Journal of Sports for All and Recreation
Herkes için Spor ve Rekreasyon Dergisi

2024, 6(2)
Araştırma Makalesi / Research Article

e-ISSN: 2687-6027

The Combined Effect of Glutamine and Creatine Supplementation on Body Hydration Level and Some Performance Parameters in Football Players

Futbolcularda Glutamin ve Kreatin Suplementasyonunun Vücut Hidrasyon Düzeyi ve Bazı Performans Parametrelerine Kombine Etkisi

Ahmet Mor[1], **Fatih Karakaş**[2], **Ali Kerim Yılmaz**[3], ***Hakkı Mor**[4], **Kürşat Acar**[5], **Erkal Arslanoğlu**[6]

[1] Sinop Üniversitesi, Spor Bilimleri Fakültesi, amor@sinop.edu.tr, 0000-0002-1181-1111
[2] Ondokuz Mayıs Üniversitesi, Çarşamba Ticaret Borsası Meslek Yüksekokulu, fatih.karakas@omu.edu.tr, 0000-0002-3366-7587
[3] Ondokuz Mayıs Üniversitesi, Yaşar Doğu Spor Bilimleri Fakültesi, akerim.yilmaz@omu.edu.tr, 0000-0002-0046-6711
[4] Ondokuz Mayıs Üniversitesi, Yaşar Doğu Spor Bilimleri Fakültesi, hakki.mor@omu.edu.tr, 0000-0003-0810-1909
[5] Sinop Üniversitesi, Spor Bilimleri Fakültesi, kursatacar@sinop.edu.tr, 0000-0001-8908-4404
[6] Sinop Üniversitesi, Spor Bilimleri Fakültesi, erkaloglu@sinop.edu.tr, 0000-0003-2066-0682

ABSTRACT

The aim of this study was to investigate the combined effect of glutamine (GLU) and creatine (CRE) supplementation on body composition, body hydration levels, and selected performance parameters in football players. Eight volunteer licensed male football players aged 19 to 23 participated in this study. The study was randomized and single-blinded. In the study, athletes were administered 10 g of glutamine and creatine before and after training for seven days. Some tests, measurements, and analyses were performed in equal physical conditions with seven-day intervals using a pre-test/post-test experimental design. The research data were analyzed with a dependent sample t-test. In the comparison of the parameters pre- and post-supplementation, statistically significant differences were found in body mass, skeletal muscle mass, total body water, body mass index (BMI), metabolic rate, protein, and mineral values ($p<0.05$). The study demonstrated that glutamine and creatine nutritional supplements positively affected balance, reaction time, Illinois agility test (IAT), vertical jump (VJ), and anaerobic power parameters, as well as body composition and body hydration level in football players. Furthermore, it was found to have a positive ergogenic effect on parameters such as lean body mass, total body water, metabolic rate, and increased performance without increasing the rating of perceived exertion (RPE). In conclusion, considering these results, it can be said that coaches and athletes can use the combined consumption of glutamine and creatine as practical nutritional support in training to achieve health and high performance.

Keywords: Glutamine, Creatine, Hydration, Body Composition, Football.

ÖZET

Bu çalışmanın amacı futbolcularda glutamin&kreatin suplementasyonunun vücut kompozisyonu ve vücut hidrasyon düzeyi ile birlikte, bazı performans parametrelerine kombine etkisini araştırmaktır. Bu çalışmaya, 19-23 yaş grubu, lisanslı aktif futbol oynayan antrenmanlı 8 gönüllü erkek futbolcu katılmıştır. Çalışma randomize ve tek kör olarak tasarlanmıştır. Çalışmada sporculara 7 gün boyunca antrenmandan önce ve sonra 10 g glutamin&kreatin verilmiştir. Sporculara iki basamaklı ön test-son test deneysel model kullanılarak 7 gün ara ile eşit fiziki şartlarda bazı testler, ölçümler ve analizler yapılmıştır. Araştırma verileri bağımlı örneklem t-test ile analiz edilmiştir. Çalışmanın antrenman öncesi ve sonrası elde edilen ön test parametreleri karşılaştırıldığında, toplam reaksiyon zamanı ve hidrasyon testleri sonuçlarına göre iki grup arasında istatistiksel olarak anlamlı farklılık bulunmuştur ($p<0,05$). Antrenman öncesi ve sonrası elde edilen son test parametreleri karşılaştırıldığında ise, hidrasyon testi sonuçlarına göre iki grup arasında istatistiksel olarak anlamlı farklılık bulunmuştur ($p<0,05$). Araştırmada suplementasyon öncesi ve sonrası parametreler karşılaştırıldığında, vücut ağırlığı, iskelet kası ağırlığı, toplam vücut suyu, beden kütle indeksi (BKİ), metabolik hız, protein ve mineral değerlerinde istatistiksel olarak anlamlı farklılık tespit edilmiştir ($p<0,05$). Araştırma sonucunda, glutamin&kreatin besin takviyelerinin futbolcularda vücut kompozisyonu ve vücut hidrasyon düzeyi ile denge, reaksiyon zamanı, çeviklik, dikey sıçrama ve anaerobik güç parametrelerinde olumlu etki ettiği tespit edilmiştir. Bunun yanında, yağsız vücut kütlesi, toplam vücut suyu, metabolik hız gibi parametrelere de olumlu bir ergojenik etkiye sahip olduğu ve algılanan zorluk derecesini (AZD) artırmadan performans artışı sağladığını belirtebiliriz. Tüm bu sonuçlar dikkate alınarak, glutamin&kreatin kombine tüketiminin, antrenör ve sporcuların sağlık ve yüksek performans elde etmek için antrenmanlarda etkili bir besin desteği olarak kullanabileceğini söyleyebiliriz.

Anahtar Kelimeler: Glutamin, Kreatin, Hidrasyon, Vücut Kompozisyonu, Futbol.

Citation: *Mor, A., Karakaş, F., Yılmaz, A.K., Mor, H., Acar, K., & Arslanoğlu, E. (2024). The Combined Effect of Glutamine and Creatine Supplementation on Body Hydration Level and Some Performance Parameters in Football Players, Herkes için Spor ve Rekreasyon Dergisi, 6 (2), 169-179.*

Gönderme Tarihi/Received Date: *23.05.2024*

Kabul Tarihi/Accepted Date: *30.06.2024*

Yayımlanma Tarihi/Published Online: *30.06.2024*

https://doi.org/10.56639/jsar.1488916

Sorumlu Yazar/Corresponder author: *hakki.mor@omu.edu.tr*

INTRODUCTION

Football, which requires many physical and physiological requirements to be met, is a game involving short, high-intensity intermittent efforts for two 45-minute halves that stimulate both aerobic and anaerobic systems (Kilding et al., 2008; Iaia et al., 2009; Bandelow et al., 2010; Meira et al., 2023). The physiological demands of football require improved aerobic and anaerobic fitness of players. Although the importance of aerobic fitness levels in football has been noted in previous studies, in recent years, it has been recognized that the most decisive actions during a football match are covered by anaerobic metabolism (Yáñez-Silva et al., 2017). In fact, the physical characteristics required in footballers for an optimal competitive performance are increasing. These physical characteristics include repetitive accelerations, decelerations, running at different tempos, changing of direction, jumping in different directions, dribbling, kicking, and tackling. Moreover, while the total distances covered in football remain the same, the number of high-intensity activities such as change of direction and sprints is increasing (Mor et al., 2021; Hostrup & Bangsbo, 2023; Meira et al., 2023). Endurance, strength, speed, power, jumping, explosive power, balance, change of direction ability, flexibility, acceleration, and reaction time are considered as determining factors for success in football. Although aerobic-based activities such as running at a slow and medium intensity are predominant during a football match, high-intensity anaerobic activities at maximal or submaximal pace are essential and decisive on athletic performance (Flôres et al., 2023; Meira et al., 2023; Mor et al., 2022; Siyah et al., 2023). Indeed, anaerobic energy release plays a vital role in the performance of a number of related activities during a football match, such as sprinting, jumping, kicking, tackling, and change-of-direction, which can determine the match result (Yáñez-Silva et al., 2017).

