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The effects of an acute aerobic exercise session with L-Arginine supplementation on selected psychomotor and physiological parameters in cyclists recovered from COVID-19

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A B S T R A C T

Objective: The COVID-19 pandemic represents one of the major global crises of this century, bringing complications that can hinder the return to sport in infected athletes. Evidence suggests aerobic exercise and L-Arginine supplementation may accelerate COVID-19 recovery. Hence, this study aimed to examine the effects of an acute aerobic exercise session with L-Arginine supplementation on selected psychomotor and physiological parameters in cyclists recovered from COVID-19.
Methods and Materials: Thirty-two male mountain bikers aged 18-25 years from Qazvin, Iran were randomized into four groups of eight: aerobic exercise + L-Arginine supplementation, control, aerobic exercise + placebo, and L-Arginine alone. Participants underwent pre- and post-testing surrounding an acute aerobic cycling session. The Shapiro-Wilk test assessed normality of data distribution. Analysis of covariance evaluated between-group differences. Statistical analyses were performed using SPSS version 26.
Findings: Analysis of covariance revealed significant between-group differences on psychomotor performance, maximal oxygen consumption, and peak anaerobic power variables (all $p<0.05$). Post-hoc Bonferroni tests showed the aerobic exercise + L-Arginine group had significantly greater improvements than aerobic + placebo and L-Arginine groups ($p<0.05$), with no differences between L-Arginine and control.
Conclusion: Aerobic exercise combined with L-Arginine supplementation appears an effective strategy for enhancing psychomotor and physiological performance in cyclists recovered from COVID-19.
Keywords: *Aerobic exercise, L-Arginine supplementation, psychomotor function, physiological indices, COVID-19.*

1. Introduction

With the numerous advancements in the fields of medicine and disease treatment, there will not be a practical cure available for a new or pandemic disease when it first emerges, which in turn leads to many problems and concerns in societies. With the global spread of COVID-19, lifestyles of many people changed rapidly within a few days (Balliu, 2021). This new lifestyle included restrictions on movement and quarantine at home, which led to a decrease in physical activity across all age groups (Hussein et al., 2020). Additionally, due to the unknown nature of this disease, the problems and side effects caused by the disease have led to challenges that generally include psychological disorders in individuals (Jimeno-Almazán et al., 2021).

Research evidence has shown that one of the ways to improve performance, enhance physical fitness, and combat the side effects of the disease is through physical activity and exercise, as exercise improves the immune system's ability to respond to viral infections. Furthermore, exercise has positive effects on various body systems, including the cardiovascular and nervous systems (Nieman & Wentz, 2019). One of the exercise methods that has a comprehensive effect on the body is aerobic exercise, and its effects have been observed abundantly (Saleh et al., 2021). On the other hand, in terms of nutritional solutions, athletes nowadays widely use sports supplements. One of these sports supplements is L-Arginine, which has an amino acid structure that, due to its performance-enhancing effects, increases the secretion of anabolic hormones and fuels in sports, generally preventing the undesirable effects and side effects of excessive exercise and fatigue (Tsai et al., 2009).

Cycling is one of the most efficient forms of human transportation that requires less energy per unit distance than any other land transportation. Professional cycling competitions are one of the toughest sports that combine intensity, duration, and repetition of exercise (McCole et al., 1990). Cross-country cycling is a mountain biking competition that is usually held in one day on off-road routes (Lee et al., 2002). Due to the nature and environmental conditions, this sport requires maximum capacity in power, oxygen consumption, lactate threshold, and the ability to maintain these needs (Impellizzeri et al., 2005).

