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The Acute Effects of Aerobic Exercise on Cognitive Functions in Young Adults

Genç Yetişkinlerde Aerobik Egzersizin Kognitif Fonksiyonlar Üzerine Akut Etkilerinin İncelenmesi

Aziz DENGİZ[1]*, Nermin KART[2], Emre BASKAN[3], Güzin KARA ÇAKICI[3], Özden AKYOL BASKAN[2]

[1]Muş Alparslan University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Muş,Türkiye
[2]Sinerji Healthy Life Centre, Denizli,Türkiye
[3]Pamukkale University, Faculty of Physiotherapy and Rehabilitation, Denizli,Türkiye

*Corresponding author: ptazizdengiz@gmail.com

ABSTRACT

Objective: The acute effects of aerobic exercise on cognitive function in young adults are well-established, yet the acute effects of exercise on cognitive function remain incompletely understood. We aimed to investigate the acute effects of 1-session aerobic exercise on cognitive functions in healthy young adults. The study included 52 healthy young adults (24 males, 28 females) studying at the Faculty of Physiotherapy and Rehabilitation between 2020 and 2022. Material and Method: The exercise routine consisted of a 5-minute warm-up, followed by a 20-minute period of increased intensity, and concluded with a 5-minute cool-down. We employed the Stroop Test to evaluate the participants' attention levels. In addition, the number sequence (SD) subtest of the Wechsler Memory Scale-Generalized Form (WMS-G) was used to assess the participants' memory level pre- and post-exercise. Results: The mean age of the participants was 23.34±1.13 years. The participant showed significant improvement in stroop test times but not for number of correct and errors (Stroop 1, stroop 2, stroop 3, stroop 4, and stroop 5= p< 0.0001, p< 0.008, p< 0.0001, p< 0.0001, and p< 0.001, respectively). The participant showed no significant improvement in WMS-G values (WMS-G normal and WMS-G reverse= p>0.308 and p >0.329). Conclusion: Aerobic exercise has been found to potentially have beneficial effects on cognitive abilities in young adults, even after a single session. Clinicians in the field of cognitive rehabilitation may enhance treatment outcomes by incorporating aerobic activities into rehabilitation programs. Further studies with large sample groups and different types of aerobic exercises (swimming, running, etc.) are important to more clearly demonstrate the acute effects of aerobic exercises on cognitive functions.

Keywords: *Aerobic exercise, Cognitive function, Stroop test*

ÖZ

Amaç: Aerobik egzersizin kognitif fonksiyonlar üzerindeki etkileri iyi bilinmektedir, ancak aerobik egzersizin kognitif fonksiyonlar üzerindeki akut etkileri tam olarak anlaşılamamıştır. Bu çalışmada, sağlıklı genç yetişkinlerde 1 seans aerobik egzersizin bilişsel fonksiyonlar üzerindeki akut etkilerini araştırmayı amaçladık. Gereç ve Yöntemler: Çalışmaya 2020- 2022 yılları arasında Fizyoterapi ve Rehabilitasyon Fakültesi'nde öğrenim gören 52 sağlıklı genç yetişkin (24 erkek, 28 kadın) dâhil edildi. Katılımcılara Ergoline®-Ergoselect200 bisiklet ergometresi kullanılarak bir seans aerobik egzersiz yaptırılmıştır. Egzersiz rutini 5 dakikalık ısınma, ardından 20 dakikalık yüklenme ve 5 dakikalık soğuma periyodundan oluşmuştur. Katılımcıların dikkat düzeyleri Stroop Testi'yle, bellek düzeyleri Wechsler Bellek Ölçeği-Genelleştirilmiş Formunun (WBÖ-G) sayı dizisi (SD) alt testi ile değerlendirilmiştir. Değerlendirmeler egzersiz öncesi ve sonrası olmak üzere 2 kez yapılmıştır. Bulgular: Katılımcıların yaş ortalaması 23,34 ± 1,13 yıl olarak tespit edilmiştir. Katılımcıların Stroop Testi sürelerinde anlamlı iyileşme görülmüş ancak doğru ve hata sayılarında anlamlı bir fark oluşmamıştır. (Stroop 1, stroop 2, stroop 3, stroop 4 ve stroop 5= sırasıyla p< 0,0001, p<0,008, p< 0,0001, p< 0,0001 ve p< 0,001). Katılımcıların WBÖ-G değerlerinde anlamlı bir fark gözlenmemiştir (WBÖ-G normal ve WBÖ-G ters p>0,308 ve p >0,329). Sonuç: Aerobik egzersizin, tek bir seanstan sonra bile genç yetişkinlerde kognitif fonksiyonlar üzerinde olumlu etkileri olabilir. Koginitif becerilerin geliştirilmesinde, aerobik aktiviteler düşünülmeli ve egzersiz programlarına dâhil edilmelidir.Aerobik egzersizlerin kognitif fonksiyonlar üzerine akut etkilerini daha net farklı aerobik egzersiz türleri (yüzme, koşma vb.) ile daha fazla çalışma yapılması önem arz etmektedir.

