

## Research Article

# Effects of ultra-short race pace training (USRPT) with Beta-alanine supplementation on physical fitness in young soccer players

Mohammad Amin Farhani<sup>1</sup>, Hamid Rajabi<sup>1\*</sup>, Reza Nourmohammad<sup>2</sup>


## Abstract

This study aims to investigate the effectiveness of the USRPT system combined with beta-alanine supplementation on the physical performance of elite young soccer players. Forty-four young soccer players were purposefully selected and divided into four groups of 11 players: exercise-only (placebo), exercise with a supplementation, supplementation-only, and a control group. After a 10-minute warm-up, subjects performed the 25-minute USRPT protocol in three weekly sessions, followed by regular team training. The supplementation group consumed 4 grams of beta-alanine daily for six weeks, split into two doses 60 minutes before and after each training session. Body composition, aerobic fitness (Half-time test), anaerobic power (RAST test), 20-meter sprint, muscle endurance, and Borg's Rate of Perceived Exertion (RPE) were measured in the pre-test and post-test. The repeated measures ANOVA revealed a significant difference in aerobic power, anaerobic power, muscular endurance, and fatigue drag index between the exercise-placebo and exercise-plus-supplementation groups after 40 days ( $P=0.001$ ). No significant differences were found between the supplementation and control groups in other variables ( $P>0.05$ ). This research found that the USRPT system effectively improves aerobic and anaerobic power in soccer players. It also suggests that when combined with USRPT, beta-alanine supplementation reduces fatigue and enhances performance. Beta-alanine boosts sports performance by increasing Carnosine in muscle cells and offering antioxidant benefits. Coaches and athletes aiming to improve physical performance may consider using beta-alanine alongside targeted training.

**Key Words:** USRPT system, Beta-alanine, Carnosine, Physical fitness

1. Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, Kharazmi University, Tehran, Iran. 2. Department of Physical Education and Sport Sciences, Saveh Branch, Islamic Azad University, Saveh, Iran.

\*Author for correspondence: [hrajabi@khu.ac.ir](mailto:hrajabi@khu.ac.ir)

 M A F: 0009-0009-6874-7710; H R: 0000-0002-3276-1598; R N: 0009-0002-0519-3756

## Introduction

One of the high-intensity interval training systems first used by swimming coaches as an effective method to improve swimmers' endurance performance is race-pace training for very short distances (USRPT), which has gradually gained attention in other sports (Rushall, 2013, 2018). In this approach, continuous training sets (like swimming or running) are performed at a race pace (similar to race pace) but over much shorter distances than the actual race (for example, a quarter of the race distance) with minimal rest time (Rushall, 2011). For instance, the USRPT system is done at maximum intensity with 20 × 50 meters of freestyle swimming and 35 seconds at a 1:1 rest ratio (Cuenca-Fernández et al., 2023). Fatigue induced by the USRPT seems to impact various performance variables and enhances athletes' fatigue tolerance at the cellular and muscular tissue level (Nugent et al., 2019). To boost the effects of fatigue tolerance training, athletes have also turned to certain sports supplementations that claim to delay or reduce muscle cell fatigue. Among these, beta-alanine is a non-essential amino acid in the human body that increases cellular carnosine levels (C. Harris et al., 1998; Hill et al., 2007). Researchers have reported that beta-alanine has ergogenic effects on athletic performance (Raizel et al., 2019). For this reason, the effects of sports activities on fatigue have been studied (Sheikholeslami-Vatani et al., 2016). Short-term beta-alanine supplementation (2.3 to 6.4 g/day for 4 to 24 weeks) has been found to significantly increase intramuscular carnosine concentrations (Dinarvand et al., 2024). Beta-alanine can act as a cellular buffer to reduce acidosis in active muscles during high-intensity Exercise by increasing the carnosine levels of muscle fibers. This supplementation is a non-essential amino acid made in the liver as the final metabolite for reducing nitrogenous organic bases of Uracil and thymine. Beta-alanine, in combination with the essential amino acid histidine, causes the formation of Carnosine in muscle cells, which can greatly reduce acidosis caused by high-intensity Exercise in muscles, especially in fast glycolytic fibers. Carnosine is a multifunctional dipeptide with many roles, such as buffering, fighting free radicals (antioxidant

biomarker), regulating enzyme activity, and regulating calcium in the cellular sarcoplasmic reticulum. Carnosine is broken down in the human body by the enzyme carnosine, which is mostly present in tissues other than skeletal muscle and partly explains why the concentration of Carnosine is higher in muscle tissue than in other tissues (Maté-Muñoz et al., 2018). During a soccer game, the average activity intensity cannot increase beyond the lactate threshold; therefore, players cannot spend much time playing above the lactate threshold (Helgerud et al., 2001). For example, during the 90 minutes of a match, soccer players may run between 10 and 12 kilometers at an intensity of 80 to 90 percent of the maximum beat, but in total, they spend very little time at high threshold intensities (Hoff et al., 2002; Mcmillan et al., 2005). On the other hand, to increase a team's ability in matches, it is necessary to reduce the players' fatigue during the match according to the different conditions of the game and the implementation of different tactics. This has shown that teams with better endurance and aerobic power will have a higher ability to stay active and ultimately score in the final moments of the match (Impellizzeri et al., 2008). Therefore, having an optimal level of aerobic fitness can be a determining factor in maintaining athletes' performance during competition. High aerobic capacity affects players' physical and tactical performance (Chamari et al., 2004). Exercises that improve aerobic fitness, such as maximal oxygen consumption, running economy, and lactate threshold, can improve soccer players' physical, technical, and tactical performance (Helgerud, 1994). In addition, a soccer player performs about 1000 to 1400 short activities in the game, sometimes repeated repeatedly with very little rest (Mohr et al., 2003). It can be concluded that aerobic and anaerobic fitness are valuable factors for success in soccer. Considering the importance of aerobic and anaerobic physiological adaptations in soccer and the interval nature of soccer, the role of interval training in this field has been highlighted (Keyhanian et al., 2015). Performing interval training by creating aerobic and anaerobic adaptations increases maximum oxygen consumption (Helgerud et al., 2001; Hoff et al., 2002) power, fatigue resistance (A. Hawley et al., 1997), increase the activity of oxidative and glycolytic enzymes (MacDougall et al., 1998), lactate tolerance (Karp, 2000), motor efficiency and increase lactate excretion in soccer players (Keyhanian et al., 2015). Therefore, interval training is a good option that increases the training pressure to improve aerobic power ( $VO_{2max}$ ), anaerobic power, and, consequently, the performance of the athletes (Helgerud et al., 2001). Aerobic exercise can reduce chronic inflammation. This effect is mediated through cross-talk between the immune and nervous systems (Gleeson et al., 2011). Aerobic exercise can stimulate the parasympathetic system, which helps lower the resting heart rate and improve the body's autonomic balance. This effect occurs through cross-talk between the central and cardiovascular nervous systems (Dishman et al., 2006).

