

# Effect of acute aerobic exercise on short-term memory, long-term memory, and working memory in medical students of a tertiary care center in India: Possible role of endocannabinoids



Madhu Chaudhary<sup>1</sup>, Salman Masood<sup>2</sup>, Mojahid Anwar<sup>3</sup>, Shahnawaz Alam<sup>4</sup>, Najmul Aqib Khan<sup>5</sup>, Fareha Husain Khan<sup>6</sup>, Qazi Rais Ahmad<sup>7</sup>

<sup>1,4</sup>Assistant Professor, <sup>7</sup>Professor and Head, Department of Physiology, Rama University, Kanpur, <sup>2</sup>Assistant Professor, Department of Physiology, <sup>3</sup>Assistant Professor, Department of Forensic Medicine, Venkateshwara Institute of Medical Sciences, Gajraula, Uttar Pradesh, <sup>5</sup>Assistant Professor, Department of Community Medicine, Government Medical College, Haldwani, Uttarakhand, <sup>6</sup>Senior Resident, Department of Physiology, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India

Submission: 06-01-2022

Revision: 26-04-2022

Publication: 01-06-2022

## ABSTRACT

**Background:** Recent studies have suggested that memory might benefit from physical exercise. Some studies also show that exercise has adverse effects on short-term memory. The number of studies on the effects of a single bout of exercise on memory is rather limited, and their results are inconsistent. In this study, we want to see the effect of a single bout of aerobic exercise on memory (short term and long term) when the learning session is before the exercise. We also want to see the effect of aerobic exercise on working memory when the learning session is after the exercise. **Aims and Objectives:** The aim is to find the effect of aerobic exercise on working, short-term and long-term memory. **Materials and Methods:** Sixty healthy medical students were divided into two groups of 30 each. Both groups were asked to listen to 20 Arabic words (proper nouns) before the experiment. Students having any knowledge of Arabic were excluded from the study. Then, one group performed high-intensity exercise on a Bicycle Ergometer for 30 min and the other group silently relaxed on a chair. The subjects were asked to repeat the words heard after 20 min of exercise and 24 h of exercise. Data were recorded manually and analyzed statistically. In another experiment, the words were listened after the exercise was over, and the subjects were asked to recall after 20 min of exercise. Unpaired t-test was applied to compare the data between the two groups, and P-value and t-value were calculated. **Results:** When the words were recalled 20 min after exercise, the mean number of recalled words was more in the relaxing group (RG) than in the exercise group, but the result was reverse when recall was made 24 h after the exercise, i.e., more recall by exercise group. When the learning session was after the exercise and subjects were asked to recall words 20 min after the exercise, we found more recall by RG than the exercise group. **Conclusion:** We conclude that aerobic exercise has an adverse effect on short-term memory and working memory but has a beneficial effect on long-term memory.

**Key words:** Aerobic exercise; Endocannabinoids; Memory; Short term

## INTRODUCTION

Many studies have been performed to see the effect of exercise on short-term memory and long-term memory.

The effects of exercise on memory varied according to the timing of exercise with respect to learning and the intensity of exercise. Recent studies have shown that memory might benefit from physical exercise. Some studies also show that

### Access this article online

**Website:**

<http://nepjol.info/index.php/AJMS>

**DOI:** 10.3126/ajms.v13i6.42052

**E-ISSN:** 2091-0576

**P-ISSN:** 2467-9100

Copyright (c) 2022 Asian Journal of Medical Sciences



This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

### Address for Correspondence:

Dr. Shahnawaz Alam, Assistant Professor, Department of Physiology, Rama University, Kanpur - 208 001, Uttar Pradesh, India.

**Mobile:** +91-9761333443. **E-mail:** salaam0490@gmail.com

exercise has adverse effects on short-term memory. The number of studies on the effects of a single bout of exercise on memory is limited, and their results are inconsistent so far with some studies showing beneficial effects and some showing adverse effects. In a study performed by Labban and Etneir,<sup>1</sup> participants performed exercise for 30 min and were asked to recall their memories immediately after the exercise. They did not find a significant memory benefit in participants exercising after a learning session compared to a resting condition, whereas memory improved in participants who had exercised before learning. In most studies reporting beneficial effects of acute physical exercise on long-term memory, participants exercised before or during learning.<sup>2-5</sup> Based on the results of these studies, it is not possible to distinguish whether exercising facilitates memory encoding, consolidation, or both processes.

In this study, we want to see the effect of a single bout of aerobic exercise on memory (short term and long term) when the learning session is before the exercise. We also want to see the effect of aerobic exercise on working memory when the learning session is after the exercise. The previous studies on this topic contain either the former or latter type of format. We will apply both type of formats in our study and reach a conclusion.