Anahtar Kelimeler: *Akut, Aerobik egzersiz, Kognitif beceri, Stroop testi*

INTRODUCTION

Aerobic exercise is any physical activity that raises the heart rate and breathing volume to supply oxygen to the working muscles. Aerobic exercise is more convenient to perform and has a lower incidence of adverse effects as compared with drugs. Aerobic exercise is advised for at least 150 minutes per week and can be done at home with activities such as jumping rope, running, or aerobic strength circuits (1). The duration of aerobic exercise can start at 10 minutes and progress up to 60 minutes, depending on fitness level and goals (2). Aerobic exercise has multiple effects such as enhanced cardiovascular well-being, decreased blood pressure, improved emotional state, weight control, and a higher quality of sleep (3). Aerobic exercise provides numerous advantages for mental well-being, such as diminishing depression and anxiety, enhancing mood, and improving cognitive performance (4,5). Empirical studies have demonstrated that engaging in aerobic exercise diminishes symptoms in individuals afflicted with depression and anxiety (6). Additionally, it enhances physical fitness, potentially mitigating the development of these ailments. The mental advantages of aerobic exercise are rooted in neurochemical processes. It lowers the levels of stress hormones in the body and promotes the release of endorphins, which act as the body's innate pain relievers and mood enhancers (7). Moreover, studies have found that exercise reduces anxiety and despair, boosts self-esteem, and eases symptoms in individuals with severe mental illness (4).

Studies have shown that engaging in aerobic exercise can result in enhancements in multiple components of brain function, such as executive function, memory, and attention. Furthermore, aerobic exercise has been linked to the promotion of neurogenesis, which refers to the generation of new brain cells, as well as the mitigation of cognitive decline in elderly people. The cognitive benefits of aerobic exercise are believed to be associated with mechanisms such as enhanced cerebral blood flow, decreased inflammation, and the secretion of neuroprotective and growth factors. Hence, including consistent aerobic activity into one's daily regimen can enhance cognitive function and promote optimal brain health (8-11).

Numerous studies have demonstrated that participating in aerobic exercise has beneficial effects on brain functioning. Nevertheless, there is a lack of recognition of the immediate effects of aerobic exercise on cognitive function. While a limited number of studies in the literature have documented the immediate impact of aerobic exercise on cognitive functions, the results remain a subject of debate (12,13). According to Kamijo et al. (14) several studies indicate that engaging in moderate-intensity aerobic exercise has the potential to improve cognitive processes, whereas high-intensity exercise may have a detrimental effect on them. Nevertheless, alternative research has indicated that engaging in high-intensity aerobics can enhance cognitive function, contingent upon the temporal alignment between the cognitive task and the exercise (13). Our studies significance lies in its ability to illustrate the immediate effects of aerobic exercise on cognitive functioning, thereby addressing the existing gaps in the scholarly literature pertaining to this topic. The primary objective of our research was to examine the immediate impacts of aerobic exercise on cognitive abilities. We hypothesised that aerobic exercise would improve cognitive functions.