One of the main factors affecting sportive performance is physical structure or physiological characteristics. In order to achieve optimal performance in a particular sport, it is necessary to have the appropriate physical structure. In competitive team sports such as football, it is of the utmost importance to have an optimal body composition that meets the physiological needs of the body and exhibits high performance (Köklü et al., 2009; Mor et al., 2019). In addition, maintaining fluid balance plays a critical role for performance and keeping body temperature in balance in both young and adult athletes. Even moderate dehydration can disproportionately increase the heart rate, leading to a decrease in cardiac output and, thus, impairment in the body's ability to regulate temperature (Kerem & Ceylan, 2020). Dehydration is common in sports competitions and training (Demirkan et al., 2010). Even 1% body weight loss can negatively affect running performance in endurance athletes. Dehydration of 3-4% of body mass leads to muscle strength, muscle power, and endurance impairments in high-intensity efforts lasting from 30 seconds to 2 minutes (Ceylan and Balcı, 2023). Also, brain functions are essential for performance in competitive situations that require skill and decision-making. Notably, various aspects of cognitive functions are known to be affected by hydration status, increases in body temperature, or the development of hypoglycemia (Bandelow et al., 2010). Accordingly, failure to eliminate dehydration not only decreases performance but can also lead to serious health problems and even death in athletes (Demirkan et al., 2010).

Glutamine is the body's most abundant non-essential amino acid and performs many essential physiological functions. Glutamine has been reported to increase cell volume and stimulate protein and glycogen synthesis (Kerksick et al., 2018). Glutamine is the most abundant amino acid in plasma and skeletal muscle, accounting for approximately 60% of total free amino acids in skeletal muscle and 20% of plasma amino acids. Glutamine can be used for the synthesis of other amino acids, proteins, nucleotides, and various biological molecules (Ahmadi et al., 2019). Glutamine is synthesized from glutamate and ammonia by the enzyme glutamine synthetase; skeletal muscle is the main tissue involved in this synthesis and is known to secrete high glutamine levels. This is the main reason why glutamine is favored by athletes (Wilson et al., 2012). Furthermore, glutamine plays a critical role in maintaining homeostasis (regulation of fluid balance, pH, body temperature, and heart rate) and is essential for the proper and efficient functioning of some body tissues, particularly the immune and gastrointestinal systems (Ahmadi et al., 2019). In addition, glutamine's involvement in gluconeogenesis, glycogen synthesis, ammonia transport, and glutathione synthesis may have beneficial effects on fatigue (Coqueiro et al., 2019).

Creatine is an amino acid derivative nutritional supplement that is widely used by athletes of all age groups. Creatine, which gained popularity in the 1990s, has been used by athletes engaged in endurance training. As its popularity increased, studies have shown that it provides certain benefits, especially in short and high-intensity strength training (Hall & Trojian, 2013). Creatine exists in two forms in the human body: 75% in phosphocreatine and the remainder in free form. Most of the body's creatine stores (95%) are located in skeletal muscle, which plays a critical role in ATP production through the phosphocreatine cycle (Hall et al., 2021). Creatine is a guanidine-derived compound that is naturally produced in the body. Creatine is not technically a separate amino acid; instead, it is synthesized endogenously in the kidney, liver, and pancreas by reactions involving the amino acids arginine, glycine, and methionine (Persky & Rawson, 2007; Candow et al., 2011). Creatine is found in high amounts in foods such as meat and fish; thus, unlike many nutritional supplements, it is not among the banned substances. Consequently, athletes utilize creatine to enhance their athletic performance without contravening the restrictions on banned substances (Kreider et al., 2017). During short-term, high-intensity exercise, ATP demand is met by both anaerobic glycolysis and the phosphocreatine cycle. Phosphocreatine is the primary source of ATP in exercises requiring less than 10 seconds of maximum effort, while anaerobic glycolysis plays an active role in ATP production between 10-30 seconds during maximum effort (Hall et al., 2021) There is a large body of scientific evidence demonstrating the positive effects of creatine supplementation on performance during anaerobic exercise, particularly during short-duration (<30 s), high-intensity, intermittent exercise (Branch, 2003; Directo et al., 2019).

The potential benefits of a combination of glutamine and creatine supplements have emerged as an intriguing area for investigation in recent years. This interest is based on the contributions of glutamine to muscle development and recovery and the capacity of creatine to enhance muscle function by increasing strength and energy levels during exercise (Mohammad et al., 2021; Vargas-Molina et al., 2022). Some studies have purported that the consumption of glutamine and creatine can augment anabolic signaling and promote the growth of muscle mass and performance enhancement, especially in strength or power athletes, through stimulation at the cellular level (Burke et al., 2023; Jaramillo et al., 2023; Newsholme et al., 2023; Lu et al., 2024). Despite numerous studies examining the effects of glutamine and creatine use on health and various performance parameters in athletes, a study investigating the effects of combined glutamine and creatine consumption on performance parameters in football players was not identified during the literature review. The aim of this study was to investigate the combined effect of glutamine and creatine supplementation on body composition, body hydration level, and some performance parameters in football players. The study's hypothesis was thus formulated as follows: the nutritional supplementation of glutamine and creatine before and after training would positively affect the health and performance of football players.

METHOD

Type of research: In this study, pre-test/post-test experimental design was used.

The population and sample of the research: In this study, 8 volunteer male football players (age: 21.14±1.46 years; height: 171.28±1.12 cm; body weight: 171.28±6.12 cm; body weight: 68.94±7.70 kg; BMI: 23.50±2.23 kg/m^2; sports age: 11.00±2.51 years) participated (Table 1). The participants in the study were selected from athletes who did not use any ergogenic support. Gpower 3.1 software (Heinrich-Heine University Düsseldorf, version 3.1.9.2, Düsseldorf, Germany) was used to determine the number of subjects. A sample size of 8 participants was found to be sufficient (Effect size: 0.50, Confidence interval: 1-β 0.95, Error: α 0.05, Actual power: 0.96). The athletes were selected from Sinop province and Sinop University Sports Sciences Laboratory was used for all tests and measurements. The athletes voluntarily participated in the research and supplementation was administered to the athletes. The athletes were not informed about the content of the supplements before the test. Using the pre-test/post-test method, some tests, measurements, and analyses were performed under equal physical conditions at 7-day intervals without interfering with the subjects' daily life and training program. The athletes' analyses, tests, and measurements were performed sequentially during the day (09:00-17:00). The athletes were required to be healthy, not to have any chronic or acute disease, and not to have any limitation of movement due to any injury for any reason. In case of any health problem in the athletes, the athlete was excluded from the study. An informed Consent Form was obtained from the athletes before the study. The athletes were asked not to perform high-intensity training for the last 24 hours before the days on which the exercises were to be performed and to be fed under match conditions before the tests. In addition, the athletes were warned not to use alcohol and stimulants and to pay attention to their nutrition and rest. Measurements (pre-post) were performed at the same time interval and under the same physical conditions.