In addition, cycling performance is influenced by various factors such as aerobic and anaerobic capacity, muscular strength and endurance, body composition, balance and agility, and visual perception (Goins, 2014). Therefore, one of the issues that coaches and athletes have always been concerned about is increasing their physical and mental abilities during exercise performance (Abel et al., 2004). In the field of sports, especially in sports that require both physical and cognitive abilities for success, it is necessary to adopt effective strategies to enhance these two abilities simultaneously (Bahmani et al., 2015). This is while in the past 3 years, the emergence of a new disease such as COVID-19 has led to a decline in the performance of athletes due to negative psychological and cognitive effects (Rajabian, Andam, & Rajabi, 2022). The consequences of this disease have affected various systems of the body, including the immune, physiological, and even cognitive systems, which have been unpredictable due to the variable effects of the disease (Fu et al., 2020). Psychologically, the negative effects of this disease have been clearly demonstrated in various studies, such as anxiety, depression, and insomnia, which have been associated with quarantine conditions to prevent the disease (Brooks et al., 2020).

Based on research evidence, the greatest impact and damage of this disease is on the respiratory system, which is one of the main causes of death (Iranpour & Ghaderian Jahromi, 2021). According to research reports, some symptoms remain in individuals for a long time after recovery from this disease, such as shortness of breath, fever, and bloody sputum. Generally, the effects that remain in the body after recovery from COVID-19 are called post-COVID-19 syndrome (Ahmed et al., 2021). Huang et al. (2021) found that up to 6 months after the recovery period, most patients experienced fatigue, muscle weakness, and sleep and stress-related problems (Huang et al., 2021). In addition, other symptoms such as shortness of breath during exercise, limitations in pulmonary respiratory capacity, and pulmonary inflammation have been reported (Nalbandian et al., 2021). The results of the studies indicate that these symptoms and effects are the basis for decreased performance and will increase the time required to return to sports activities (Hull et al., 2022). Considering the special and unique conditions that recovered COVID-19 patients have, and if they are athletes, these conditions are more sensitive. Therefore, it seems that considering exercise considerations alongside nutritional considerations can be the most effective. Therefore, the aim of this study was to determine the effect of an aerobic exercise program with L-Arginine supplementation on selected psychological, motor, and physiological indices of recovered COVID-19 cyclists.

2. Methods and Materials

2.1. Study Design and Participants

This study was an applied and quasi-experimental research with two stages of measurement, pre-test and post-test. The statistical population of this research included mountain bikers in Qazvin city who had recovered from COVID-19 (aged 18 to 25) and were selected in an available and purposive manner. After a virtual call, a total of 43

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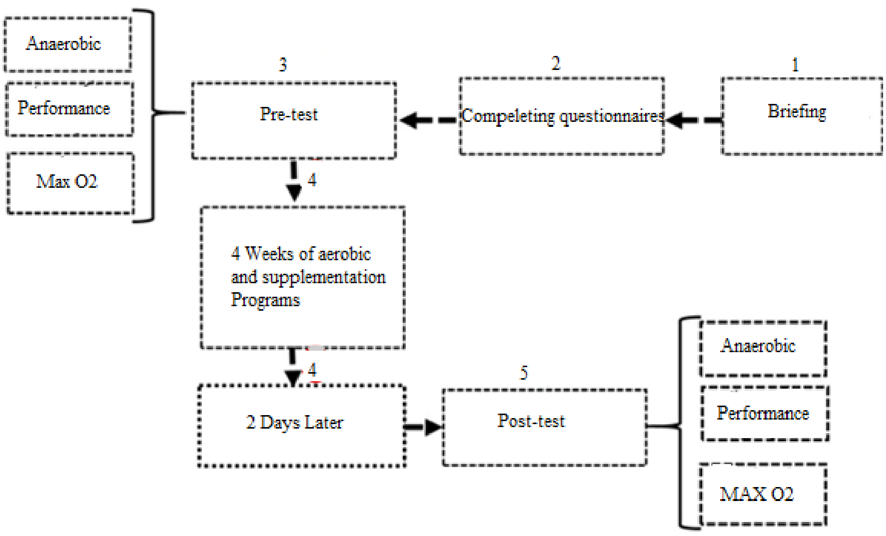
volunteers were eligible to participate in the study, of which 32 were ultimately selected based on inclusion criteria. The interventions applied in this study included a four-week aerobic exercise program and consumption of L-Arginine supplement. After selecting the participants, a briefing session was held for them to explain how to work with laboratory equipment. In addition, all selected participants were asked to complete a written consent form to voluntarily participate in the study, a physical activity questionnaire (Rahimi, 2020), and a medical history questionnaire to further control and homogenize the subjects. After completing the relevant forms, functional performance pre-tests (cognitive performance, balance, anaerobic power, and maximal oxygen consumption) were performed on the participants. In the next stage, exercise and nutritional interventions were applied, and finally, post-test functional performance evaluations (cognitive performance, balance, anaerobic power, and maximal oxygen consumption) were performed. The entry criteria for the study were: complete satisfaction and honesty of the participants, receiving at least one dose of COVID-19 vaccine, no specific disease or injury, regular participation in training sessions and supplement consumption, mild to moderate COVID-19 symptoms 3-9 months before participating in the study, and no physical activity after recovery from COVID-19 (such as fever, cough, sore throat, fatigue, headache, muscle pain, nausea, vomiting, diarrhea, loss of taste and smell) (Wang et al., 2020; Zhu et al., 2020). The exclusion criteria from the study were no specific diseases except COVID-19 two years before participating in the study, irregular and absent participation in training and laboratory sessions, occurrence of injury during exercise, consumption of tobacco, alcohol, and other supplements, and lack of complete satisfaction and honesty in the research project. After explaining the research plan, the participants were randomly divided into four groups of eight individuals, including 1- aerobic exercise + L-Arginine, 2- aerobic exercise + placebo, 3- control group, and 4- L-Arginine. The sample size was determined to be 76 individuals using G.power software version 3.1.9.2 based on information (α=0.05, β=0.8, number of groups=5, and effect size=0.4), but ultimately, 32 individuals met the criteria for participation in this study.

