitive decline [2,3]. Enduring physical activity is found to promote hippocampal neurogenesis and impede cognitive decline over time [4]. Studies suggest that there is a selective increase in gray and white matter volume in the prefrontal, temporal and parietal cortices in those adults who pursue physical activity [5,6], suggesting that these regions are particularly susceptible to exercise interventions.

Literature reveals that chronic physical exercise preserves neurocognitive functions and delay aging process more often in athletes than sedentary counterparts [7,8]. The studies employed Neurocognitive tests (NCT) battery, which is routinely administered to wide age groups, irrespective of healthy or diseased status. The NCT battery assesses various cognitive domains including attention span, concentration and various executive functions [9]. Contemporary evidence supports that even acute bouts of physical exercise provide beneficial effects on muscle power, cardiometabolic status, and neurocognition [10-12].

Though many studies demonstrate the effect of chronic exercise on cognition, there is a paucity of literature regarding the effect of single acute bout of exercise on neurocognitive status. Compared to the wealth of global literature, studies comparing the effects of acute physical exercise between athletes and non-athletes are rare in developing countries like India.

Objective of the Study

The objective of the present study was to investigate the effects of single acute bout of exercise on neurocognitive performance between athletes and non-athletes. This is one of the first studies in India, which compares the effect of single acute bout of exercise on neurocognitive performance between athletes and non-athletes.

Methods

Setting

The study was conducted in the Department of Physiology in a tertiary care hospital-cum-research institute in Pondicherry. The study procedure was carried out in a controlled setting in the Cardiovascular Research Lab facility. The lab is equipped with a treadmill, and the room temperature was maintained between 25^0C to 27^0C.

Participants

The participants were healthy male volunteers aged 18 - 25 years. The study included 80 subjects with 40 being athletes and the remaining 40 were non-athletes. All of them had participated in regional/national/international athletic event and had undergone supervised physical conditioning training during the past year. Age and BMI-matched male non-athletes who had not participated in the athletic/sports events and not had any supervised physical conditioning training in the past year were concurrently recruited as the control group. Subjects were excluded if they had a history of psychiatric illness, chronic inflammatory disorder, diabetes or regular cognitive training using yoga and biofeedback techniques. Also, the subjects who had severe comorbid illnesses such as cardiac or respiratory disorders, which prevented them from doing sub maximal exercise, were excluded from the study.

Study design

The study is a randomized controlled trial. The randomization was carried out using block randomization method using computer-generated number sequences. The sample size was calculated to be 80, with 40 in each group.

Procedure

The Institute Scientific Advisory Committee and the Institute Ethics Committee approved the study protocol. Ethical clearance from the Pondicherry University was obtained for the recruitment of athletes. Non-athletes were recruited from the colleges in and around Pondicherry. Informed consent was obtained from all the participants. The participants reported to the lab at 9 am on the day of the procedure. Baseline recording of Letter Cancellation Test (LCT), Trail Making Test-A (TMT-A), Trail Making Test-B (TMT-B), Forward Digit Span Test (FDS), Reverse Digit Span Test (RDS) were done. The tests were used to assess various aspects of cognitive domains like attention, concentration and executive function. Following that, both athletes and non-athletes underwent an acute bout of submaximal exercise on a computerized treadmill. The exercise was based on Bruce Ramp protocol, which remains the widely used graded exercise treadmill protocol to assess the cardiorespiratory fitness of an individual. It consists of multiple stages with fixed grade and speed in every stage. The heart rate of the subjects was maintained around 80% to 90% of maximum heart rate (HR_{max}). Maximum Heart Rate was calculated from the formula 220-Age. Once the target heart rate was reached, exercise was stopped. After heart rate recovery, subjects underwent LCT, TMT-A, TMT-B, FDS and RDS again.

Parameters

We chose those tests that are commonly used in the literature so that the results are easily comparable with other studies. One practice session was given to all the participants before the baseline recording and all the tests were administered at baseline and after the intervention. The following are the tests which constitute the Neuro Cognitive Test (NCT) battery.

Letter cancellation test (LCT): It is a paper and pencil test which assesses visual scanning, response speed and sustained attention of the participants [9]. The subjects were instructed to cancel out the letter 'H' which is randomly placed among the other alphabets. There were six rows; of which each row consisted of 52 letters of the English alphabet. Scoring was done based on the time taken to finish the task (in seconds) [9,13]. Also, the numbers of errors such as, omissions and commissions done by the subject were counted.

Trail Making Test

Trail Making Test (TMT) is also a paper and pencil test which includes TMT A and TMT B [9].