Experimental design: All athletes participating in the study were provided with an explanation of the research protocol and were instructed in detail on how the protocol was to be performed. The study was designed as a randomized, single-blinded study. The athletes underwent a series of tests, measurements, and analyses under similar environmental conditions at 7-day intervals using a pre-test/post-test experimental model. Before determining the athletes' performance values, a familiarisation session was conducted two days in advance. The same test, measurement, and analysis protocol was applied 4 times to each athlete (pre-test: 2 times / before and after exercise – post-test: 2 times / before and after exercise). On the days on which the tests were conducted, the participants were requested to refrain from eating for a minimum of three hours prior to the commencement of the tests. The tests were conducted at the same time of day, in accordance with the circadian rhythm. Prior to the commencement of the test, the athletes were instructed to rest and refrain from engaging in strenuous training. Initially, the height and body weight of the athletes were measured, and their body mass indexes were calculated. The athletes' resting heart rate and body temperature were determined before the performance tests. Then, a saliva sample was collected just before the exercise to determine the hydration status. The athletes were asked to warm up for 15 minutes before the test in order to be mentally and physically ready. Subsequently, the athletes underwent a series of individual performance tests in accordance with the research protocol. First, vertical jump and anaerobic power, reaction time, balance, and agility tests were measured. The study included a passive rest period of 3 minutes (Hultman et al., 1967) between the performance tests and each performance test (except the vertical jump test). The athletes then performed 25 minutes of aerobic exercise at a pulse rate of 40-50% and 20 minutes of anaerobic exercise at a pulse rate of 60-85%. Immediately after the exercise, body temperature and saliva analyses were repeated, and the performance tests were repeated in the same order. The nutritional supplementation started one day after the pre-test. The athletes used the supplements for 7 days under the researcher's supervision according to the recommended usage regimen. At the end of the 7 days of supplementation (1 day after the last supplementation), the same test, measurement, and analysis protocol (heart rate and body temperature measurement, body composition and saliva analysis, performance tests) was repeated according to the pre-test procedure. Daily supplementation was provided by the researchers to ensure that the athletes used the prescribed substances regularly for 7 days. The Sinop University Sports Science Laboratory was used for the tests and measurements in the study. All training sessions and tests were performed under similar environmental conditions (ambient temperature 23.71 ± 1.25 °C, humidity 75.85 ± 5.14%, wind 15.42 ± 9.32 km/h, pressure 1014.71 ± 2.56 mbar; mean ± SD). At the end of the performance tests, the Borg scale ranging from 0 to 10 was used to determine athletes' RPE (Borg, 1998).

Anthropometric measurements: The height was measured in cm with a portable stadiometer (Seca 213, Hamburg, Germany). Body weight was determined with a bioelectric impedance analysis device (BIA, Inbody 120, InBody Co., Ltd., Seoul, Korea). The body mass indexes of the athletes were determined as follows: after taking the height and body weight values, it was calculated by dividing the body weight by the square of the height in meters (kg/m^2).

Body composition measurements: In the study, body composition analyses of the athletes were performed using a body composition analyzer (Inbody 120 Bioimpedance, Seoul, South Korea). Body composition analysis measures body fat percentage, muscle mass, total body water, and soft tissue by using a body analyzer to send light electrical current to the body with electrodes touching the hands and feet. The device measures bone ratio, total body water, and muscle mass with great precision, as well as measuring fat for each part of the body separately using high-precision body composition analysis systems with 8-point contact "Tetrapolar Electrodes" (Mor et al., 2019).

Hydration analysis: The portable hydration test device (MX3 Diagnostics LAB Pro, Melbourne, Australia) was used to assess participants' body hydration levels. The device was convenient and easy to use for outdoor measurements and analyzed the hydration level from the saliva taken directly from the tongue with a hydration test strip. The saliva sample was taken from the tongue under the sterilization rules. The saliva sample was collected and analyzed with a hydration test strip attached to the device without waiting or undergoing any other procedure. The values and their assigned hydration status follow as ≤ 65 = Hydrated, 65-100 = Mildly Dehydrated, 101-150 = Moderately Dehydrated, >150 = Severely Dehydrated.

Heart rate variability: A heart rate monitor (Polar V800, Kempele, Finland) was used to measure the athletes' heart rate. The heart rate was obtained in beats/min by attaching a sensor to the chest and transmitting the heartbeat to the device on the arm.

Body temperature measurement: Body temperature was measured hygienically with a non-contact digital thermometer (Berrcom JXB-178, Guangzhou, People's Republic of China) at a distance of 5-10 cm from the subjects.

Balance test: A portable dynamic balance device (Togu Challenge Disc 2.0, Prien am Chiemsee, Rosenheim, Germany) was utilized to assess the balance of the subjects. The measurements were conducted in accordance with a validated procedure (Acar et al., 2024).

Reaction time test: The subjects' reaction times were determined using the Light Trainer (Reaction Development and Exercise System, Istanbul, Turkey). The measurements were conducted in accordance with a validated procedure (Mor et al., 2022).

Vertical jump and anaerobic power test: A digital vertical jump device (Takei 5406 Jump-MD Vertical Jumpmeter, Tokyo, Japan) was used to measure the vertical jump scores of the subjects. Once the athletes were ready, they quickly moved from the upright standing position to a position of 90° flexion of the knees and free swing of the arms and jumped for the maximum height. Each player performed 2 trials interspersed with 1min rest between each jump, and the best (highest) jump was recorded (Mor et al., 2022). Subjects' anaerobic power calculations were executed using the Lewis formula: Anaerobic Power (W) = {√4.9 [Body Weight (kg)] √Vertical Jump (m)} (Fox et al., 2012).

Illinois agility test: The IAT was utilized to measure agility performance using a photocell device (Seven, SE-165 Photocell Stopwatch, Istanbul, Turkey). The test was carried out in accordance with the validated procedure. (Daneshjoo et al., 2013).

Supplementation protocol: Nutritional supplements sold with the license and permission of the Ministry of Agriculture and Forestry were used in the study. The study was designed as a single-blind study, with the administration of the supplements also being conducted in a single-blind manner. Prior to the study, the athletes were asked whether they were allergic to the supplements. The supplementation method in the study was determined by considering the validated duration and dose applied in previous studies (Piattoly et al., 2013; Ahmadi et al., 2019; Wax et al., 2021). In the study, the athletes were administered glutamine and creatine at a dose of 5000 mg (5 g) 30 minutes before training and 5000 mg (5 g) immediately after training, for a total of 10,000 mg (5,000 mg glutamine, 5,000 mg creatine) for 7 days under the supervision of the researcher. The quantity of nutritional supplementation was deemed necessary to minimize any adverse effects and maximize the ergogenic effect. The athletes were not informed about the supplements administered in order to eliminate any psychological effects that may occur. In order to accurately determine the effect of supplements on any positive or negative changes that may arise in the performance parameters, the subjects' general nutrition and training programs were not disrupted. Furthermore, the subjects were warned to avoid alcohol and stimulants, not to engage in strenuous physical activity prior to the test days, and to pay attention to their nutrition and rest. The researchers provided supplementation to ensure the reliability of the study.

Data analysis: Normality was checked by using the Shapiro-Wilk test. The data obtained were analyzed with Paired Sample t-test. Cohen's d was utilized in the calculation of effect size (large $d > 0.8$, moderate $d = 0.8$ to 0.5, small $d = 0.5$ to 0.2, and trivial $d < 0.2$) (Cohen, 2013). Statistical significance was accepted as $p < 0.05$ and all data were analyzed using SPSS 22.0 (IBM Corp., Armonk, NY), and are presented as mean ± SD.

Ethics committee permission: This research was conducted in accordance with the Declaration of Helsinki and approved by the decision of Sinop University Human Research Ethics Committee (Number: E-55317723-604-01-01 Decision: 2020/015).