After investigating the effect of 8 weeks of beta-alanine supplementation on aerobic capacity and muscle fatigue in runners and soccer players, Arnerlinde et al. suggested that beta-alanine might delay the onset of fatigue (Hoffman et al., 2008). However, in another study, Sweeney and his colleagues (2010) reported that taking 6 grams of beta-alanine supplementation daily did not affect the power and level of fatigue during repetitive Exercise (Sweeney et al., 2010). It seems that beta-alanine supplementation can have a positive effect if it is accompanied by specific lactic training. In this regard, this study aimed to investigate the effect of the new training system (USRPT) along with beta-alanine supplementation on the physical performance of elite soccer players in the youth category.

## Materials and Methods

### Subjects and study protocol

The present study is of a semi-experimental type, and according to the purpose of the research, it is of a developmental type. The sample consisted of 44 young professional soccer players aged  $18.6 \pm 3.1$  years, and a body mass index of  $21.8 \pm 0.9$  kg/m<sup>2</sup> was purposefully selected. The subjects were randomly divided into 4 groups. The selection of this sample size was based on similar studies. These individuals had no underlying genetic or familial diseases and were residents of Tehran. After that, the necessary explanations for participating in the study were given to them and their coach on the soccer team, and their consent was also obtained. Several players had a history of playing in the national ranks and the Asian Vision Premier League in Tehran, and the players were present in the second half of the season during the tournament season. In addition, the exercise-supplementation, exercise-Placebo, and supplementation groups performed the USRPT protocol 3 times a week at the beginning of the training after 10 minutes of warm-up for 25 minutes. After the implementation of the protocol, the team usually practices. The control and supplementary groups continued to practice generally under the supervision of the team coach (tactical and technical exercises and playing on small courts) after the warm-up. Therefore, in a training session to get acquainted with the tests, all the subjects were asked to attend the test site and get acquainted with the desired tests. In this session, the subjects completed the consent form to participate in the research. In the pre-test session, the warm-up program was first performed, and then the post-test was taken for the field tests. All subjects were asked to show their utmost effort and accuracy in performing all the tests.

Then, the players were divided into 4 groups of 11 people: 1. Exercise-supplementation group, 2. Exercise-placebo group, 3. Supplementation group, 4. Control group. The training groups performed 3 sessions per week and 6 weeks of training according to the USRPT system. The training program was 20 round-trips

of 50 meters with high intensity and a rest of 20 seconds. After the pre-tests, the subjects in the supplementation group took 4 g/day of beta-alanine supplementation for six weeks in 2 stages and 60 minutes before and after the training session. After the end of the intervention period, the post-test was performed under the same conditions as the pre-test. The subjects were asked not to take any dietary or other drug supplementation during the six-week study period. The subjects were also asked to inform the researcher of any complications.

Participants were into four groups: exercise placebo group (n = 11), β-alanine supplementation group (n = 11), exercise- β-alanine supplementation group (n = 11), and control group (n = 11). All subjects were instructed not to change their habitual diet during the intervention and to ensure that the participants took the supplementation, as advised the participants received capsules with β-alanine or a placebo each week during the intervention (Figure 1).

**Training Protocol (USRPT)**

The term USRPT was first coined by Professor Brent Rachel in 2011 and involves performing repeated swimming intervals at a pace that corresponds to an individual's best competitive performance (i.e., race speed) but over shorter distances than the race. One of the most common USRPT programs is 20×50 meters with 20 seconds rest at the highest intensity (Rushall, 2011) The number of training sessions can be between 2 and 4 sessions per week, and in the present study, 3 sessions per week at the highest intensity were also examined. First, the record of the 200-meter run was taken, and according to the principles of the system (USRPT), 20×50-meter round-trips with a 20-second rest were performed on young soccerers over six weeks (Rushall, 2016). In Figure 2, the 200-meter record of the players of the training groups for the 50-meter repetitions is presented.

**Physical tests**

**Huff Test:** The Huff Aerobic Test is a ball endurance test for soccer players performed in a specific way (Figure 2). The cones used to design the training route of the test method were as follows: the players dribble the first 10 cones in a spiral and jump over obstacles to a height of 30 cm while carrying the ball. After that, the next cones were passed in a long spiral, and at the end

"Pre-Test"	"Loading period"	"Post-Test"
<ul style="list-style-type: none"> <li>• Body Composition</li> <li>• Muscular Endurance Test</li> <li>• 20 M Speed Test</li> <li>• Sargent Test</li> <li>• Rast Anaerobic Test</li> <li>• Huff Aerobic Test</li> <li>• RPE</li> </ul>	<ul style="list-style-type: none"> <li>• 40 days of beta-alanine loading and placebo with the USRPT training system</li> </ul>	<ul style="list-style-type: none"> <li>• Body Composition</li> <li>• Muscular Endurance Test</li> <li>• 20 M Speed Test</li> <li>• Sargent Test</li> <li>• Rast Anaerobic Test</li> <li>• Huff Aerobic Test</li> <li>• RPE</li> </ul>

Figure 1. Schematic design of the research.

Table 1. General characteristics of the subjects.

	EXE-SUB	EXE-PLA	Supplementation	Control
Age (years)	18.6 ± 3.1	19.1 ± 1.8	19.3 ± 2.1	18.8 ± 2.5
Weight (kg)	67.3 ± 2.3	65.2 ± 3.1	67.5 ± 2.7	68.3 ± 2.9
Height (cm)	177.1 ± 2.5	178.6 ± 1.4	179.3 ± 2.4	176.4 ± 3.8
B MI (kg/m2)	21.8 ± 2.9	21.5 ± 2.4	22.3 ± 3.1	21.9 ± 1.97
Body Fat (%)	9.13 ± 1.44	10.09 ± 1.29	11.94 ± 1.67	12.23 ± 1.56

of the length of the rectangle, while controlling the ball, they moved backward and then turned back and moved towards the starting point. The duration of this test is 10 minutes, and the test score is the distance that the players travel in 10 minutes (Chamari et al., 2005). The validity of this test has been confirmed in previous studies assessing the endurance of soccer players (Chamari et al., 2005).