- **TMT A:** TMT A assesses visuomotor speed and attention of the subject. In this, participants were instructed to connect 25 consecutively numbered circles in straight lines.
- **TMT B:** In TMT-B, the subject requires shifting strategy in addition to visuomotor speed and attention; hence it is a sensitive measure of executive function. Here, the participants were instructed to connect the numbers with letters such as 1 to A, 2 to B up to 12 to L. Scoring is based on the time taken by the subject to complete the task (in seconds) [14].

Forward and Reverse Digit Span Test

Forward Digit Span (FDS): It assesses the immediate verbal memory span. In this test, the examiner read out the digits sequences in increasing length and the subjects must repeat back the sequences in the same order read out by the examiner. Scoring is based on the maximum number of digits that the subject can recall.

Reverse Digit Span (RDS): This test assesses the ability to manipulate information in the verbal working memory in addition to auditory attention and short-term retentive capacity. So it is a sensitive test for the measure of executive function. The examiner read out the digit sequences of increasing length and the subject has to repeat the digit sequences in reverse order. Scoring is done by the maximum number of digits the subject is able to reverse.

Statistical analyses

Continuous variables (such as age, Height, weight, BMI) were presented as mean and SD. The difference between means for normally distributed values was compared using independent t-test (between groups). The difference between means for values which were not normally distributed was assessed using Mann-Whitney U test. Statistical significance was set at a p-value of < 0.05 (two-tailed). SPSS version 19 was used to analyse the data [15].

Results

A total of 80 participants were recruited and consisted of athletes and non-athletes (40 in each group). Table 1 summarizes the comparison of anthropometric parameters between the two groups. No significant differences existed in the mean age, height, weight and BMI between the two groups.

Parameter	Athletes (n = 40) Mean (SD)	Non-athletes (n = 40) Mean (SD)	Comparison, p value
Age (in years)	23.45 (1.67)	23.60 (1.33)	t = -0.445, p = 0.658
Height (in cm)	169.05 (4.78)	170.70 (6.25)	t = -1.327, p = 0.188
Weight (in Kg)	67.03 (6.05)	70.23 (14.20)	t = -1.311, p = 0.194
BMI (Kg/m^2)	23.45 (2.04)	24.13 (4.11)	t = -0.931, p = 0.355

Table 1: *Baseline characteristics of the study sample (N = 80).*
**p < 0.05, statistically significant.*

When the neurocognitive tests were compared between athletes and non-athletes at baseline, there was no significant difference in the Letter Cancellation Test, Trail Making Test A and B, forward and reverse digit span test (Table 2).

Parameter	Athletes (n = 40) Mean (SD)	Non-athletes (n = 40) Mean (SD)	Comparison, p value
LCT (in secs)	99.23 (15.41)	112.17 (16.73)	t = 0.627, p = 0.723
TMT-A (in secs)	33.00 (10.40)	31.95 (9.48)	t = 0.472, p = 0.638
TMT-B (in secs)	51.10 (8.67)	51.33 (19.02)	t = -0.068, p = 0.946
FDS (digits)	7.10 (0.81)	7.08 (0.79)	t = 0.139, p = 0.890
RDS (digits)	5.78 (1.07)	5.90 (1.10)	t = -0.513, p = 0.609

Table 2: *Baseline comparison of cognitive parameters between athletes and non-athletes.*

Following the intervention (acute bout of exercise), all the 80 participants showed significant improvement in the cognitive parameters. We found that the time taken to complete the LCT, TMT-A and B have reduced significantly after the exercise in both the groups. The ability to remember and recall the numbers in forward and reverse digit span test has improved after the intervention in both athletes and non-athletes. The results are depicted in figure 1.