Figure 1

Study procedure



In the first stage of the pre-test measurement, cognitive performance, balance, aerobic capacity, and maximum oxygen consumption were evaluated according to the Figure 1. After applying exercise and nutritional interventions, post-test measurements were taken again after 48 hours.

2.2. Interventions

2.2.1. Aerobic Training

The aerobic training program consisted of 12 aerobic exercise sessions on a treadmill, including 10 minutes of warm-up and cool-down and 35 minutes of moderate-

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intensity aerobic exercise. The maximum exercise intensity was 60 to 75% of maximum heart rate, which was calculated using the formula MHR=220-age. The Borg Rating of Perceived Exertion Scale was used to control exercise intensity. Participants were asked to maintain their maximum activity level ranking between 13 and 15 (somewhat hard to hard) on the Borg scale. Exercise intensity was also controlled by heart rate using a Polar HP CosMos heart rate monitor.

2.2.2. *Supplementation*

For supplementation, the L-Arginine supplement produced by a pharmaceutical company and the vital dietary supplement Karen (Yazd, Iran), which is approved by the Ministry of Health, were used. The supplements were administered in the form of 200 mg tablets, 5 grams half an hour before exercise for the relevant participants. In addition, dextrose tablets (produced by Karen) were used for the control group at a dose of 5 grams, which was a similar process to the L-Arginine intervention. None of the participants had any knowledge of the contents of the supplement packages until the end of the study.

2.3. *Measures*

The Good Balance stability meter was used to evaluate balance in both static and dynamic states. The Winna performance recording device was used to evaluate psychomotor performance. The Wingate test was used to evaluate aerobic capacity, which was performed using a Monark 894 E ergometer. Participants reached their maximum oxygen consumption with the Bruce test, and a gas analyzer (MM3B) was used to evaluate and analyze respiratory gases and determine maximum oxygen consumption.

2.4. *Data analysis*

The Shapiro-Wilk test was used to examine the normality of the data, and the analysis of covariance and Bonferroni post-hoc test were used to examine the changes in each of the indicators at different stages. All statistical data were analyzed using SPSS version 26.

3. Findings and Results

The descriptive characteristics of the improved cyclists with COVID-19 are shown in Table 1.