**Body composition:** To measure the thickness of the skin fold, a digital Harpenden caliper was used at seven points of skin fold thickness in the subscapular, armpits, triceps, flanks, chest, abdomen, and quadriceps femoris (Shirzad, 2021). To increase the accuracy of the measurements, each area was measured three times, and the criterion was the total mean. One person did all measurements with sufficient training to work with calipers (Shirzad, 2021). At first, the specified parts' height, weight, and fat thickness were measured using a Harpenden caliper with an accuracy of 0.2 mm.

**Muscular endurance:** The sit-up test measured muscular endurance in one minute. The highest number of repetitions was recorded as a record in one minute. In short, the hands were crossed over the shoulders, and the athlete had to reach the elbows to the knees without lifting the hips and then turn back and hit the ground behind the shoulders (Gibson et al., 2024).

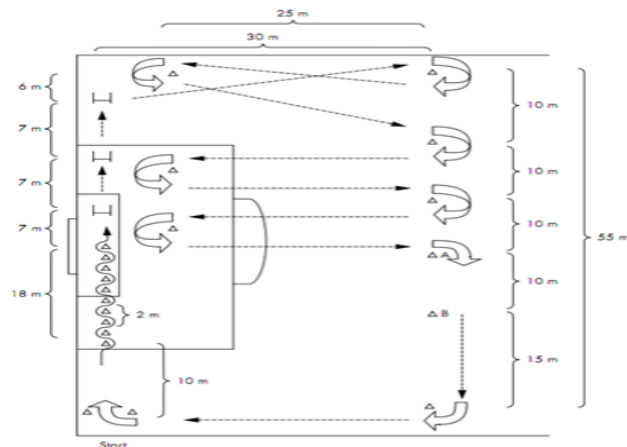


Figure 2. Each player must carry the ball in the path that has been determined. The rehearsal area is 35 meters wide and 55 meters long. The player must move the distance between cones A to B backward (Gharahdaghi et al., 2013).

**Table 2.** Mean  $\pm$  SD of muscular endurance (Sit-Ups), 20 m speed test (s), Sargent jump test (cm), Rast anaerobic power test (w), post-testing.

		Pre-Test	Post-Test	P-value
		Mean $\pm$ Sd	Mean $\pm$ Sd	
Muscular Endurance (Sit-Ups)	EXE-SUB	56.28 $\pm$ 3.29	60.14 $\pm$ 2.11	*0.001
	EXE-PLA	53.64 $\pm$ 2.87	58.91 $\pm$ 1.91	*0.001
	Supplementation	55.32 $\pm$ 2.17	56.14 $\pm$ 2.08	0.112
	Control	57.07 $\pm$ 2.19	59.56 $\pm$ 2.19	0.151
20 m Speed test (s)	EXE-SUB	3.42 $\pm$ 0.36	2.98 $\pm$ 0.22	0.447
	EXE-PLA	3.64 $\pm$ 0.75	3.02 $\pm$ 0.55	0.192
	Supplementation	3.39 $\pm$ 0.81	3.30 $\pm$ 0.89	0.331
	Control	3.22 $\pm$ 0.64	3.13 $\pm$ 0.88	0.210
Sargent Jump test (cm)	EXE-SUB	51.42 $\pm$ 4.76	54.08 $\pm$ 3.43	0.220
	EXE-PLA	49.42 $\pm$ 3.42	55.10 $\pm$ 2.22	0.255
	Supplementation	52.20 $\pm$ 3.74	54.13 $\pm$ 2.51	0.174
	Control	52.65 $\pm$ 3.20	53.43 $\pm$ 2.07	0.136
Rast anaerobic power test (w)	EXE-SUB	519.68 $\pm$ 7.54	725.21 $\pm$ 5.08	*0.006
	EXE-PLA	526.4 $\pm$ 5.33	722.41 $\pm$ 4.13	0.159
	Supplementation	512.4 $\pm$ 4.3	597.16 $\pm$ 3.22	0.223
	Control	535.34 $\pm$ 7.22	527.49 $\pm$ 6.91	0.451

\*indicates a significant difference from pre- to pos-testing ( $p < 0.05$ )

**RAST anaerobic power test:** The RAST test measured power indices (peak power, mean power, minimum power, and fatigue index). Two pairs of photocells were placed at the start and end line of 35 meters. The subject stood at a distance of 70 cm from the starting line in each repetition and started running at maximum speed with the sound of the machine's horn at the end, after passing in front of the optical eye, the timer stopped, and the device recorded the person's record. The subject ran this distance 6 times at full speed and rested for 10 seconds between each run stage (Abbasian et al., 2012).

**Sargent Jump (Vertical Jump):** To perform this test, the subject first stands by the wall in a profile position and then raises his upper hand and marks on the wall with his middle finger so that his height is recorded in a unique form with his hand outstretched (without a stroke). Then, the subject would bend his knees about 90 degrees in a standing position next to the wall, immediately jump vertically upwards with a quick leap, and touch the wall with his hand at the peak of the jump. Each subject performed this movement thrice, his best record was recorded (Chaouachi et al., 2010).

**20 m Speed Test:** This test measures athletes' speed at a distance of 20 meters. To ensure the best effort is made, it is conducted in a two-on-two and competitive manner (Gisladdottir et al., 2024).

**Borg Rate of Perceived Exertion Scale:** This scale evaluated

subjects' perception of pressure. The scale scored 6, which indicates very light activity and feeling the least pressure, and 20, which shows tough activity and feeling the most pressure. The individual responds to this scale on a self-reported basis (Teixeira et al., 2024). To determine the players' training pressure, the pressure perception index was taken from the players in the pre-test and post-test stages immediately after the end of the training protocol.

### Statistical analysis

Indices of central tendency and dispersion were used to describe the findings. The Shapiro-Wilk test was used to check the normality of the data, and the Levene test was used to check the equality of variance of the variables. The repeated measures ANOVA test with the between-group factor was used to compare the groups. Data analysis was performed using SPSS version 27 software, and the significance level was set at  $P \leq 0.05$ .