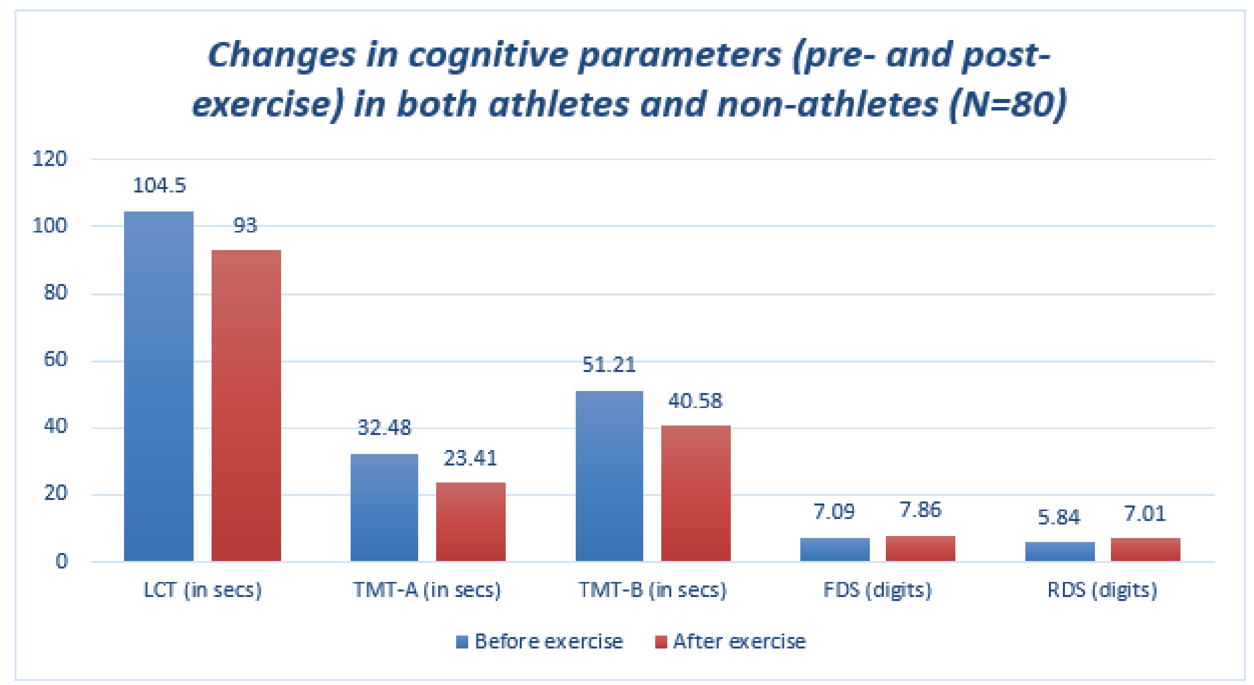

Figure 1: *Changes in cognitive parameters (pre- and post-exercise) in both athletes and non-athletes (N = 80).*

We wanted to compare which group has performed better after the intervention. We found that athletes have performed better than non-athletes in forward digit span test after the intervention. However, for the rest of the parameters, the performance was similar in the study group and control group (Table 3).

Parameter	Athletes (n = 40) Mean (SD)	Non-athletes (n = 40) Mean (SD)	Comparison, p value
LCT (in secs)	87.63 (19.63)	99.17 (18.57)	t = 0.896, p = 0.406
TMT-A (in secs)	23.98 (9.87)	22.85 (7.17)	t = 0.583, p = 0.561
TMT-B (in secs)	42.78 (10.06)	38.38 (13.72)	t = 1.636, p = 0.106
FDS (digits)	7.88 (0.40)	7.85 (0.36)	t = 0.291, p = 0.025*
RDS (digits)	6.80 (1.09)	7.23 (0.80)	t = -1.987, p = 0.060

Table 3: *Group differences in cognitive parameters (post-exercise) between athletes and non-athletes.*
**p < 0.05, statistically significant*

Discussion

In the present study, two groups (athletes and non-athletes) were matched for age, height, weight and BMI and there was no significant difference in the anthropometric parameters between the two groups.

The neuro-cognitive profile of the study and the control groups were compared at the baseline and after the intervention. At the baseline, there were no significant difference between athletes and non-athletes. This made the two groups comparable for the study.

Following an acute bout of treadmill exercise, all the participants (both athletes and non-athletes) showed a significant improvement in the neuro-cognitive tests such as LCT, TMT A, TMT B, FDS and RDS. The improvement in the cognitive profile could be explained by the fact that acute exercise facilitates cognitive processing via a general arousal effect [16]. Also, physical fitness enhances cognition by increasing attention allocation to stimulus encoding, and concentration during task preparation [3,16]. It has been revealed in non-human animal studies that aerobic exercise increases the neuronal proliferation and survival of brain derived neurotrophic factor (BDNF), insulin like growth factor, vascular endothelial growth factor-1 (VEGF-1) and serotonin [17].

Other studies suggest that, during exercise there is an increase in the cerebral blood flow due to increase in the brain metabolism, which in turn improves cognitive function by altering the regulation of oxygen, carbon dioxide, glucose and lactate to the neural tissue. This may be the underlying reason for the exercise-induced changes in the brain [18].

Weinstein., *et al*. recently revealed that adults with higher cardiovascular fitness exhibit significant volumetric and functional improvements, particularly in the prefrontal areas and anterior cingulate [19]. These brain structures underpin inhibition and executive processes. It has also been suggested that exercise upregulates angiogenesis and neurogenesis [20,21]. Finally, greater neural connectivity has been observed in physically active participants in comparison to physically passive or inactive participants [22].