Table 1

Descriptive statistics (M= Mean; SD= Standard Deviation)

Groups / Descriptive characteristics	Aerobic + Supplementation	Aerobic + Placebo (N=8)	Supplementation (L-Arginine) (N=8)	Control (N=8)
Age (YearO	22.87±1.45	43.75±2.22	92.37±1.22	75.75±1.22
Height (cm)	176.37±6.88	09.50±6.176	98.75±1.175	18.87±4.178
Weight (kg)	73.71±6.62	96.36±4.73	36.42±2.74	87.82±4.75
BMI (kg/m^2)	23.66±1.12	21.53±1.23	03.08±1.24	95.67±0.23

The results showed that the distribution of pre-test and post-test data in the groups was normal (p>0.05). Also, the condition of equality of variances in the pre-test and post-test groups and the homogeneity of regression slopes were established. Given the establishment of the assumptions of the covariance test, this test was used to examine the differences in mean cognitive performance indicators (time to correct selection, number of correct selections, number of correct withdrawals) in the four groups in the post-test stage after removing the pre-test effect, and a significant difference was found (p=0.00). The Bonferroni post-hoc test was used to determine the location of intergroup differences based on the significant statistical difference.

The results post-hoc test a significant difference between the supplement control group and the aerobic exercise - L-Arginine supplement group and the aerobic exercise - placebo group for cognitive performance indices (correct selection time) (F1,3=35.29, p=0.000, η2=0.47) & (F1,3=35.29, p=0.000, η2=0.79), (number of correct withdrawals) (F1,3=38.94, p=0.001, η2=0.44) & (F1,3=38.94, p=0.000, η2=0.81)), (number of correct selections) (F1,3=19.89, p=0.024, η2=0.26) & (F1,3=19.89, p=0.005, η2=0.68)). Generally, considering the higher effect size of cognitive performance indices in the aerobic exercise + supplement group, it seems that the use of aerobic exercise with L-Arginine supplement had a greater improvement effect Figure 2.

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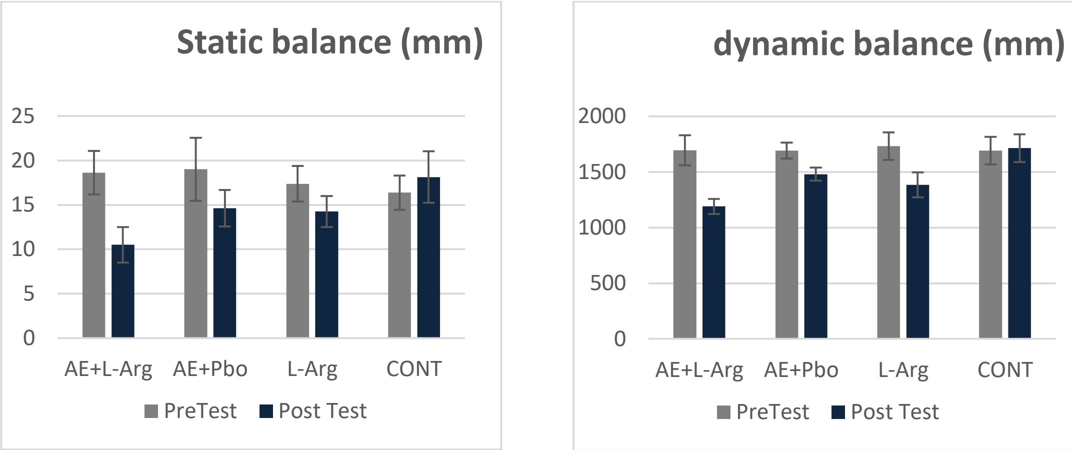
Figure 2

Bonferroni post-hoc test results for comparing means in four test groups for cognitive performance; correct selection time (a), number of correct selections (b), and number of correct withdrawals (c).