MATERIAL and METHOD

Study Design

This study involved 52 healthy young adults studying at Pamukkale University's Faculty of Physiotherapy and Rehabilitation between 2020 and 2022. The inclusion criteria were as follows: asemptomatic healthy adults, between the ages of 18 and 27, understood the purpose of the study. The exclusion criteria were as follows: young adults who had cardiac, pulmonary, physical, and psychological problems; young people whose use of drugs affected their cognitive and aerobic performance; and young people who had visual and hearing problems.

Participants

We calculated a total sample size of 45 with an effect size of 0.951, a power of 0.95, and an error probability of 0.05. We used G*Power 3.19 (Heinrich Heine University, Dusseldorf, Germany) for the sample size calculations (15). We excluded 8 of the 60 participants because they did not meet the inclusion criteria of the study. We completed the study with 52 participants.

Outcome Measurements

We recorded the demographic characteristics of the participants on a demographic data form that we created beforehand. We assessed the participants' attention levels using the Stroop Test pre and post aerobic exercise. Additionally, we examined the participants' memory using the number sequence (SD) subtest of the Wechsler Memory Scale-Generalized Form (WMS-G).

The Stroop Colour and Word Test (SCWT) was used to assess an individual's executive processing abilities, selective attention capacity, and processing speed. This test, which consists of five different cards, requires participants to complete the given task as quickly as possible, recording their time in seconds. The tasks on the cards were as follows: 1. Reading the colour names written in black pen on the card (e.g., black, blue, red); 2. Reading the colour names printed in colour on the card; 3. Saying the colours of the shapes printed in colour on the card; 4. Saying the colour of a word coloured but not written on the card; 5. Saying the colour of a word whose colour name is written on the card but whose colour may differ. At the end of the test, we recorded the completion time, the number of errors made, and the number of corrections (16).

The Wechsler Memory Scale-Generalized Form (WMS-G) was employed to evaluate the participant's memory level. VMS has the capacity to assess various memory functions, including auditory memory, visual memory, visual working memory, immediate memory, and delayed memory, in individuals aged between 16 and 90. We used digital span subtest of VMS-G to assess memory functions. In this subtest, the individual is presented with a consecutive sequence of numbers and instructed to count them in the same sequence. Subsequently, a consecutive sequence of numbers is presented to the individual, who is then instructed to enumerate the numbers in reverse. Digit span subtest consists of 16 numbers, 8 straight number sequences and 8 reversed number sequences. The VMS-G digital span subtest has shown excellent reliability in individuals aged between 21 and 30 (Cronbhach's alpha: 0.88) (17,18).

Procedure

A total of 52 individuals engaged in aerobic exercise using the Ergoline®-Ergoselect200 bicycle ergometer. The exercise routine consisted of a 5-minute warm-up, followed by a 20-minute loading period, and concluded with a 5-minute cool-down (12,19).

Throughout the exercise, participants maintained a heart rate that did not surpass 60–70% of their maximum heart rate. We conducted a pre-exercise assessment session and a 2-minute post-exercise session. We calculated the maximum heart rate as 220 minus the participant's age (20).

Statistical Analysis

Collected data were processed using SPSS version 23.0 (IBM Corp., Armonk, NY, 227 USA) for Windows. The normalities of data distributions were assessed using the Kolmogorow Smirnow test ($p<0.05$), skewness, and kurtosis values. The Paired Simple test was used for parametric variables to asses within group differences, and results are expressed as mean, standart deviations, minumum-maximum. The Wilcoxon's signed-rank test was performed for non-parametric variables to analyze within-group differences, and results are expressed as medians, minumum and maximum. The level of significance was set at $p<0.05$.

RESULTS

This study included 52 young adults (24 males and 28 females). (46.2 % males /53.8% females). The mean age of the participants was 23.34 ± 1.13 years. Body mass index (BMI) of participants were found 22.50 ± 2.95 kg/m2 (Table 1).

Table 1: Demographic Values of Participants,

	X± sd	Min – Max
Age (year)	23.34±1.13	20-27
Height (cm)	171±9.18	155-187
Weight (kg)	65.1±14.5	35-97
BMI (kg/m^2)	22.5±2.95	16.60-29.90
Gender(male/female)	24/28	-
Gender (%)	(46.2% / 53.8%)	

X: Mean, sd: Standart deviations, Min-Max: Minimum - Maximum, cm: Santimeter, kg: Kilogramme, BMI: Body mass index, kg/m^2: Kilogramme /meter square, %: Percentage.