RESULTS

Table 1. Descriptive information of subjects

Variables	X	SD
Age (yr)	21.14	1.46
Height (cm)	171.28	6.12
Body mass (kg)	68.94	7.70
BMI (kg/m^2)	23.50	2.23
Training age (yr)	11.00	2.51

X = Mean; SD = Standard deviation

Table 2. Comparison of performance parameters of subjects before supplementation

Variables	Tests: Before training X±SD	Tests: After training X±SD	d	t	p
Balance (p)	2.93±.75	2.53±.96	0.46	1.837	.116
VJ (cm)	58.00±12.26	53.00±8.38	0.47	1.581	.165
VJ (w)	1151.37±122.59	1109.21±165.02	0.29	1.402	.210
IAT (s)	16.29±.73	16.14±.53	0.23	1.246	.259
Elapsed time (s)	35.59±3.90	31.74±1.19	1.33	2.508	**.046***
Average reaction time (s)	1.18±.12	1.05±.04	1.45	2.420	.052
Fastest reaction time (s)	.73±.06	.70±.04	0.58	1.524	.178
Slowest reaction time (s)	2.63±1.03	1.79±.42	1.06	1.815	.119
Last reaction time (s)	1.19±.30	1.06±.24	0.47	1.026	.345
Body temperature (ºC)	36.50±.20	36.28±.32	0.82	2.287	.062
Hydration (mOsm/l)	63.00±17.34	80.57±13.92	1.11	-2.668	**.037***

**(p<0.05); X = Mean; SD = Standard deviation; d = Cohen's d effect size*

Table 2 presents the pre-test parameters obtained before and after training. There was a statistically significant difference between the two groups in elapsed time and hydration tests ($p<0.05$), while there was no statistical significance in other values ($p>0.05$). A small effect size was found between the two groups in balance, vertical jump, anaerobic power, agility, and last reaction time values; a moderate effect size was detected in the fastest reaction time, while there was a large effect size in elapsed time, average reaction time, slowest reaction time, body temperature and hydration values.

Table 3. Comparison of performance parameters of subjects after supplementation

Variables	Tests				
	Before training	**After training**	**d**	**t**	**p**
	X±SD	**X±SD**			
Balance (p)	2.66±.68	2.36±.68	0.44	2.146	.076
VJ (cm)	54.71±7.45	55.42±9.46	0.08	-.581	.582
VJ (w)	1153.18±153.35	1157.99±152.47	0.03	-.355	.735
IAT (s)	16.42±.87	16.41±.86	0.01	.105	.920
Elapsed time (s)	30.79±1.17	30.19±1.52	0.44	1.151	.294
Average reaction time (s)	1.02±.03	1.00±.05	0.48	1.259	.255
Fastest reaction time (s)	.70±.05	.68±.04	0.44	1.666	.147
Slowest reaction time (s)	1.74±.36	1.61±.32	0.38	.674	.525
Last reaction time (s)	1.13±.34	1.06±.27	0.22	1.065	.328
Body temperature (ºC)	36.64±.48	36.20±.21	1.18	1.894	.107
Hydration (mOsm/l)	59.57±9.62	44.57±11.08	1.44	3.374	**.015***

**(p<0.05); X = Mean; SD = Standard deviation; d = Cohen's d effect size*

Table 3 presents the post-test parameters obtained before (BT) and after (AT) training. There was a statistically significant difference between the two groups in the hydration test ($p<0.05$), while there was no statistical significance in other values ($p>0.05$). A small effect size was found between the two groups in balance, elapsed time, average reaction time, fastest reaction time, slowest reaction time, and last reaction time values, while there was a large effect size in body temperature and hydration values.

Table 4. Comparison of body composition, heart rate and RPE of subjects before and after supplementation

Variables	Period				
	Pre-test	**Post-test**	**d**	**t**	**p**
	X±SD	**X±SD**			
Body mass (kg)	68.94±7.70	70.60±8.26	0.20	-4.833	**.003***
Skeletal muscle mass (kg)	33.91±4.41	35.20±4.94	0.27	-5.199	**.002***
Body fat mass (kg)	9.67±2.55	9.22±2.46	0.17	1.159	.291
Total body water (l)	43.40±5.35	44.94±6.02	0.27	-4.881	**.003***
Body fat percentage (%)	14.04±3.83	13.15±3.77	0.23	1.825	.118
BMI (kg/m^2)	23.50±2.23	24.07±2.37	0.24	-5.164	**.002***
Metabolic rate (kcal)	1649.85±157.31	1695.28±176.13	0.27	-4.955	**.003***
Protein (kg)	11.90±1.45	12.31±1.64	0.26	-4.833	**.003***
Mineral (kg)	3.97±.47	4.10±.51	0.26	-3.807	**.009***
Heart rate (beats/min)	70.57±3.77	66.28±5.82	0.87	1.875	.110
RPE	3.14±1.46	2.00±.57	1.02	1.549	.172

*(p<0.05); X = Mean; SD = Standard deviation; d = Cohen's d effect size

Table 4 presents the body composition, heart rate, and AZD parameters in pre- and post-supplementation. There was a statistically significant difference in body mass, skeletal muscle mass, total body water, BMI, metabolic rate, protein, and mineral values ($p<0.05$), while there was no statistical significance in other values ($p>0.05$). A small effect size was found between the two groups in body mass, skeletal muscle mass, total body water, body fat percentage, BMI, metabolic rate, protein, and mineral values, while there was a large effect size in heart rate and RPE.

Table 5 presents the parameters in pre- and post-supplementation. There was a statistically significant difference in AT anaerobic power, BT elapsed time, BT average reaction time, and AT hydration values ($p<0.05$),), while there was no statistical significance in other values ($p>0.05$). A small effect size was found between the two groups in BT-AT balance, BT-AT vertical jump, AT anaerobic power, AT agility, AT fastest reaction time, AT slowest reaction time, BT-AT body temperature, and BT hydration values; a moderate effect size was detected BT fastest reaction time while there was a large effect size in BT-AT elapsed time, BT-AT average reaction time, BT slowest reaction time and AT hydration values.

Table 5. Comparison of performance parameters of subjects before and after supplementation

Variables		Tests: Pre-supplementation X±SD	Tests: Post-supplementation X±SD	d	t	p
Balance (p)	BT	2.93±.75	2.66±.68	0.37	1.951	.099
	AT	2.53±.96	2.36±.68	0.20	.697	.512
VJ (cm)	BT	58.00±12.26	54.71±7.45	0.32	1.218	.269
	AT	53.00±8.38	55.42±9.46	0.27	-1.393	.213
VJ (w)	BT	1151.37±122.59	1153.18±153.35	0.01	-.068	.948
	AT	1109.21±165.02	1157.99±152.47	0.30	-3.370	**.015***
IAT (s)	BT	16.29±.73	16.42±.87	0.16	-.841	.432
	AT	16.14±.53	16.41±.86	0.37	-1.568	.168
Elapsed reaction time (s)	BT	35.59±3.90	30.79±1.17	1.66	3.054	**.022***
	AT	31.74±1.19	30.19±1.52	1.13	2.003	.092
Average reaction time (s)	BT	1.18±.12	1.02±.03	1.82	3.135	**.020***
	AT	1.05±.04	1.00±.05	1.10	1.909	.105
Fastest reaction time (s)	BT	.73±.06	.70±.05	0.54	1.275	.249
	AT	.70±.04	.69±.04	0.25	1.123	.304
Slowest reaction time (s)	BT	2.63±1.03	1.74±.36	1.15	1.998	.093
	AT	1.79±.42	1.61±.32	0.48	.923	.392
Last reaction time (s)	BT	1.19±.30	1.13±.34	0.18	.355	.735
	AT	1.06±.24	1.06±.27	0.00	.000	1000
Body temperature (ºC)	BT	36.50±.20	36.64±.48	0.38	-1.125	.304
	AT	36.28±.32	36.20±.21	0.29	.548	.604
Hydration (mOsm/l)	BT	63.00±17.34	59.57±9.62	0.24	.540	.609
	AT	80.57±13.92	44.57±11.08	2.86	5.505	**.002***