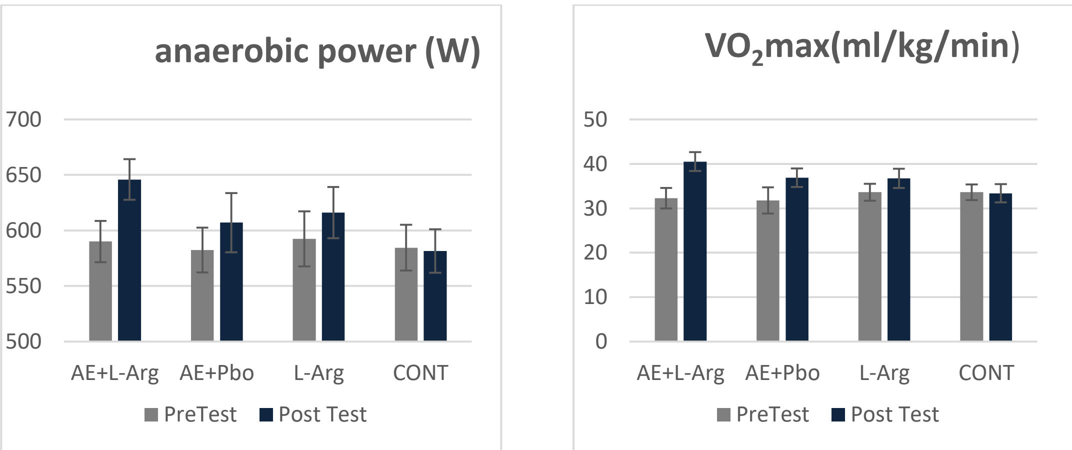


AE+L-Arg: Aerobic exercise+L-Arginine supplement group; AE+Pbo: Aerobic exercise+Pelacebo group; L-Arg: L-Arginine supplement group; Cont: Control group.

Regarding balance, the results of the covariance analysis showed that there was a significant difference in the mean of static and dynamic balance in the four groups in the post-test phase after removing the pre-test effect (p=0.00). Also, the results of the Bonferroni follow-up test showed that there was a significant difference between the supplement control group and the aerobic exercise - L-Arginine supplement group and the aerobic exercise - placebo group for dynamic balance (($F_{1,3}$=59.05, p=0.024, η^2=0.73) & ($F_{1,3}$=59.05, p=0.0000, η^2=0.86)) and static balance (($F_{1,3}$=19.39, p=0.003, η^2=0.37) & ($F_{1,3}$=19.39, p=0.004, η^2=0.68)). Considering the higher effect size in the aerobic exercise + supplement group, it seems that the use of aerobic exercise with L-Arginine supplement had a greater improvement effect on static and dynamic balance Figure 3.

Figure 3

Bonferroni post-hoc test results for comparing means in four test groups for cognitive performance; correct selection time (a), number of correct selections (b), and number of correct withdrawals (c).



AE+L-Arg: Aerobic exercise+L-Arginine supplement group; AE+Pbo: Aerobic exercise+Pelacebo group; L-Arg: L-Arginine supplement group; Cont: Control group.

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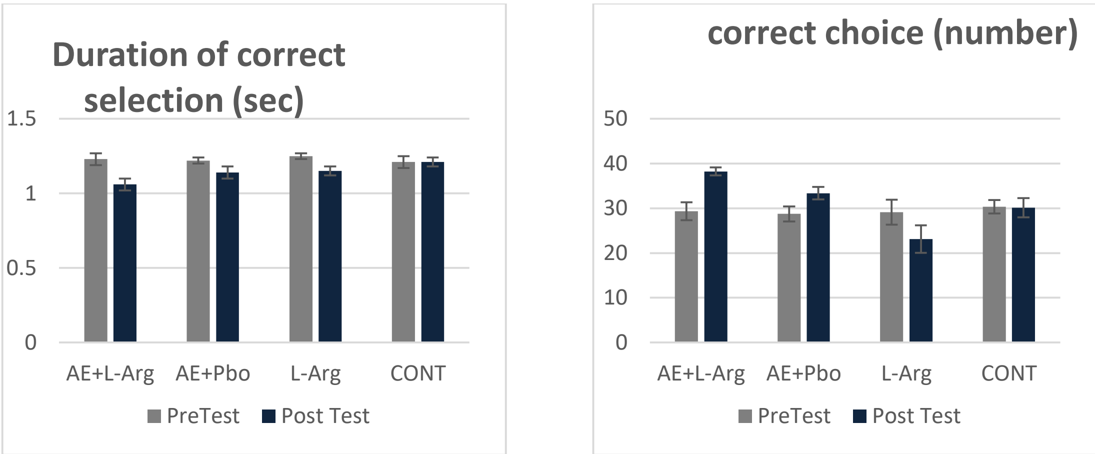
Regarding anaerobic power and maximum oxygen consumption, the results of the covariance analysis showed that there was a significant difference in the mean of the four groups in the post-test phase after removing the pre-test effect (p=0.00). Also, the results of the Bonferroni follow-up test showed that there was a significant difference between the supplement control group and the aerobic exercise - L-Arginine supplement group and the aerobic exercise - placebo group for anaerobic power (($F_{1,3}$=51.97, p=0.00, η2=0.54)) & ($F_{1,3}$=51.97, p=0.00, η^2=0.85)) and maximum oxygen consumption (($F_{1,3}$=51.97, p=0.00, η^2=0.54) & ($F_{1,3}$=51.97, p=0.00, η2=0.85)). Considering the higher effect size in the aerobic exercise + supplement group, it seems that the use of aerobic exercise with L-Arginine supplement had a greater improvement effect on anaerobic power and maximum oxygen consumption Figure 4.