Conclusion

We conclude that exercise is beneficial for cognitive performance even for an acute bout of physical activity. The small sample size, studying only male subjects, and selection of age-restricted population are some of the limitations which hinder the generalizability of our observations. Future studies should overcome these shortcomings and assess the neurobiological underpinnings of effects of acute exercise on general population.

Acknowledgments

The authors thank the study subjects for their participation in the study and technical staff for the technical support they have provided.

Sources of Funding

Intramural funding from JIPMER, Pondicherry (Grant number: JIP/Res/Intra-Corr/08/2015 dated 8thDecember 2015 and JIP/Res/Intra-MD-MS/sec/04/2014 dated 31st December 2015).

Conflict of Interest

None.

Bibliography

1. Subramanian SK., *et al*. "Effect of Structured and Unstructured Physical Activity Training on Cognitive Functions in Adolescents - A Randomized Control Trial". *Journal of Clinical and Diagnostic Research* 9.11 (2015): CC04-CC09.
2. Katz P., *et al*. "Physical activity, obesity, and cognitive impairment among women with systemic lupus erythematosus". *Arthritis Care and Research* 64.4 (2012): 502-510.
3. Hillman CH., *et al*. "The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children". *Neuroscience* 159.3 (2009): 1044-1054.
4. Yau S., *et al*. "Physical exercise-induced adult neurogenesis: a good strategy to prevent cognitive decline in neurodegenerative diseases?" *BioMed Research International* (2014): 403120.
5. Colcombe SJ., *et al*. "Aerobic fitness reduces brain tissue loss in aging humans". *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences* 58.2 (2003): 176-180.
6. Colcombe SJ., *et al*. "Cardiovascular fitness, cortical plasticity, and aging". *Proceedings of the National Academy of Sciences of the United States of America* 101.9 (2004): 3316-3321.
7. Zhao E., *et al*. "Chronic exercise preserves brain function in masters athletes when compared to sedentary counterparts". *Physician and Sportsmedicine* 44.1 (2016): 8-13.
8. Tseng BY., *et al*. "Masters athletes exhibit larger regional brain volume and better cognitive performance than sedentary older adults". *Journal of Magnetic Resonance Imaging* 38.5 (2013): 1169-1176.
9. Sharma VK., *et al*. "Study the effect of age and gender related differences on common paper and pencil neurocognitive tests in adolescents". *Journal of Clinical and Diagnostic Research* 8.11 (2014): BC05-BC10.
10. Rivera-Brown AM and Frontera WR. "Principles of exercise physiology: responses to acute exercise and long-term adaptations to training". *PM&R* 4.11 (2012): 797-804.
11. Yi X., *et al*. "Effects of acute exercise and chronic exercise on the liver leptin-AMPK-ACC signaling pathway in rats with type 2 diabetes". *Journal of Diabetes Research* (2013): 946432.
12. Drollette ES., *et al*. "Acute exercise facilitates brain function and cognition in children who need it most: an ERP study of individual differences in inhibitory control capacity". *Developmental Cognitive Neuroscience* 7 (2014): 53-64.

13. Pradhan B and Nagendra HR. "Normative data for the letter-cancellation task in school children". *International Journal of Yoga* 1.2 (2008): 72-75.

14. Reitan RM. "Trail Making Test: Manual for administration and scoring". Reitan Neuropsychology Laboratory (1992).

15. SPSS I. SPSS for Windows (version 19) SPSS. Inc Chic Ill (2010).

16. Kumar N., *et al*. "Effect of acute moderate exercise on cognitive P300 in persons having sedentary lifestyles". *International Journal of Applied and Basic Medical Research* 2.1 (2012): 67-69.

17. Brezun JM and Daszuta A. "Serotonin may stimulate granule cell proliferation in the adult hippocampus, as observed in rats grafted with foetal raphe neurons". *European Journal of Neuroscience* 12.1 (2000): 391-396.

18. Delp MD., *et al*. "Exercise increases blood flow to locomotor, vestibular, cardiorespiratory and visual regions of the brain in miniature swine". *Journal of Physiology* 533.3 (2001): 849-859.

19. Weinstein AM., *et al*. "The association between aerobic fitness and executive function is mediated by prefrontal cortex volume". *Brain, Behavior, and Immunity* 26.5 (2012): 811-819.

20. Kramer AF and Erickson KI. "Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function". *Trends in Cognitive Sciences* 11.8 (2007): 342-348.

21. Zoeller RF. "Exercise and Cognitive Function: Can Working Out Train the Brain, Too?" *American Journal of Lifestyle Medicine* 4.5 (2010): 397-409.

22. Pérez L., *et al*. "The effects of chronic exercise on attentional networks". *PloS One* 9.7 (2014): e101478.

Volume 7 Issue 9 September 2018