### Aims and objectives

To find out the effect of acute aerobic exercise on short term, long term and working memory of medical students of an Indian Medical College.

## MATERIALS AND METHODS

Sixty healthy university students were selected as subjects from young medical students of Rama University. Subjects were divided into two groups of 30 students each; one who performed high-intensity exercise (HIE) was considered the case group and the other was the relaxing group (RG) which was considered the control group.

### Eligibility criteria

Cases were the Medical Students of Rama Medical College, Kanpur, with age between 18 and 25 years. Cases look apparently healthy. Body weight was between 45 and 80 kg. Cases include both male and female students. Controls were the Medical Students of Rama Medical College, Kanpur, with age between 18 and 25 years. Controls look apparently healthy. Body weight was between 45 and 80 kg. Controls include both male and female students.

### Exclusion criteria

1. Subjects having any knowledge of the Arabic language,
2. Age more than 25 years,
3. Weight >80 kg,

4. Patients with diabetes mellitus,
5. Patients suffering from any psychiatric or neurological illness,
6. Smokers, and
7. Patients with cardiovascular and respiratory diseases were excluded from this study.

### Pre-experimental screening

During the screening, all the subjects were asked to listen to 40 pseudowords, each followed by a proper English word. After 20 min, subjects were asked to write down English words associated with pseudowords. Subjects remembering more than 20 words were excluded from the study. Four subjects were rejected due to this criterion. Two were excluded due to health problems and one was excluded because of smoking.

We also assessed the subjects' cardiovascular fitness, and we determined an individually adjusted intensity for the exercise intervention. For this, they performed an incremental exercise test on a cycle ergometer. Cycling started at 30-Watts and was increased in 30-Watt steps. Each step took 3 min. The cadence had to be at least 60 rotations/min. Heart rate was measured continuously with a health band. At the end of each step, participants had to estimate their perceived exertion using the Borg scale. This scale has previously been shown to be a valid tool for measuring perceived exertion.<sup>6</sup> The exercise test was terminated when participants reported subjective exhaustion.  $VO_2$  max was estimated as described in Storer et al.<sup>7</sup>

Informed consent was taken from all the students according to the Helsinki Declaration (2013). Ethical clearance was taken from the Institutional Ethical Committee of Rama University, Kanpur. Students were asked to perform exercise for 30 min on a Bicycle Ergometer in the Department of Physiology. Intensity was set for heavy exercise group as 80% of their maximum heart rate.

### Experiment no. 1

All the subjects were asked to listen to 20 Arabic words just before the exercise. Half of the subjects performed HIE for 30 min on a Bicycle Ergometer and the remaining half sat silently on a relaxing chair. Memory was tested 20 min after the completion of the exercise to assess for short-term memory. Subjects were asked to repeat the words heard before the exercise. The number of words repeated was recorded manually, and the data were analyzed statistically in the two groups using unpaired t-test. Subjects were provided water to drink after the exercise to prevent dehydration.

### Experiment no. 2

The same subjects used in the above experiment were assessed after 24 h of the completion of the exercise. Both the groups were asked to repeat the words heard before

the exercise. The number of words repeated by each group was recorded manually, and data were analyzed statistically using unpaired t-test. This experiment was done to assess long-term memory of the subjects.

### Experiment no. 3

In another set of experiment, students were asked to listen to 20 Arabic words 5 min after the exercise and have to recall the words after 20 min of exercise. The exercise groups performed HIE for 30 min on a Bicycle Ergometer and the RG sat silently on a relaxing chair. Both the groups were asked to recall the words 20 min after the completion of the exercise. The data were recorded manually and analyzed statistically using unpaired t-test. This experiment was done to assess working memory.  $P < 0.05$  will be considered significant for all the experiments.

## RESULTS

General characteristics cases and controls are listed in Table 1.

### Experiment no. 1

In the first experiment when the exercise was performed after learning and words were recalled after 20 min of completion of exercise, the mean number of recalled words was more in the RG as compared to the exercise group (HIE) (Table 2).

### Experiment no. 2

When the same groups were asked to recall the words after 24 h, the results were different. In this case, the exercising group has more mean number of recalled words than RG (Table 2).

### Experiment no. 3

In this case, subjects were allowed to listen to words 5 min after exercise and were asked to recall 20 min after exercise.

The RG was allowed to listen to the words at the same time and was asked to recall after 20 min of rest. This time RG recorded more mean number of recalled words as compared to the exercising group (Table 2).

### Statistical analysis

Data were analyzed by applying unpaired t-test and using Graphpad Prism 9.0 software.