Participants completed the stroop 1 test in 8.11 seconds before aerobic exercise. After the aerobic exercise, the completion time decreased to 7.37 seconds. There was a significant difference in stropp 1 test times between pre- and post-exercise values (p: 0.0001, Table 2).

Participants completed the stroop 2 test in 8.89 seconds before aerobic exercise. After the aerobic exercise, the completion time decreased to 7.78 seconds. There was a significant difference in stropp 2 test times between pre- and post-exercise values (p: 0.008, Table 2).

Participants completed the stroop 3 test in 10.9 seconds before aerobic exercise. After the aerobic exercise, the completion time decreased to 9.32 seconds. There was a significant difference in stropp 3 test times between pre- and post-exercise values (p: 0.0001, Table 2).

Participants completed the stroop 4 test in 12.0 seconds before aerobic exercise. After the aerobic exercise, the completion time decreased to 10.9 seconds. There was a significant difference in stropp 4 test times between pre- and post-exercise values (p: 0.0001, Table 2).

Participants completed the stroop 5 test in 18.0 seconds before aerobic exercise. After the aerobic exercise, the completion time decreased to se16.2 seconds. There was a significant difference in stropp 5 test times between pre- and post-exercise values (p: 0.001, Table 2).

The participants showed no nosignificant improvement in stroop test number of corrects and errors (Stroop 1, stroop 2, stroop 3, stroop 4, and stroop 5= $p>0.05$) (Table 2).

The participant showed no significant improvement in WMS-G values (WMS-G normal and WMS-G reverse= p:0.308 and p:0.329) (Table 2).

Table 2: Comparison of Pre and Post Aerobic Exercise Values of Stroop and WMS-G Test.

		Pre exercise Median (Min – Max)	Post exercise Median (Min – Max)	w	P
Stroop 1	**Time (second)**	8.11 (5.20 – 10.91)	7.37 (5.03 – 9.56)	1202	**0.0001***
	Number of errors	0. (0 - 0)	0. (0 - 1)	0.	1.00
	Number of correct	0. (0 - 1)	0. (0 - 0)	3.00	0.346
Stroop 2	**Time (second)**	8.89 (8.68 – 19.71)	7.78 (8.09– 14.18)	978.5	**0.008***
	Number of errors	0. (0 - 0)	0. (0 - 0)	0.	-
	Number of correct	80. (0 - 1)	0. (0 - 2)	20.0	0.236
Stroop 3	**Time (second)**	10.9 (7.0 – 15.08)	9.32 (7.0-14.99)	1273	**0.0001***
	Number of errors	0. (0 - 1)	0. (0 - 2)	0.	1.00
	Number of correct	0. (0 - 4)	0. (0 - 2)	51.5	0.685
Stroop 4	**Time (second)**	12.0 (8.68-19.71)	10.9 (8.09 – 14.71)	1288	**0.0001***
	Number of errors	0. (0 - 0)	0. (0 - 1)	1.50	0.586
	Number of correct	0. (0 - 2)	0. (0 - 3)	71.5	0.05
Stroop 5	**Time (second)**	18.0 (10.56 – 31.09)	16.2 (8.9 – 22.27)	1059	**0.001***
	Number of errors	0. (0 - 2)	0. (0 - 3)	21.5	0.951
	Number of correct	0. (0 - 5)	0. (0 - 2)	197	0.329
WMS-G	**WMS-G normal**	5.50 (4 - 8)	6.00 (3 - 8)	271	0.308
	WMS-G reverse	5.00 (3 - 7)	5.00 (3 - 7)	203	0.372

Memory Scale-Generalized, *p < 0.05
X: mean, SD: Standard deviation, Min-Max: Minimum - Maximum, w: Wilcoxon test statistics, WMS-G:Wechsler

DISCUSSION and CONCLUSION

The primary goal of the present research was to examine the immediate effects of aerobic exercise on cognitive functions in young adults. A notable enhancement in the cognitive abilities of young adults was demonstrated subsequent to a solitary session. The cognitive performance of adults may be enhanced by engaging in moderate-intensity aerobic exercise, whereas high-intensity exercise has the potential to hinder it. Nevertheless, alternative research has indicated that cognitive function can be enhanced with high-intensity exercise, contingent upon the temporal alignment between the cognitive activity and the exercise (12,13).