**(p<0.05); X = Mean; SD = Standard deviation; d = Cohen's d effect size; BT =Before training; AT = After training*

DISCUSSION

The aim of this study was to investigate the combined effects of glutamine and creatine supplementation on balance, reaction time, agility, vertical jump, and anaerobic power performance parameters, along with body composition and body hydration level in football players. The present study is the first study to investigate the effects of glutamine and creatine combined consumption on selected parameters in football players via its experimental design. The main findings of the present study were an improvement in body hydration levels and an increase in lean body mass and metabolic rate. Additionally, there was a statistically significant difference in anaerobic power and reaction time in pre- and post-supplementation values. However, improvement was observed in all results in the pre- and post-supplementation comparisons, although it did not reach significance. These findings are consistent with our hypothesis that glutamine and creatinine combined consumption can be considered practical nutritional support in training to achieve health and high performance.

In the present study, in the comparison of body hydration level and performance parameters such as balance, VJ, anaerobic power, IAT, and reaction time in pre- and post-supplementation, it was found that glutamine-creatine combined use had a positive effect on body fluid balance and performance in all test results. A number of studies corroborate these findings (Hakimi et al., 2012; Khorshidi-Hosseini & Nakhostin-Roohi, 2013). In a study conducted with ten female college basketball players, researchers reported that rehydration with L-alanyl-L-glutamine ingestion resulted in a greater extent of basketball skill performance and visual reaction time compared to water only (Hoffman et al., 2012). Similarly, the study by Kaldirimci et al. (2015) suggested that glutamine ingestion significantly improved reaction time, while vertical jump performance showed no significant difference. In another study, low dose (300 mg·500 ml−1) and high dose (1 g·500ml−1) of L-alanyl-L-glutamine supplementation appeared to possibly maintain or enhance reaction time in upper and lower body performances greater than no hydration status. Researchers elucidated this result by the mechanism of glutamine providing rehydration in skeletal muscle by increasing fluid and electrolyte absorption from the gut (Pruna et al., 2016). Furthermore, Nakhostin-Roohi et al. (2016) administered glutamine or placebo supplementation to nineteen healthy young men for seven days. The results indicated that glutamine may attenuate oxidative stress and muscle damage markers following 14 km running by its potentially beneficial impact on the antioxidant system. It is well documented that glutamine supplementation has specific benefits, including supporting the immune system, increasing glycogen production, reducing catabolic effects, and increasing water/electrolyte absorption. The maintenance of a positive protein balance and the anabolic effects of glutamine supplementation have the potential to enhance athletic performance, including power, vertical jump, and muscle strength, due to an increase in muscle mass (Ahmadi et al., 2019). The mechanism underlying glutamine's ability to increase strength and power has been attributed to the following: (1) increasing muscle cell hydration, which reduces creatine kinase and cell lesions during exercise; (2) maintaining the balance between catabolic and anabolic hormone responses and normal leukocyte counts (Cordova-Martinez et al., 2021); (3) accelerating muscle glycogen resynthesis during recovery (Bowtell et al., 1999; Coqueiro et al., 2019) and reducing plasma lactate concentration (Rowlands et al., 2012). Contrary to the abovementioned mechanism, supplementation did not significantly improve lower body strength in the present study. A study carried out with young football players showed that low-dose, oral creatine supplementation ((0.03 g.kg.d−1 during 14 d) increased peak power and average power outputs in the Wingate Anaerobic Test (Yáñez-Silva et al., 2017). Similarly, Juhász et al. (2009) applied 20 g/day creatine–monohydrate for five days and creatine supplementation enhanced dynamic strength and increased consecutive maximal swim performance in highly trained adolescent swimmers. Moreover, Johnston et al. (2009) reported that creatine supplementation (4 × 5 g·d−1 for 6 days) reduced muscle mass and strength loss in the upper limb in young men. Piattoly et al. (2013) reported that 6-day glutamine supplementation did not affect acute recovery after strenuous exercise but improved time trial to exhaustion performance and enhanced power indices in WAnT in experienced cyclists. Also, relatively long-term creatine ingestion of 28 d, at a dose of 20 g/d on days 1–4, 10 g/d on days 5-6, and 5 g/d on days 7-28, improved repeated block jump performance in college-level basketball players (Lamontagne-Lacasse et al., 2011). Additionally, jumps, sprint, repeated sprinting, endurance, and change of direction performance increased in both placebo and creatine (20 g/d for a week-5 g/d in the remaining five weeks) with training intervention in female football players, but the creatine group seemed to gain more performance improvement in the jump and repeated sprinting (Ramírez-Campillo et al., 2016). Similarly, Camic et al. (2014) administered creatine loading to male athletes for 28 days along with a series of measurements, including anaerobic performance (vertical-broad jumps, sprints, shuttle run, and 3-cone drill), upper and lower body muscular strength and endurance (bench press and leg extension) and body composition. Consistent with the abovementioned studies, creatine supplementation resulted in significant performance enhancement in the vertical jump, shuttle run, 3-cone drill, muscular endurance for bench press, and body composition. Conversely, studies have also demonstrated that glutamine and creatine supplementation does not enhance strength, endurance, anaerobic power, physical performance, or body composition (Candow et al., 2001; Antonio et al., 2002; Kerksick et al., 2006; Hakimi et al., 2012). Silveira et al. (2014) suggested that long-term glutamine and creatine supplementation failed to improve local muscular resistance, flexibility, and both aerobic and anaerobic capacity during and after 5 sessions × 90 min/a week training over 12 weeks. Surprisingly, however, performance indices through three different time zones (at the beginning-T1, 6 week-T2, and 12 week-T3) appeared to differ in several tests; supplementation showed no significant ergogenic effect. A recent study has reported that short-term high-dose (20g/d for seven days) creatine ingestion has no consistent benefits on recovery, body composition, and performance indices through a strenuous exercise period in professional cyclists. Even in a strictly scheduled dietary intake and training load setting during training camp, creatine supplementation ergogenicity remained unclear (Barranco-Gil et al., 2024). Likewise, high-dose creatine supplementation (20g/d for 8 days) did not lead to a significant difference in WAnT performance (Marinho et al., 2024), while muscular performance, including sit-to-stand, 10 repetitions maximum (RM) strength and maximal voluntary contraction showed no improvement following 20 g/d of creatine monohydrate supplementation (Parsowith et al., 2024).