Figure 4

Bonferroni post-hoc test results for comparing means in four test groups for anaerobic power (a) and maximum oxygen consumption (b).



AE+L-Arg: Aerobic exercise+L-Arginine supplement group; AE+Pbo: Aerobic exercise+Pelacebo group; L-Arg: L-Arginine supplement group; Cont: Control group.

4. Discussion and Conclusion

The aim of the present study was to investigate the effect of four weeks of aerobic exercise with L-Arginine supplementation on the psychomotor performance, maximal oxygen consumption, and aerobic capacity of COVID-19 recovered cyclists. The results of the study showed that four weeks of aerobic exercise and L-Arginine supplementation had a positive effect on the psychomotor performance (cognitive function and balance) of COVID-19 recovered cyclists. Overall, it appeared that participants in the aerobic exercise + L-Arginine supplementation group had much better results compared to the L-Arginine supplementation group. In this regard, the study by Shahidi et al. (2020) titled "Physical activity during COVID-19 quarantine" provides recommendations for maintaining physical activity during the COVID-19 pandemic (Shahidi, Stewart Williams, & Hassani, 2020). The results of the study by Miyazaki et al. (2022) also showed that aerobic exercise improves cognitive performance during the COVID-19 quarantine (Miyazaki et al., 2022).

Generally, these positive effects and benefits will be achieved through processes that lead to effectiveness. However, it should be noted that the underlying mechanisms and processes of the effect of aerobic exercise on psychomotor performance, including cognitive function and balance, in COVID-19 recovered patients are not fully understood. In terms of COVID-19 recovery, it is possible that increasing neurotrophic factors resulting from aerobic exercise can enhance neural repair and recovery. It should be noted that COVID-19 is associated with inflammation, which can have negative effects on cognitive function and balance. It has been shown that aerobic exercise reduces inflammation in various populations, including individuals with neurological diseases. It is possible that aerobic exercise can have similar anti-inflammatory effects in recovering COVID-19 patients, which can help improve psychomotor performance. On the other hand, COVID-19 recovery can be a stressful and challenging psychological

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experience that can have negative effects on cognitive function and balance. It has been shown that aerobic exercise improves mood and reduces anxiety and depression (Craft & Perna, 2004), which can help improve psychomotor performance. Researchers suggest that the positive effects of aerobic exercise on semantic memory may be due to increased blood flow and neural plasticity in the hippocampus, a brain region important for memory. Regarding the effect of L-Arginine supplementation on balance, there are limited studies, and most studies show improvement in some balance parameters with L-Arginine supplementation, but there are limited results regarding the direct effect of L-Arginine supplementation on balance. It has been shown that L-Arginine may also have a direct effect on brain function through its role in the synthesis of neurotransmitters such as nitric oxide and dopamine. Nitric oxide plays a very important role in neural communication and synaptic plasticity (Griffiths, Jones, & Palmer, 1997).