### Results

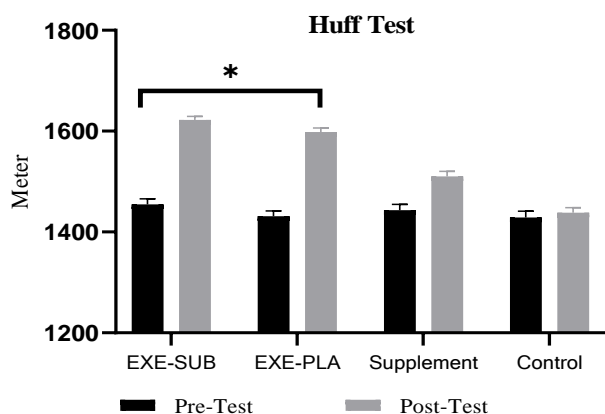
Tables 1 and 2 present the findings related to the soccer players' physical tests group in the four groups of exercise-supplementation, placebo exercise group, supplementation group, and control group in two stages: pre-test and post-test. In Table 2, the skinfold thickness of the subjects is presented in seven sites.

The normality of the data distribution of all variables in the present

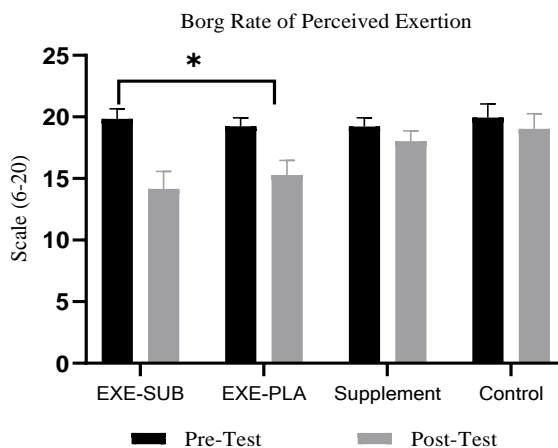
study was confirmed using the Shapiro-Wilk test ( $P < 0.05$ ). The results of the repeated ANOVA test showed a significant difference in aerobic power, anaerobic power, muscular endurance, and fatigue perception index between the exercise-placebo and exercise groups with supplementation. However, there was no statistically significant difference between the supplementation and control groups between the variables of aerobic power, anaerobic power, muscular endurance, 20 m speed, and fatigue perception index ( $P > 0.05$ ). The results of the Huff aerobic test in (Figure 3) show the mean and standard deviation. According to the results of the repeated ANOVA test with intergroup factor, there was no significant difference between the four groups in the Huff aerobic test. However, there was a significant difference within the group in the exercise-supplementation and placebo exercise groups. Furthermore, the exercise-supplementation and exercise-placebo groups showed a significant improvement in the Huff aerobic test compared to the pre-test results. The results of the Exercise Fatigue Perception Index showed that the exercise-supplementation and placebo groups experienced a reduction in fatigue, and there was a statistically significant difference. In addition, no significant difference was observed between the groups after examining the repeated ANOVA test with the intergroup factor (Figure 4). The results of the groups' mean anaerobic power (RAST) showed a significant difference between the exercise-supplementation and placebo exercise groups (Figure 5 A). In addition, the results of the fatigue percentage of the RAST anaerobic test in (Figure 5 B) showed no significant difference. In contrast, the players' fatigue decreased in the Exercise-supplementation, placebo exercise, and supplementation groups.

## Discussion

This study investigated the effect of a training system (USRPT) combined with beta-alanine supplementation on young soccer pl-

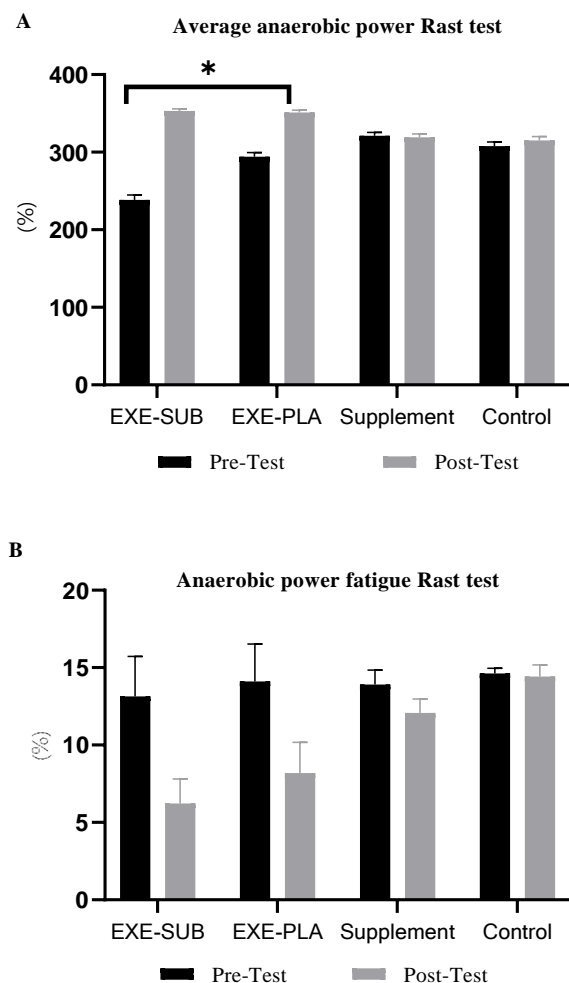


**Figure 3.** Mean  $\pm$  SD values for Huff test (m), Exercise Placebo group ( $n = 11$ ), supplementation group ( $n = 11$ ), Exercise-supplementation group ( $n = 11$ ), control group ( $n = 11$ ). \*indicates a significant difference from pre- to post-testing ( $p < 0.05$ ).



**Figure 4.** Mean  $\pm$  SD values for Borg Rate of Perceived Exertion Scale (20-6), Exercise Placebo group ( $n = 11$ ), supplementation group ( $n = 11$ ), Exercise-supplementation group ( $n = 11$ ), control group ( $n = 11$ ) \*indicates a significant difference from pre- to post-testing ( $p < 0.05$ ).