## DISCUSSION

The main purpose of the present study was to assess the effect of a single bout of aerobic exercise on short-term memory, long-term memory and working memory. The results of Experiment no.1 showed the effect of exercise on short-term memory. When the words were recalled after 20 min of stopping the exercise, the subjects of HIE group recalled lesser number of words than RG. This showed that HIE has an adverse effect on short-term memory. This effect may be explained by the effect of endogenous cannabinoids on working memory, as exogenous cannabinoids are reported to impair working memory and spatial learning. They do so by interfering with hippocampal-dependent neuronal processes responsible for memory.<sup>8</sup>

In Experiment no.2 when the words were recalled after 24 h of exercise then, HIE group recalled more mean number of words than RG. That is HIE group retained more of initially learned words. Using this method, we were able to study the effects of physical exercise during the early phases of memory consolidation, provided that learning conditions were constant in both groups. Our results suggest that physical exercise enhances long-term memory by facilitating the early stages of memory consolidation. Our results are consistent with reports of the previous studies showing that exercising after learning did not improve immediate

**Table 1: General characteristics of cases and controls**

Characteristics	High-Intensity Exercise Group (n=27)	Relaxing Group (n=26)
Mean age (years)	20.53	20.70
Mean weight (Kg)	57.80	58.46
Mean of systolic BP before the experiment (mmHg)	105	106
Cardiovascular fitness (mean VO <sub>2</sub> max in mL/min)	2600.54	2630.89
Mean number of correctly recalled words memory pretest	10.54	9.89

BP: Blood pressure

**Table 2: Mean number of recalled words by both groups**

Experiment	(n=27) HIE* Group	(n=26) Relaxing Group	t-value	P-level
1. Mean number of words recalled after 20 min of exercise	11.9	15.366	8.531	0.0001 (S)
2. Mean number of recalled words after 24 h of exercise	14.066	12.6	2.223	0.03 (S)
3. Mean number of recalled words 20 min after exercise (learning after exercise experiment-3)	10.33	14.53	10.04	0.0001(S)

\*HIE: High-intensity exercise, †S: Significant

memory,<sup>1</sup> but improvements were only seen after a delay of at least 24 h.<sup>9</sup> Roig et al., argued that memory tests administered too early after encoding when memory traces are still undergoing consolidation, are not able to detect exercise-induced memory gains and might even interrupt the consolidation process.<sup>10</sup> As the timing of memory tests relative to the exercise interventions differ between studies, and this variability might explain inconsistent results in the previous studies. The reason for poor memory of exercising group might be exercise-induced arousal and exhaustion. Null effects or detrimental effects of physical exercise on cognitive performance were mostly seen in studies with HIE protocols, leading to dehydration and exhaustion.<sup>10-12</sup> In our study, however, subjects had the opportunity to drink water during and after the exercise session. While the exercising group was exercising on a stationary bicycle, the RG sat stationary in a relaxing chair. Thus, it might be possible that RG silently rehearsed the words learned which improved their short-term memory. However, the RG showed more forgetting after 24 h compared to the exercise group, suggesting that short-term memory and long-term consolidation were differentially affected by the experimental interventions. Further studies are required which introduce a task that interferes with memory rehearsal to rule out these effects on memory.

Results of Experiment no. 3 suggest that high-intensity aerobic exercise has an adverse effect on working memory. Our results are in line with a few studies. A recent study investigating higher cognitive functioning during exercise has shown that prolonged running and cycling produce deficiencies in prefrontal-dependent cognitive processes such as sustained attention and working memory.<sup>13</sup> One possible explanation of these findings may be that the increased endocannabinoid release during the exercise results in decreased metabolism in the prefrontal regions and altered cognitive function. Therefore, it can be said that endocannabinoids mediate the effects of acute exercise on working memory and short-term memory in the prefrontal region and hippocampus. Our results proved that exercise has an adverse effect on short-term and working memory, but it has a beneficial effect on long-term memory. Our study is in consistence with the previous studies. Hotting et al., found in their study that exercise after learning did not enhance short-term memory. Instead, short-term memory was found to be enhanced in participants of the RG than in participants of a HIE group and a low-intensity exercise group.<sup>14</sup>

#### Limitations of the study

In our study, Exercise group performed only high intensity exercise. So these results may not be true for persons performing low intensity exercise and moderate intensity exercise.

## CONCLUSION

We conclude that exercise has an adverse effect on short-term and working memory, but it has a beneficial effect on long-term memory.

## ACKNOWLEDGMENT

Heartiest Thanks to Dr. Shubham and Dr. Pavan for their support during the study.