One of the results of the present study showed that 12 sessions of aerobic exercise and L-Arginine supplementation had a positive effect on the anaerobic power of COVID-19 recovered cyclists. However, considering the larger effect size of the aerobic exercise-supplement group, it can be concluded that aerobic exercise with L-Arginine supplementation had a greater effect on anaerobic power compared to L-Arginine supplementation alone. In this regard, Kin Isler and Kusar (2006) investigated the effect of stair aerobic exercise on the anaerobic performance of men and women. This study included 24 healthy participants (12 men and 12 women) with a mean age of 26.3 ± 2.7 years. The results showed that the aerobic exercise group had significant improvements in peak power output, mean power output, and fatigue index compared to the control group (Kin-Isler & Kosar, 2006). There are several mechanisms that may explain the beneficial effects of aerobic exercise on anaerobic power. These include improved energy production, increased lactate threshold, improved muscle buffering capacity, and increased muscle fiber absorption (Glaister et al., 2008). Additionally, the present study's results indicated a positive effect of L-Arginine supplementation on the anaerobic power of COVID-19 recovered cyclists. Moreover, during anaerobic exercise, the body relies on stored energy sources and does not require oxygen to produce energy. This type of exercise can lead to the production of lactic acid, which can cause fatigue and decreased athletic performance. It has been shown that L-Arginine supplementation increases nitric oxide production, which can improve blood flow and nutrient delivery to working muscles. This may help to mitigate the effects of lactic acid accumulation, delay fatigue, and improve anaerobic power. Additionally, it has been shown that L-Arginine supplementation increases the activity of enzymes involved in energy production, such as creatine kinase and adenosine triphosphate synthase, which may help improve anaerobic power. It is important to note that the effects of L-Arginine supplementation on anaerobic power may vary depending on individual factors such as training status, diet, and overall health. Furthermore, further research is needed to fully understand the mechanisms and processes by which L-Arginine supplementation affects anaerobic power (Bailey et al., 2010).

Moreover, the results indicate a positive effect of 12 sessions of aerobic exercise and L-Arginine supplementation on the maximum oxygen consumption of COVID-19 recovered cyclists. However, considering the larger effect size of the aerobic exercise-supplement group, it can be concluded that aerobic exercise with L-Arginine supplementation had a greater effect on maximum oxygen consumption compared to L-Arginine supplementation alone. In this regard, research evidence shows that aerobic exercises such as walking, cycling, and respiratory muscle training can improve lung function, reduce the risk of pulmonary fibrosis, and improve the quality of life of COVID-19 patients. However, the intensity, frequency, and duration of aerobic exercises should be tailored to the individual's health status and monitored by a qualified healthcare professional. Aerobic exercise can lead to adaptation in muscle fibers, including a shift towards a higher proportion of slow-twitch muscle fibers that are more efficient in using oxygen for energy production. It is believed that these adaptations are achieved by increasing the expression of myoglobin, a protein that binds oxygen in muscle cells and facilitates its use for energy production. Additionally, aerobic exercise can lead to adaptation in the nervous system, including an increase in the recruitment and firing rate of motor units, which can improve muscle contraction efficiency and reduce the oxygen cost of exercise.

5. Limitations and Suggestions

Overall, these mechanisms and processes contribute to the observed improvement in VO2max with aerobic exercise. However, the specific contribution of each mechanism may vary depending on the individual and the type and intensity of exercise. Further research is needed to

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fully understand the underlying mechanisms of the effects of aerobic exercise on VO2max. Most studies in this area have shown that aerobic exercise can improve VO2max. However, it should be noted that the effects of aerobic exercise on VO2max may vary depending on factors such as the type and intensity of exercise, duration of intervention, and characteristics of the study population. Overall, there were some limitations to this study, including the lack of complete control over the quality of sleep and physical activity, and the motivation of participants, which should be addressed in future research. In general, the results indicate a positive effect of aerobic exercise and L-Arginine supplementation on the motor performance of COVID-19 recovered cyclists. However, it appears that aerobic exercise with L-Arginine supplementation has a greater effect compared to supplementation alone.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethics principles

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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