-ayers' aerobic and anaerobic performance indices. The results of the present study showed a significant difference in the exercise (USRPT) group - placebo and Exercise (USRPT) along with beta-alanine supplementation on aerobic power, anaerobic power, muscular endurance, and reduction of fatigue in soccer players. However, no significant difference was observed in the control group and the beta-alanine supplementation -only group on the indices of aerobic power, anaerobic power, muscle endurance, 20-meter sprint speed, explosive power, and rate of perceived exertion. One of the main reasons for the lack of effectiveness of beta-alanine supplementation in the present study is the short duration of loading (7 days), as previous studies that examined the positive effect of the supplement on reducing fatigue emphasized the length of the loading period (Saunders et al., 2017; Stout et al., 2007). Limitations beyond the study's control: Lack of control over lifestyle, genetic characteristics, lack of control over sleep quality, and fatigue of the subjects may affect some factors. To minimize these limitations, the subjects were given the necessary advice a week in advance, and an attempt was made to place all subjects in the same conditions regarding physical activity, diet, food control, and careful control of fatigue and sleep quality. The process of beta-alanine's effect itself has only limited ergogenic effects (Raizel et al., 2019), and it appears that the ergogenic effects associated with beta-alanine are related to an increase in muscle carnosine content. With its  $H^+$  hydrogen-ion buffer capacity, Carnosine plays an important role in maintaining intracellular acid-base homeostasis (Ostfeld & Hoffman, 2023). Therefore, by increasing the carnosine content in skeletal muscle, beta-alanine Supplementation increases intracellular buffering capacity and provides greater tolerance or delay in muscle fatigue during sustained anaerobic activity (Artioli et al., 2010; Hoffman et al., 2018; Varanoske et al., 2019). Beta-



**Figure 5.** Mean  $\pm$  SD values for Average anaerobic power (w/kg) and fatigue (%), Exercise Placebo group (n = 11), supplementation group (n = 11), Exercise-supplementation group (n = 11), control group (n = 11). \*indicates a significant difference from pre- to post-testing ( $p < 0.05$ ).

alanine itself is ineffective as an antioxidant (Boldyrev et al., 2010; Boldyrev et al., 2013; Decker et al., 2000), but its ability to increase tissue carnosine content may lead to a reduction in oxidative stress response, inflammation, and muscle damage (Packer, 1997). Supplementation, without lactic training, probably does not affect performance. Supporting this, the results of Hoffman et al.'s research did not report a positive effect with beta-alanine supplementation for 4 weeks, 4.5 grams of supplementation per day (Hoffman et al., 2008). However, the dosage of the supplementation, as well as the level and type of sport, can play a role in the effect size of supplementation use. For example, a study observed that taking beta-alanine 4.8 grams daily for 4 weeks reduced fatigue during repeated bouts of Exercise in 400-meter runners (Derave et al., 2007). In confirming the role of beta-alanine supplementation dosage, the researchers concluded from a review of the studies that an average beta-alanine loading of 170 grams significantly improved athletic performance

(Hobson et al., 2012). Therefore, the short time supplementation period in the present study, in line with the research of Hoffman et al., can be considered as the possible reason for the lack of results in improving buffering capacity and reducing neuromuscular fatigue in the supplement group (Hoffman et al., 2008). Also, in a study by Saunders et al. (2012) investigating the effect of beta-alanine supplementation on soccer players, it was shown that consuming 4 mg of beta-alanine 4 times a day at 3-4 hours intervals for 12 weeks improved the aerobic power of the exercise-supplementation group. Also, the players' speed performance increased significantly compared to before. Therefore, the results of the present study are not in line with the research of Saunders et al., and no significant difference in the 20-meter speed performance of the groups was observed (Saunders et al., 2012). Rosas et al. (2017), a double-blind, placebo-controlled study, tested beta-alanine supplementation in 16 soccer athletes with 4.8 grams per day in 6 doses every 2 hours over 6 weeks and reported significant improvements in jump and speed performance compared to the control group. Therefore, the present study's speed and jump results are inconsistent with Rosas et al.'s research (Rosas et al., 2017). The results of the present study are in line with the results of the study of reduction in perceived exertion between the exercise supplementation and exercise-placebo groups. They showed that beta-alanine consumption may lead to increased time to exhaustion in performing muscle endurance activity and improved aerobic capacity in elite rowers by delaying lactate accumulation (Gharaat et al., 2020). This research showed that beta-alanine consumption could delay fatigue through its effect on intramuscular pH buffering. Therefore, consuming low and high doses of beta-alanine supplementation can significantly reduce perceived exertion. Also, there was a greater reduction in fatigue in the exercise-supplementation group than in the exercise-placebo, supplementation, and control group (Behpoor & Yoosefi, 2017). Glenn et al. (2014) investigated the effect of Wingate training combined with acute consumption of 6 grams of beta-alanine supplementation on perceived exertion and heart rate in female cyclists and found no significant difference in improving performance and heart rate in athletes; however, perceived exertion decreased significantly. As a result, 6 grams of beta-alanine supplementation reduced perceived exertion in female cyclists and is not consistent with the results of the present study in the supplementation group (Glenn et al., 2015). Considering the training group's (USRPT) results in the present study, there was a significant difference in aerobic power, anaerobic power, muscular endurance, and reduced perception of pressure to the training protocol. Therefore, it seems that a proper training system can increase aerobic and anaerobic capacity and performance and reduce fatigue. Interval training with short work periods, short rest periods, and high intensity, such as the USRPT training system, can lead to performance development of

athletes (Åstrand et al., 1960; Goldsmith, 2016; Stott, 2012). The USRPT system increases the amount of oxygen that can be used at a certain level of intensity from Exercise. This is one of the most important advantages of using USRPT compared to traditional training methods, which explains the lower fatigue (Shirzad, 2021). Aerobic exercise can cause cross-talk between different metabolic pathways. For example, exercise can stimulate muscle tissue signals, leading to increased insulin sensitivity and improved glucose metabolism. This effect can also indirectly affect other tissues (Pedersen & Febbraio, 2012). In support of this, a study implementing the USRPT training system on female basketball players showed a significant difference in players' speed and perceived exertion (Gibson et al., 2024). Therefore, based on the findings of the present study, it can be said that beta-alanine supplementation probably reduces fatigue by affecting intramuscular pH and improving athletic performance, especially perceived exertion (Hobson et al., 2012). On the other hand, the players' performance improved with beta-alanine supplementation, but there was no statistically significant difference in the control group. Considering the importance of aerobic capacity, anaerobic capacity, performance tests, and delaying fatigue in sports fields, it seems that beta-alanine supplementation can be helpful. According to the results of the present study, it is hoped that new insights will be generated in elite sports, performance improvement, and fatigue delay. However, beta-alanine and Carnosine are intracellular buffers requiring tissue biopsies to measure, which was impossible due to limitations. Also, it is necessary that in future research, if possible, their muscle lactate levels be measured. This is because anaerobic testing results in lactic acid accumulation, and measuring blood lactate can also be helpful in future research (Helgerud, 1994). Aerobic exercise and supplements work together to improve health and function. Cross-talk between signaling pathways in the body enhances the mutual effects of exercise and Supplementation and helps us better understand these processes.