Other findings of the present study were that glutamine-creatine combined use had positive effects on body composition, total body water, metabolic rate, and RPE. Lehmkuhl et al. (2003) administered 8-week glutamine and creatine supplementation in male and female athletes and found that the use of glutamine and creatine increased body mass, lean body mass, and power production rate during cycle ergometer bouts. A growing body of evidence suggests that glutamine ingestion has beneficial effects on body composition and athletic performance. In healthy non-athlete male participants, 8-week glutamine ingestion (0.35 g/kg/day) increased muscle strength and improved body composition, including increased body mass, fat-free mass, and reduced body fat (Hakimi et al., 2012). Also, creatine has been well established to preserve energy during strenuous exercise, and creatine supplementation in combination with heavy resistance exercise is known to improve physical performance, lean mass gain, and muscle function (Volek et al., 1997; Kreider, 2003; Brudnak, 2004). Accordingly, 10-week creatine-protein-carbohydrate supplementation resulted in greater improvements in 1 RM strength, lean body mass, muscle cross-sectional area, and contractile protein compared to protein-carbohydrate ingestion (Cribb et al., 2007). Typically, creatine is characterized by its ability to provide anabolic stimulation due to increased water retention (Antonio et al., 2021). The study results demonstrated positive outcomes following long-term creatine supplementation (Galvan et al., 2016). On the contrary, a study by Silva et al. (2007) denoted inconsistent results. In the study, researchers administered 20 g of creatine and maltodextrin as a placebo to female swimmers for 21 days and evaluated the performance. With respect to the findings, creatine consumption for 3 weeks appeared to influence hydrodynamic variables specific to swimming but did not affect performance, body weight, and body composition. Candow et al. (2001) found that glutamine supplementation (0.9 g/kg lean tissue mass/day) had no significant effect on muscle performance and body composition during resistance training as a result of their study with healthy young adults, both male and female. In another study, researchers examined the effects of nutritional supplements such as creatine, ribose, and glutamine on parameters such as muscle strength, muscular endurance, and body composition in strength-trained male athletes. The researchers reported that nutritional supplements did not significantly improve the parameters compared to the control group (Falk et al., 2003). This result is surprising because glutamine provides protein balance in the organism, plays a cell regulatory role, and enhances immune function (Shah et al., 2020). It may improve muscle function by alleviating the local inflammatory response to muscle pain that occurs after eccentric contractions, especially in resistance exercises (Paulsen et al., 2010; Mohammad et al., 2021). Furthermore, the reduction in symptoms of muscle damage due to glutamine supplementation may be attributed to various factors including increased availability of amino acids, additional energy intake from supplementation, and elevated protein synthesis. Moreover, Caris and Thomatieli-Santos (2020) suggested that glutamine intake (20 g/d for six days) prior to intense exercise may reduce the increase in RPE and could be a beneficial strategy for those engaged in exercise. Similarly, in a study assessing resistance-trained male athletes, Paiva et al. (2020) administered creatine supplementation (20 g/d) for seven days. The study results indicated that creatine supplementation led to enhanced bench press performance compared to a placebo, without an increase in RPE. Additionally, Volek et al. (2004) examined a series of values, including strength, body mass, lean body mass, body fat percentage, and bone mineral content. The researchers suggested that creatine supplementation (0.3 g/kg/d for a week-0.05 g/kg/d for three weeks) may result in an increase in lean body mass. Furthermore, creatine supplementation appeared to be effective for maintaining muscle performance during the initial phase of high-volume resistance training, which may otherwise result in minor performance decrements.

In conclusion, the current research findings indicate that the combined consumption of glutamine and creatine nutritional supplements positively affects balance, reaction time, agility, vertical jump, and anaerobic power parameters, along with body composition and body hydration level in football players. In addition, considering the other results, it can be stated that it has a positive ergogenic effect in providing optimum body composition specific to football, gaining lean body mass, maintaining total body water and regulating metabolic rate, and providing performance improvement without increasing the rating of perceived exertion. Collectively, we can say that the combined consumption of glutamine and creatine is an effective nutritional supplement to increase body hydration levels and athletic performance along with providing optimum body composition, and coaches and athletes can use it as an effective nutritional supplement in training to achieve health and high performance.

Practical application: According to the findings of the present study and growing body of evidence in literature, glutamine and creatine are known to contribute to hydration by drawing water into muscle cells. Moreover, both are effective in water retention in the body by allowing more water to be drawn into the muscle cells. Thus, they can be advantageous for athletes in terms of athlete health and performance, especially in competitions and training in hot and humid environments. The combined use of these nutritional supplements provides maximum ergogenic effect in terms of body hydration status. Therefore, practitioners and coaches may incorporate glutamine&creatine supplementation into their nutrition strategy. In addition, the present study design can be repeated in different sports during the camp period. Thus, athletes' training and nutrition schedules may be followed strictly, which in turn improves reliability. Also, this study can be conducted with tailored training or exercise modalities specific to the sports.

Acknowledgement: This study was supported by Sinop University Scientific Research Coordination Unit. Project Number: SBF-1901-21-001, 2021.

Funding Information: This study was carried out with the support of the University of Sinop under the scientific research project number SBF-1901-21-001.

Conflicts of Interest: The authors declare no conflicts of interest.

Authorship Statement: All listed authors meet the criteria for authorship, and they are in agreement with the content presented in this manuscript.

References

Acar, K., Mor, A., Mor, H., Kargın, Z., Alexe, D. I., Abdioğlu, M., Karayiğit, R., Alexe, C.I., Cojocaru, A.M. & Mocanu, G. D. (2024). Caffeine Improves Sprint Time in Simulated Freestyle Swimming Competition but Not the Vertical Jump in Female Swimmers. Nutrients, 16(9), 1253.

Ahmadi, A. R., Rayyani, E., Bahreini, M. & Mansoori, A. (2019). The Effect of Glutamine Supplementation on Athletic Performance, Body Composition, and Immune Function: A systematic review and a meta-analysis of clinical trials. Clinical Nutrition, 38(3), 1076-1091.

Antonio, J., Candow, D. G., Forbes, S. C., Gualano, B., Jagim, A. R., Kreider, R. B., Rawson, E. S., Smith-Ryan A. E., VanDusseldorp, T. A., Willoughby, D. S. & Ziegenfuss, T. N. (2021). Common Questions and Misconceptions About Creatine Supplementation: What Does The Scientific Evidence Really Show? Journal of the International Society of Sports Nutrition, 18(1), 13.

Antonio, J., Sanders, M. S., Kalman, D., Woodgate, D. & Street, C. (2002). The Effects of High-Dose Glutamine Ingestion on Weightlifting Performance. The Journal of Strength & Conditioning Research, 16(1), 157-160.

Bandelow, S., Maughan, R., Shirreffs, S., Ozgünen, K., Kurdak, S., Ersöz, G. & Dvorak, J. (2010). The Effects of Exercise, Heat, Cooling and Rehydration Strategies on Cognitive Function in Football Players. Scandinavian Journal of Medicine and Science in Sports, 20, 148-160.

Barranco-Gil, D., Alejo, L. B., Revuelta, C., Górriz, M., Pagola, I., Ozcoidi, L. M., … Valenzuela, P. L. (2024). High-Dose Short-Term Creatine Supplementation Without Beneficial Effects in Professional Cyclists: A Randomized Controlled Trial. Journal of the International Society of Sports Nutrition, 21(1).

Borg, G. (1998). Borg's Perceived Exertion and Pain Scales. Champaign, IL: Human Kinetics.

Branch, J. D. (2003). Effect of Creatine Supplementation on Body Composition and Performance: A Meta-Analysis. International Journal of Sport Nutrition and Exercise Metabolism, 13(2), 198-226.

Brudnak, M. A. (2004). Creatine: Are The Benefits Worth The Risk? Toxicology Letters, 150(1); 123-130: 2004.

Burke, R., Piñero, A., Coleman, M., Mohan, A., Sapuppo, M., Augustin, F., Aragon, A.A., Candow, D.G., Forbes, S.C., Swinton, P. & Schoenfeld, B. J. (2023). The Effects of Creatine Supplementation Combined With Resistance Training on Regional Measures of Muscle Hypertrophy: A Systematic Review With Meta-Analysis. Nutrients, 15(9), 2116.

Camic, C. L., Housh, T. J., Zuniga, J. M., Traylor, D. A., Bergstrom, H. C., Schmidt, R. J., Johnson, G. O. & Housh, D. J. (2014). The Effects of Polyethylene Glycosylated Creatine Supplementation on Anaerobic Performance Measures and Body Composition. The Journal of Strength & Conditioning Research, 28(3); 825-833.