The literature extensively documents the impact of prolonged aerobic exercise on cognitive functioning (21, 22). Nevertheless, the comprehensive awareness of the immediate impacts of aerobic exercise on cognitive functions remains insufficient owing to variations in parameters such as intensity of exercise, duration, and intensity, as well as its utilisation across diverse age cohorts and in relation to various medical conditions (12,13). In a study involving 12 elderly and 12 young males, Komijo et al. examined the short-term impacts of aerobic exercise on cognitive performance. They observed that the latent phase of P3, which is believed to reflect the brain activity involved in maintaining working memory during updates to the mental model of the stimulus environment, increased during both light and moderate aerobic exercise in both age groups. However, the amplitude of P3 only increased in the young adult group following moderate aerobic exercise. Furthermore, both groups experienced significant improvements in reaction time following moderate exercise (14).

In order to examine the impact of aerobic exercise on cognitive function, a cross-over study was conducted on a group of 20 patients diagnosed with Parkinson's disease. These participants

underwent training on a recumbent bicycle ergometer known as the 700 Excite + Recline, provided by Technogym USA©, which is located in Seattle, Washington. Subsequently, these individuals were enrolled in a specific aerobic exercise programme that involved performing the exercises at an intensity level of 50% heart rate reserve (HRR) for a duration of 20 minutes. Participants in both the exercise and control conditions showed a reduction in decision-reaction time, according to the study by Silveira and Roy Also, this study found that participants had a slower decision reaction time for the target stimulus in comparison to non-target stimuli, regardless of the time or experiment (23).
A study has examined the acute effects of moderate exercise on cognitive functions, specifically the Stroop test. According to this study short periods of moderate exercise can enhance activity in the dorsolateral prefrontal cortex, a brain region associated with executive functions, and enhance cognitive performance on tests such as the Stroop test (24). This is achieved by boosting the activation of brain regions involved in cognitive control and goal-directed behavior, such as the left dorsolateral prefrontal cortex. In parallel with the above-mentioned studies, our results have shown significant improvement in Stroop test times. These results showed that aerobic exercise, even for one session, may be effective on cognitive functions. We bring these findings to the attention of specialists working in neurorehabilitation, cognitive rehabilitation, and sports rehabilitation.

Engaging in intense aerobic exercise has been found to have immediate positive effects on memory functioning. Research has shown that engaging in one session of moderate-intensity aerobic exercise can improve working memory (25) and the ability to differentiate between similar memories, declarative memory, and procedural memory (26). The results indicate that engaging in intense aerobic exercise can have a beneficial effect on tasks related to memory, emphasising the potential of exercise as a non-pharmacological approach to improve memory function in people of various age groups (27,28). In our study, we observed a slight improvement in memory capacity, but it was not statistically significant. We believe that the duration and intensity of exercise may play a role in this.

Due to the limited quantity and heterogeneity of studies examining the immediate impact of aerobic exercise on cognitive functions, further research is required in this domain. Our study observed enhancements in cognitive functions that align with the aforementioned literature. Consequently, our study will contribute to the expanding body of research in this particular field.

Naturally, our study had some limitations. We conducted our study solely on healthy individuals, underscoring the importance of studies involving individuals with cognitive impairments. Furthermore, our study did not incorporate any form of grouping or randomization. Furthermore, our study did not incorporate any form of grouping or randomization.

In improving cognitive skills, the integration of aerobic exercises into the program may contribute to the development of these skills. With the goal to acquire more understanding of the immediate impacts of aerobic exercise, a variety of aerobic exercise types—such as running and swimming—is necessary.

Declaration of Ethical Code: The present study obtained approval from the Non-Interventional Clinical Research Ethics Committee at Pamukkale University (Ethics number: 60116787-020/15169). Before participating in the study, all participants were required to give written consent after receiving comprehensive information about the study protocol, which was in accordance with the ethical principles outlined in the Declaration of Helsinki for human experimentation.

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