## Conclusion

The findings of this study showed that the USRPT training system is an effective method for increasing aerobic and anaerobic power in soccer players. This method helps to improve  $VO_{2max}$  and reduce fatigue by creating physiological adaptations. Also, taking beta-alanine Supplementation along with this training system can significantly reduce or delay fatigue and improve performance. Coaches and professionals can use beta-alanine Supplementation as an energy-boosting agent to increase performance and minimize athlete fatigue.

## What is already known on this subject?

One of the high-intensity interval training systems first used by

swimming coaches as an effective method to improve swimmers' endurance performance is race-pace training for very short distances USRPT. This training system was implemented for the first time in soccer. Researchers have reported that beta-alanine has ergogenic effects on athletic performance (9), and its impact on exercise-induced fatigue has been investigated (10). This has been confirmed by observing higher concentrations of Carnosine in highly stressed muscle cells, which experience the most significant  $H^+$  accumulation during intense physical activity due to beta-alanine supplementation. Beta-alanine may act as a cellular buffer to reduce acidity in active muscles during high-intensity Exercise by increasing muscle carnosine levels.

## What does this study add?

Enhancing the muscle cell buffering system through anaerobic training and specialized supplementation has improved athletic performance, particularly among soccer players. However, the effects of various training protocols and specific types of supplementation on enhancing the muscle cell buffering system and athlete performance are still questionable. This study aims to investigate the effectiveness of the USRPT training system combined with beta-alanine supplementation on the physical performance of elite young soccer players.

### Organ Cross-Talk Tips:

- Effective tissue-organ crosstalk facilitated by targeted supplementation like beta-alanine can significantly enhance athletic performance, particularly in sports requiring high-intensity efforts, such as soccer.

## Acknowledgements

We wish to thank our participants for their time and effort.

## Funding

No sources of funding were sought or awarded for this study.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This study's procedures were carried out under the Helsinki Statement regarding human research. Participants also signed an informed consent form before participation.

**Informed consent** Participants signed an informed consent form prior to participation in the study.

## Author contributions

Conceptualization: M.A.F., H.R., R.N.; Methodology: M.A.F., H.R.

R.N.; Software: M.A.F., H.R., R.N.; Validation: H.R., Formal analysis: M.A.F., H.R., R.N.; Investigation: M.A.F., H.R., R.N.; Resources: M.A.F., H.R., R.N.; Data curation: H.R.; Writing - original draft: M.A.F., H.R., R.N.; Writing - review & editing: M.A.F., H.R., R.N.; Visualization: M.A.F., H.R., R.N.; Supervision: H.R. Project administration: H.R.; Funding acquisition: H.R.

## References

- A. Hawley, J., Myburgh, K., Noakes, T. D., & Dennis, S. (1997). Training techniques to improve fatigue resistance and enhance endurance performance. *Journal of Sports Sciences*, 15(3), 325-333. <https://doi.org/10.1080/026404197367335>
- Abbasian, S., Golzar, S., Onvani, V., & Sargazi, L. (2012). The predict of RAST Test from WANT test in Elite Athletes. *Research Journal of Recent Sciences*, 2277, 2502. [https://www.isca.me/rjrs/archive/v1i3/11.ISCA-RJRS-2012-044\\_Done.pdf](https://www.isca.me/rjrs/archive/v1i3/11.ISCA-RJRS-2012-044_Done.pdf)
- Artioli, G. G., Gualano, B., Smith, A., Stout, J., & Lancha Jr, A. H. (2010). Role of beta-alanine supplementation on muscle carnosine and exercise performance. *Med Sci Sports Exerc*, 42(6), 1162-1173. <https://doi.org/10.1249/MSS.0b013e3181c74e38>
- Åstrand, I., Åstrand, P. O., Christensen, E. H., & Hedman, R. (1960). Intermittent muscular work. *Acta Physiologica Scandinavica*, 48(3-4), 448-453. <https://doi.org/10.1111/j.1748-1716.1960.tb01879.x>
- Behpoor, N., & Yoosefi, S. (2017). The Effect of  $\beta$ -Alanine Supplementation on Serum Lactate Response and Muscular Endurance in Male Bodybuilders. *Iranian Journal of Nutrition Sciences & Food Technology*, 12(2), 19-26. [https://nsft.sbmu.ac.ir/browse.php?a\\_id=2280&sid=1&slc\\_lang=en](https://nsft.sbmu.ac.ir/browse.php?a_id=2280&sid=1&slc_lang=en)
- Boldyrev, A., Stvolinsky, S., Fedorova, T., & Suslina, Z. (2010). Carnosine as a natural antioxidant and geroprotector: from molecular mechanisms to clinical trials. *Rejuvenation Research*, 13(2-3), 156-158. <https://doi.org/10.1089/rej.2009.0923>
- Boldyrev, A. A., Aldini, G., & Derave, W. (2013). Physiology and pathophysiology of carnosine. *Physiological reviews*. <https://doi.org/10.1152/physrev.00039.2012>
- C. Harris, R., Dunnett, M., & Greenhaff, P. L. (1998). Carnosine and taurine contents in individual fibres of human vastus lateralis muscle. *Journal of Sports Sciences*, 16(7), 639-643. <https://doi.org/10.1080/026404198366443>
- Chamari, K., Hachana, Y., Kaouech, F., Jeddi, R., Moussa-Chamari, I., & Wisløff, U. (2005). Endurance training and testing with the ball in young elite soccer players. *British journal of sports medicine*, 39(1), 24-28. <https://doi.org/10.1136/bjism.2003.009985>
- Chamari, K. a., Hachana, Y., Ahmed, Y., Galy, O., Sghaier, F., Chatard, J., Hue, O., & Wisløff, U. (2004). Field and laboratory testing in young elite soccer players. *British journal of sports medicine*, 38(2), 191-196. <https://doi.org/10.1136/bjism.2002.004374>
- Chaouachi, A., Castagna, C., Chtara, M., Brughelli, M., Turki, O., Galy, O., Chamari, K., & Behm, D. G. (2010). Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals. *The Journal of Strength & Conditioning Research*, 24(8), 2001-2011. <https://doi.org/10.1519/JSC.0b013e3181aeb181>
- Cuenca-Fernández, F., Boullosa, D., Ruiz-Navarro, J. J., Gay, A., Morales-Ortiz, E., López-Contreras, G., & Arellano, R. (2023). Lower fatigue and faster recovery of ultra-short race pace swimming training sessions. *Research in Sports Medicine*, 31(1), 21-34. <https://doi.org/10.1080/15438627.2021.1929227>
- Decker, E., Livisay, S., & Zhou, S. (2000). A re-evaluation of the antioxidant activity of purified carnosine. *BIOCHEMISTRY C/C OF BIOKHMIIIA*, 65(7), 766-770. <https://pubmed.ncbi.nlm.nih.gov/10951093/>
- Derave, W., Özdemir, M. S., Harris, R. C., Pottier, A., Reyngoudt, H., Koppo, K., Wise, J. A., & Achten, E. (2007).  $\beta$ -Alanine supplementation augments muscle carnosine content and attenuates fatigue during repeated isokinetic contraction bouts in trained sprinters. *Journal of applied physiology*. <https://doi.org/10.1152/jappphysiol.00397.2007>
- Dinarvand, A., Sharifi, G., & Davood, M. (2024). A review of the role of beta-alanine supplementation in football. *Journal of Physiology of Movement & Health*, 2(4), 51-61. <http://sanad.iau.ir/fa/Article/1118920>
- Dishman, R. K., Berthoud, H. R., Booth, F. W., Cotman, C. W., Edgerton, V. R., Fleshner, M. R., Gandevia, S. C., Gomez-Pinilla, F., Greenwood, B. N., Hillman, C. H., Kramer, A. F., Levin, B. E., Moran, T. H., Russo-Neustadt, A. A., Salamone, J. D., Van Hoomissen, J. D., Wade, C. E., York, D. A., & Zigmond, M. J. (2006). Neurobiology of exercise. *Obesity (Silver Spring)*, 14(3), 345-356. <https://doi.org/10.1038/oby.2006.46>
- Gharaat, M. A., Kashef, M., Eidi Abarghani, L., & Sheykhloovand, M. (2020). Effect of beta alanine on lactate level and Specific performance of elite male rowers. *Journal of Sabzevar University of Medical Sciences*, 27(1), 73-81. [https://jsums.medsab.ac.ir/article\\_1273.html?lang=en](https://jsums.medsab.ac.ir/article_1273.html?lang=en)
- Gharahdaghi, N., Kordi, M. R., & Gaeini, A. A. (2013). The Effect of Four Weeks of High Intensity Aerobic Interval Training (Hoff) on VO<sub>2</sub>max, T<sub>max</sub> and vVO<sub>2</sub>max in Iranian Soccer Players. *Journal of Sport Biosciences*, 5(2), 47-57. [https://jsb.ut.ac.ir/article\\_35039.html](https://jsb.ut.ac.ir/article_35039.html)
- Gibson, A. L., Wagner, D. R., & Heyward, V. H. (2024). Advanced fitness assessment and exercise prescription. *Human kinetics*. <https://us.humankinetics.com/products/advanced-fitness-assessment-and-exercise-prescription-9th-edition-ebook-with-hkpropel-online-video>
- Gisladdottir, T., Petrović, M., Sinković, F., & Novak, D. (2024). The relationship between agility, linear sprinting, and vertical jumping performance in U-14 and professional senior team sports players. *Frontiers in sports and active living*, 6, 1385721. <https://doi.org/10.3389/fspor.2024.1385721>