Candow, D. G., Chilibeck, P. D., Burke, D. G., Davison, S. K. & Smith-Palmer, T. (2001). Effect of Glutamine Supplementation Combined With Resistance Training in Young Adults. European Journal of Applied Physiology, 86(2); 142-149.

Candow, D. G., Chilibeck, P. D., Burke, D. G., Mueller, K. D. & Lewis, J. D. (2011). Effect Of Different Frequencies of Creatine Supplementation on Muscle Size And Strength in Young Adults. The Journal of Strength & Conditioning Research, 25(7), 1831-1838.

Caris, A. V. & Thomatieli-Santos, R. V. (2020). Carbohydrate and Glutamine Supplementation Attenuates The Increase in Rating of Perceived Exertion During Intense Exercise in Hypoxia Similar To 4200 M. Nutrients, 12(12); 3797.

Ceylan, B. & Balci Ş. S. (2023). Dehydration and Rapid Weight Gain Between Weigh-In and Competition in Judo Athletes: The Differences Between Women and Men. Research in Sports Medicine, 31(4), 462-472.

Cohen, J. (2013). Statistical Power Analysis for the Behavioral Sciences. Academic Press: Cambridge, MA, USA.

Coqueiro, A. Y., Rogero, M. M. & Tirapegui, J. (2019). Glutamine As an Anti-Fatigue Amino Acid in Sports Nutrition. Nutrients, 11(4), 863.

Cribb, P. J., Williams, A. D. & Hayes, A. (2007). A Creatine-Protein-Carbohydrate Supplement Enhances Responses to Resistance Training. Medicine and Science in Sport and Exercise, 39(11). 1960-1968.

Daneshjoo, A., Mokhtar, A.H., Rahnama, N. & Yusof, A. (2013) Effects of The 11+ And Harmoknee Warm-Up Programs on Physical Performance Measures in Professional Soccer Players. Journal of Sports Science and Medicine, 12(3):489–496.

Demirkan, E., Koz, M. & Kutlu, M. (2010). Sporcularda Dehidrasyonun Performans Üzerine Etkileri ve Vücut Hidrasyon Düzeyinin İzlenmesi. Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi, 8(3), 81-92.

Directo, D., Wong, M. W., Elam, M. L., Falcone, P., Osmond, A. & Jo, E. (2019). The Effects of A Multi-Ingredient Performance Supplement Combined With Resistance Training on Exercise Volume, Muscular Strength, and Body Composition. Sports, 7(6), 152.

Falk, D. J., Heelan, K. A., Thyfault, J. P. & Koch, A. J. (2003). Effects of Effervescent Creatine, Ribose, and Glutamine Supplementation on Muscular Strength, Muscular Endurance, and Body Composition. The Journal of Strength & Conditioning Research. 17(4), 810-816.

Flôres, F. S., Lourenço, J., Phan, L., Jacobs, S., Willig, R. M., Marconcin, P. E. P., Casanova, N., Soares, D., Clemente, F. M. & Silva, A. F. (2023). Evaluation of Reaction Time During The One-Leg Balance Activity in Young Soccer Players: A Pilot Study. Children, 10(4):743.

Fox, E., Bowers, R. & Foss, M. (2012). Beden Eğitimi ve Sporun Fizyolojik Temelleri. Ankara: Spor Yayınevi.

Galvan, E., Walker, D. K., Simbo, S. Y., Dalton, R., Levers, K., O'Connor, A., Goodenough, C., Barringer, N. D., Greenwood, M., Rasmussen, C., Smith, S. B., Riechman, S. E., Fluckey, J. D., Murano, P. S., Earnest, C. P. & Kreider, R. B. (2016). Acute and Chronic Safety and Efficacy of Dose Dependent Creatine Nitrate Supplementation and Exercise Performance. Journal of the International Society of Sports Nutrition, 13(1), 12.

Hakimi, M., Mohamadi, M. A. & Ghaderi, Z. (2012). The Effects of Glutamine Supplementation on Performance and Hormonal Responses in Non-Athlete Male Students During Eight Week Resistance Training. Journal of Human Sport and Exercise, 7(4), 770-782.

Hall, M. & Trojian, T. H. (2013). Creatine Supplementation. Current Sports Medicine Reports, 12(4), 240-244.

Hall, M., Manetta, E. & Tupper, K. (2021). Creatine Supplementation: An Update. Current Sports Medicine Reports, 20(7), 338-344.

Hoffman, J. R., Williams, D. R., Emerson, N. S., Hoffman, M. W., Wells, A. J., McVeigh, D. M., McCormack, W. P., Mangine, G. T., Gonzalez, A. M. & Fragala MS. (2012). L-Alanyl-L-Glutamine Ingestion Maintains Performance During a Competitive Basketball Game. Journal of the International Society of Sports Nutrition, 9(1), 4.

Hostrup, M. & Bangsbo, J. (2023). Performance Adaptations to Intensified Training in Top-Level Football. Sports Medicine, 53, 577–594.

Hultman, E., Bergström, J. & Anderson, N. M. (1967). Breakdown and Resynthesis of Phosphorylcreatine and Adenosine Triphosphate in Connection With Muscular Work in Man. Scandinavian Journal of Clinical and Laboratory Investigation, 19(1), 56-66.

Iaia, F. M., Ermanno, R. & Bangsbo, J. (2009). High-Intensity Training in Football. International Journal of Sports Physiology and Performance, 4(3), 291-306.

Jaramillo, A. P., Jaramillo, L., Castells, J., Beltran, A., Mora, N. G., Torres, S., Parraga, G.C.B., Vallejo, M.P. & Santos, Y. (2023). Effectiveness of Creatine in Metabolic Performance: A Systematic Review and Meta-Analysis. Cureus, 15(9).

Johnston, A. P. W., Burke, D. G., MacNeil, L. G. & Candow, D. G. (2009). Effect of Creatine Supplementation During Cast-Induced Immobilization on The Preservation of Muscle Mass, Strength, and Endurance. The Journal of Strength & Conditioning Research, 23(1), 116-120.

Juhász, I., Györe, I., Csende, Z., Racz, L. & Tihanyi, J. (2009). Creatine Supplementation Improves The Anaerobic Performance of Elite Junior Fin Swimmers. Acta Physiologica Hungarica, 96(3), 325-336.

Kaldirimci, M., Sajedi, H., Sam, C. T., Mizrak, O. & Kavurmaci, H. (2015). Glutamine Supplementation and Basketball Players Power Performance Changes. Journal of Sports Science, 3, 298-304.

Kerem, M. & Ceylan, B. (2020). Kadın Hentbolcuların Maç Günü Hidrasyon Durumları. Sportif Bakış: Spor ve Eğitim Bilimleri Dergisi, 7(1), 35-43.

Kerksick, C. M., Rasmussen, C. J., Lancaster, S. L., Magu, B., Smith, P., Melton, C., Greenwood, M., Almada, A. L., Earnest, C. P. & Kreider, R. B. (2006). The Effects of Protein And Amino Acid Supplementation on Performance and Training Adaptations During Ten Weeks of Resistance Training. The Journal of Strength & Conditioning Research, 20(3), 643-653.

Kerksick, C. M., Wilborn, C. D., Roberts, M. D., Smith-Ryan, A., Kleiner, S. M., Jäger, R., Collins, R., Cooke, M., Davis, J. N., Galvan, E., Greenwood, M., Lowery, L. M., Wildman, R., Antonio, J. & Kreider, R. B. (2018). ISSN Exercise & Sports

Nutrition Review Update: Research & Recommendations. Journal of the International Society of Sports Nutrition, 15(1), 38.