## REFERENCES

1. Labban JD and Etnier JL. Effects of acute exercise on long term memory. *Res Q Exerc Sport*. 2011;82(4):712-721. <https://doi.org/10.1080/02701367.2011.10599808>
2. Schmidt-Kassow M, Kulka A, Gunter TC, Rothermich K, Kotz SA. Exercising during learning improves vocabulary acquisition: behavioural and ERP evidence. *Neurosci Lett*. 2010;482(1):40-44. <https://doi.org/10.1016/j.neulet.2010.06.089>
3. Schmidt-Kassow M, Deusser M, Thiel C, Otterbein S, Montag C, Reuter M, et al. Physical exercise during encoding improves vocabulary learning in young female adults: A neuroendocrinological study. *PLoS One*. 2013;8(5):e64172. <https://doi.org/10.1371/journal.pone.0064172>
4. Schmidt-Kassow M, Zink N, Mock J, Thiel C, Vogt L, Abel C, et al. Treadmill walking during vocabulary encoding improves verbal long-term memory. *Behav Brain Funct*. 2014;10:24. <https://doi.org/10.1186/1744-9081-10-24>
5. Winter B, Breitenstein C, Mooren FC, Voelker K, Fobker M, Lechtermann A, et al. High impact running improves learning. *Neurobiol Learn Mem*. 2007;87(4):597-609. <https://doi.org/10.1186/1744-9081-10-24>
6. Grant S, Aitchison T, Henderson E, Christie J, Zare S, McMurray J, et al. A comparison of the reproducibility and the sensitivity to change of visual analogue scales, Borg scales, and likert scales in normal subjects during submaximal exercise. *Chest*. 1999;116(5):1208-1217. <https://doi.org/10.1378/chest.116.5.1208>
7. Storer TW, Davis JA, Caiozzo VJ. Accurate prediction of Vo2max in cycle ergometry. *Med Sci Sports Exerc*. 1990;22(5):704-712. <https://doi.org/10.1249/00005768-199010000-00024>
8. Dietrich A and McDaniel WF. Endocannabinoids and exercise. *Br J Sports Med*. 2004;38(5):536-541.
9. Roig M, Skriver K, Lundbye-Jensen J, Kiens B and Nielsen JB. A single bout of exercise improves motor memory. *PLoS One*. 2012;7(9):e44594. <https://doi.org/10.1371/journal.pone.0044594>
10. Cian C, Koulmann N, Barraud PA, Raphael C, Jimenez C and Melin B. Influence of variations in body hydration on cognitive function: Effect of hyperhydration, heat stress, and exercise-induced dehydration. *J Psychophysiol*. 2000;14(1):29-36. <https://doi.org/10.1027//0269-8803.14.1.29>
11. Covassin T, Weiss L, Powell J and Womack C. Effects of a maximal exercise test on neurocognitive function. *Br J Sports Med*. 2007;41(6):370-374. <https://doi.org/10.1136/bjism.2006.032334>

12. Tomporowski PD, Ellis NR and Stephens R. The immediate effects of strenuous exercise on free-recall memory. *Ergonomics*. 1987;30(1):121-129.  
<https://doi.org/10.1080/00140138708969682>
13. Dietrich A and Sparling PB. Endurance exercise selectively impairs prefrontal dependent cognition. *Brain Cogn*. 2004;55(3):516-524.  
<https://doi.org/10.1016/j.bandc.2004.03.002>
14. Hötting K, Schickert N, Kaiser J, Röder B and Schmidt-Kassow M. The effects of acute physical exercise on memory, peripheral BDNF, and cortisol in young adults. *Neural Plasticity*. 2016;2016:6860573.  
<https://doi.org/10.1155/2016/6860573>

**Authors Contribution:**

**MC-** Conceptualization, methodology, and experiments; **SM-** Validation and methodology; **MA-** Formal analysis and validation; **SA-** Conceptualization, data curation, writing original draft, review, and editing preparation; **NAK-** Software application; **FHK-** Formal Analysis; **QRA-** Review and editing preparation.

**Work attributed to:**

The work attributed to the Rama Medical College, Rama University, Kanpur, Uttar Pradesh - 208001, India.

**Orcid ID:**

Dr. Madhu Chaudhary - <https://orcid.org/0000-0001-7138-8864>  
Dr. Salman Masood - <https://orcid.org/0000-0002-4091-7628>  
Dr. Mojahid Anwar - <https://orcid.org/0000-0002-3257-7854>  
Dr. Shahnawaz Alam - <https://orcid.org/0000-0001-7292-1907>  
Dr. Najmul Aqib Khan - <https://orcid.org/0001-6575-5023>  
Dr. Fareha Husain Khan - <https://orcid.org/0000-0002-7589-5318>  
Dr. Qazi Rais Ahmad - <https://orcid.org/0000-0001-5046-1399>

**Source of Support:** Nil, **Conflicts of Interest:** None declared.