- Gleeson, M., Bishop, N. C., Stensel, D. J., Lindley, M. R., Mastana, S. S., & Nimmo, M. A. (2011). The anti-inflammatory effects of exercise: mechanisms and implications for the prevention and treatment of disease. *Nat Rev Immunol*, 11(9), 607-615. <https://doi.org/10.1038/nri3041>
- Glenn, J. M., Smith, K., Moyon, N. E., Binns, A., & Gray, M. (2015). Effects of acute beta-alanine supplementation on anaerobic performance in trained female cyclists. *Journal of nutritional science and vitaminology*, 61(2), 161-166. <https://doi.org/10.3177/jnsv.61.161>
- Goldsmith, W. (2016). The distance debate: how much swim training should we be doing. *Swimming World Magazine*.
- Helgerud, J. (1994). Maximal oxygen uptake, anaerobic threshold and running economy in women and men with similar performances level in marathons. *European journal of applied physiology and occupational physiology*, 68, 155-161. <https://doi.org/10.1007/BF00244029>
- Helgerud, J., Engen, L. C., Wisløff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine & Science in Sports & Exercise*, 33(11), 1925-1931. <https://doi.org/10.1097/00005768-200111000-00019>
- Hill, C. A., Harris, R. C., Kim, H. J., Harris, B. D., Sale, C., Boobis, L. H., Kim, C. K., & Wise, J. A. (2007). Influence of  $\beta$ -alanine supplementation on skeletal muscle carnosine concentrations and high intensity cycling capacity. *Amino acids*, 32, 225-233. <https://doi.org/10.1007/s00726-006-0364-4>
- Hobson, R. M., Saunders, B., Ball, G., Harris, R., & Sale, C. (2012). Effects of  $\beta$ -alanine supplementation on exercise performance: a meta-analysis. *Amino acids*, 43, 25-37. <https://doi.org/10.1007/s00726-011-1200-z>
- Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British journal of sports medicine*, 36(3), 218-221. <https://doi.org/10.1136/bjism.36.3.218>
- Hoffman, J. R., Ratamess, N. A., Faigenbaum, A. D., Ross, R., Kang, J., Stout, J. R., & Wise, J. A. (2008). Short-duration  $\beta$ -alanine supplementation increases training volume and reduces subjective feelings of fatigue in college football players. *Nutrition research*, 28(1), 31-35. <https://doi.org/10.1016/j.nutres.2007.11.004>
- Hoffman, J. R., Varanoske, A., & Stout, J. R. (2018). Effects of  $\beta$ -alanine supplementation on carnosine elevation and physiological performance. *Advances in Food and Nutrition Research*, 84, 183-206. <https://doi.org/10.1016/bs.afnr.2017.12.003>
- Impellizzeri, F. M., Rampinini, E., Maffiuletti, N. A., Castagna, C., Bizzini, M., & Wisløff, U. (2008). Effects of aerobic training on the exercise-induced decline in short-passing ability in junior soccer players. *Applied Physiology, Nutrition, and Metabolism*, 33(6), 1192-1198. <https://doi.org/10.1139/H08-111>
- Karp, J. R. (2000). Interval training for the fitness professional. *Strength & Conditioning Journal*, 22(4), 64. <https://doi.org/10.1519/00126548-200008000-00021>
- MacDougall, J. D., Hicks, A. L., MacDonald, J. R., McKelvie, R. S., Green, H. J., & Smith, K. M. (1998). Muscle performance and enzymatic adaptations to sprint interval training. *Journal of applied physiology*, 84(6), 2138-2142. <https://doi.org/10.1152/jappl.1998.84.6.2138>
- Keyhanian, A., Ebrahim, K., Rajabi, H., & Marandi, S. M. (2015). Comparison the effect of resistance exercise with active and passive rest on aerobic and anaerobic fitness in soccer players. *Research in Sport Medicine and Technology*, 13(9), 47-62. <https://doi.org/10.18869/acadpub.jsmt.13.9.47>
- Maté-Muñoz, J. L., Lougedo, J. H., Garnacho-Castaño, M. V., Veiga-Herreros, P., Lozano-Estevan, M. d. C., García-Fernández, P., de Jesús, F., Guodemar-Pérez, J., San Juan, A. F., & Domínguez, R. (2018). Effects of  $\beta$ -alanine supplementation during a 5-week strength training program: a randomized, controlled study. *Journal of the International Society of Sports Nutrition*, 15, 1-12. <https://doi.org/10.1186/s12970-018-0224-0>
- McMillan, K., Helgerud, J., Macdonald, R., & Hoff, J. (2005). Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British journal of sports medicine*, 39(5), 273-277. <https://doi.org/10.1136/bjism.2004.012526>
- Mohr, M., Krstrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences*, 21(7), 519-528. <https://doi.org/10.1080/0264041031000071182>
- Nugent, F., Comyns, T., Kearney, P., & Warrington, G. (2019). Ultra-Short Race-Pace Training (USRPT) In Swimming: Current Perspectives. *Open Access J Sports Med*, 10, 133-144. <https://doi.org/10.2147/oajsm.S180598>
- Ostfeld, I., & Hoffman, J. R. (2023). The effect of  $\beta$ -alanine supplementation on performance, cognitive function and resiliency in soldiers. *Nutrients*, 15(4), 1039. <https://doi.org/10.3390/nu15041039>
- Packer, L. (1997). Oxidants, antioxidant nutrients and the athlete. *Journal of Sports Sciences*, 15(3), 353-363. <https://doi.org/10.1080/026404197367362>
- Pedersen, B. K., & Febbraio, M. A. (2012). Muscles, exercise and obesity: skeletal muscle as a secretory organ. *Nat Rev Endocrinol*, 8(8), 457-465. <https://doi.org/10.1038/nrendo.2012.49>
- Raizel, R., Coqueiro, A. Y., Bonvini, A., & Tirapegui, J. (2019). Sports and energy drinks: Aspects to consider. In *Sports and energy drinks* (pp. 1-37). Elsevier. <https://doi.org/10.1016/B978-0-12-815851-7.00001-2>
- Rosas, F., Ramírez-Campillo, R., Martínez, C., Caniunqueo, A., Cañas-Jamet, R., McCrudden, E., Meylan, C., Moran, J., Nakamura, F. Y., & Pereira, L. A. (2017). Effects of plyometric training and beta-alanine supplementation on maximal-intensity exercise and endurance in female soccer players. *Journal of human kinetics*, 58(1), 99-109. <https://doi.org/10.1515/hukin-2017-0072>
- Rushall, B. (2011). Swimming energy training in the 21st century: the justification for radical changes. *Swimming Sci Bull*, 39, 1-59.

Rushall, B. (2018). Step-by-step USRPT planning and decision-making processes and examples of USRPT training sessions, microcycles, macrocycles, and technique instruction. *Swimming Sci Bull*, 47, 1-67. <https://coachsci.sdsu.edu/swim/bullets/47GUIDE.pdf>

Rushall, B. (2016). USRPT defined: after two years USRPT comes of age. *Swimming Sci Bull*, 49, 1-17.

Rushall, B. (2013). Understanding a USRPT set. *Swimming Sci Bull*, 45, 1-4.

Saunders, B., Elliott-Sale, K., Artioli, G. G., Swinton, P. A., Dolan, E., Roschel, H., Sale, C., & Gualano, B. (2017).  $\beta$ -alanine supplementation to improve exercise capacity and performance: a systematic review and meta-analysis. *Br J Sports Med*, 51(8), 658-669. <https://doi.org/10.1136/bjsports-2016-096396>

Saunders, B., Sunderland, C., Harris, R. C., & Sale, C. (2012).  $\beta$ -alanine supplementation improves YoYo intermittent recovery test performance. *Journal of the International Society of Sports Nutrition*, 9, 1-5. <https://doi.org/10.1186/1550-2783-9-39>

Sheikholeslami-Vatani, D., Bolurian, M. R., & Rahimi, R. (2016). Acute effects of different doses of beta-alanine supplement on neuromuscular fatigue and lactate accumulation after intense interval exercise. [https://umj.umsu.ac.ir/browse.php?a\\_id=2842&sid=1&slc\\_lang=en](https://umj.umsu.ac.ir/browse.php?a_id=2842&sid=1&slc_lang=en)

Shirzad, E. (2021). A new model for talent identification in karate based on artificial intelligence algorithms. *Research in Sport Medicine and Technology*, 19(21), 37-54. <https://doi.org/10.29252/jsmt.19.1.37>

Stott, M. (2012). The case for less volume. *Swimming Technique Magazine*. Phoenix, AZ: Sports Publications Inc, 29-30.

Stout, J., Cramer, J., Zoeller, R., Torok, D., Costa, P., Hoffman, J., Harris, R., & O'kroy, J. (2007). Effects of  $\beta$ -alanine supplementation on the onset of neuromuscular fatigue and ventilatory threshold in women. *Amino acids*, 32(3), 381-386. <https://doi.org/10.1007/s00726-006-0474-z>

Sweeney, K. M., Wright, G. A., Brice, A. G., & Doberstein, S. T. (2010). The effect of  $\beta$ -alanine supplementation on power performance during repeated sprint activity. *The Journal of Strength & Conditioning Research*, 24(1), 79-87. <https://doi.org/10.1519/JSC.0b013e3181c63bd5>

Teixeira, J. E., Encarnação, S., Branquinho, L., Ferraz, R., Portella, D. L., Monteiro, D., Morgans, R., Barbosa, T. M., Monteiro, A. M., & Forte, P. (2024). Classification of recovery states in U15, U17, and U19 sub-elite football players: a machine learning approach. *Front Psychol*, 15, 1447968. <https://doi.org/10.3389/fpsyg.2024.1447968>

Varanoske, A. N., Stout, J. R., & Hoffman, J. R. (2019). Effects of  $\beta$ -alanine supplementation and intramuscular carnosine content on exercise performance and health. In *Nutrition and enhanced sports performance* (pp. 327-344). Elsevier. <https://doi.org/10.1016/bs.afnr.2017.12.003>