Khorshidi-Hosseini, M. & Nakhostin-Roohi, B. (2013). Effect of Glutamine and Maltodextrin Acute Supplementation on Anaerobic Power. Asian Journal of Sports Medicine, 4(2), 131.

Kilding, A. E., Tunstall, H. & Kuzmic, D. (2008). Suitability Of FIFA's "The 11" Training Programme For Young Football Players–Impact on Physical Performance. Journal of Sports Science and Medicine, 7(3), 320-326.

Köklü Y., Özkan A., Alemdaroğlu U. & Ersöz G. (2009). Genç Futbolcuların Bazı Fiziksel Uygunluk ve Somatotip Özelliklerinin Oynadıkları Mevkilere Göre Karşılaştırılması. Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi, 7(2), 61-68.

Kreider, R. B. (2003). Effects of Creatine Supplementation on Performance and Training Adaptations. Molecular and Cellular Biochemistry, 244(1), 89-94.

Kreider, R. B., Kalman, D. S., Antonio, J., Ziegenfuss, T. N., Wildman, R., Collins, R., Candow, D. G., Kleiner, S. M., Almada, A. L. & Lopez, H. L. (2017). International Society of Sports Nutrition Position Stand: Safety and Efficacy of Creatine Supplementation in Exercise, Sport, and Medicine. Journal of the International Society of Sports Nutrition, 14(1), 18.

Lamontagne-Lacasse, M., Nadon, R. & Goulet, E. D. B. (2011). Effect of Creatine Supplementation on Jumping Performance in Elite Volleyball Players. International Journal of Sports Physiology and Performance, 6, 525-533.

Lehmkuhl, M., Malone, M., Justice, B., Trone, G., Pistilli, E., Vinci, D., Haff, E. E., Kilgore, J. L. & Haff, G. G. (2003). The Effects of 8 Weeks of Creatine Monohydrate and Glutamine Supplementation on Body Composition and Performance Measures. The Journal of Strength & Conditioning Research, 17(3), 425-438.

Lu, T. L., Zheng, A. C., Suzuki, K., Lu, C. C., Wang, C. Y. & Fang, S. H. (2024). Supplementation of L-Glutamine Enhanced Mucosal Immunity and Improved Hormonal Status of Combat-Sport Athletes. Journal of the International Society of Sports Nutrition, 21(1), 41-53.

Marinho, A.H., Silva-Cavalcante, M.D., Cristina-Souza, G., Sousa, F.A.B., Ataide-Silva, T., Bertuzzi, R., de Araujo, G.G. & Lima-Silva, A.E. (2024). Caffeine, but Not Creatine, Improves Anaerobic Power Without Altering Anaerobic Capacity in Healthy Men During a Wingate Anaerobic Test. International Journal of Sport Nutrition and Exercise Metabolism, 34(3),137-144.

Meira, F. C., Franke, R. d. A., da Costa, D. L., Nakamura, F. Y. & Baroni, B. M. (2023). Does Sprint and Jump Performance of Football Players From a Premier League Academy Change Throughout The Season? Sport Sciences for Health, 1-8.

Mohammad, S. M., Mahdi, A. M. & Parisa, S. (2021). The Effect of Intense Physical Activity Session With Glutamine Supplementation on Selected Factors of Wrestlers' Immune System. International Journal of Science and Research Archive, 2(2), 145-150.

Mor, A., İpekoğlu, G., Baynaz, K., Arslanoğlu, C., Acar, K. & Arslanoğlu, E. (2019). Futbolcularda BCAA ve Kreatin Alımının Vücut Kompozisyonu Üzerine Etkisi. Beden Eğitimi ve Spor Bilimleri Dergisi, 13(3), 274-285.

Mor, A., Karakaş, F., Mor, H., Yurtseven, R., Yılmaz, A. K. & Acar, K. (2022). Genç Futbolcularda Direnç Bandı Egzersizlerinin Bazı Performans Parametrelerine Etkisi. Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi, 20(3), 128-142.

Mor, A., Yurtseven, R., Mor, H. & Acar, K. (2021). 11-12 Yaş Grubu Futbolcularda Farklı Isınma Protokollerinin Bazı Performans Parametrelerine Etkisi. Spormetre Beden Eğitimi ve Spor Bilimleri Dergisi, 19(4), 72-83.

Nakhostin-Roohi, B., Javanamani, R., Zardoost, N. & Ramazanzadeh R. (2016). Influence of Glutamine Supplementation on Muscle Damage and Oxidative Stress Indices Following 14 km Running. Hormozgan Medical Journal, 20(5), 323-331.

Newsholme, P., Diniz, V. L. S., Dodd, G. T. & Cruzat, V. (2023). Glutamine Metabolism and Optimal Immune and CNS Function. Proceedings of the Nutrition Society, 82(1), 22-31.

Paiva, J. M., Souza, C. O., Valle, V. O., Forbes, S. C., Pereira, R. & Machado, M. (2020). Creatine Monohydrate Enhanced Fixed and Planned Load Reduction Resistance Training Without Altering Ratings of Perceived Exertion. Journal of Exercise and Nutrition, 3(3).

Parsowith, E. J., Stock, M. S., Kocuba, O., Schumpp, A., Jackson, K., Brooks, A. M., Larson, A., Dixon, M. & Fairman, C. M. (2024). Impact of Short-Term Creatine Supplementation on Muscular Performance among Breast Cancer Survivors. Nutrients, 16(7), 979.

Paulsen, G., Crameri, R., Benestad, H. B., Fjeld, J. G., Mørkrid, L., Hallén, J. & Raastad, T. (2010). Time Course of Leukocyte Accumulation in Human Muscle After Eccentric Exercise. Medicine & Science in Sports & Exercise, 42(1), 75-85.

Persky, A. M. & Rawson, E. S. (2007). Creatine and Creatine Kinase in Health and Disease. Subcellular Biochemistry, 46:275–89.

Piattoly, T., Parish, T. R. & Welsch, M. A. (2013). L-Glutamine Supplementation: Effects on Endurance, Power and Recovery. Current Topics in Nutraceutical Research, 11(1-2), 55-62.

Pruna, G. J., Hoffman, J. R., McCormack, W. P., Jajtner, A. R., Townsend, J. R., Bohner, J. D., La Monica, M. B., Wells, A. J., Stout, J. R., Fragala, M. S. & Fukuda, D. H. (2016). Effect of Acute L-Alanyl-L-Glutamine and Electrolyte Ingestion on Cognitive Function and Reaction Time Following Endurance Exercise. European Journal of Sport Science, 16(1), 72-79.

Ramírez-Campillo, R., González-Jurado, J. A., Martínez, C., Nakamura, F. Y., Peñailillo, L., Meylan, C. M., Caniuqueo, A., Canas-Jamet, R., Moran, J., Alonso-Martínez, A. M. & Izquierdo, M. (2016). Effects of Plyometric Training and Creatine Supplementation on Maximal-Intensity Exercise and Endurance in Female Soccer Players. Journal of Science and Medicine in Sport, 19(8), 682-687.

Shah, A. M., Wang, Z. & Ma, J. (2020). Glutamine Metabolism and Its Role in Immunity, a Comprehensive Review. Animals, 10(2), 326.

Silva, A. J., Machado Reis, V., Guidetti, L., Bessone Alves, F., Mota, P., Freitas, J. & Baldari, C. (2007). Effect of Creatine on Swimming Velocity, Body Composition and Hydrodynamic Variables. Journal of Sports Medicine and Physical Fitness, 47(1), 58.

Silveira, C. L., de Souza, T. S. P., Batista, G. R., de Araújo, A. T., da Silva, J. C. G., de Sousa, M. D. S. C., Marta, C. & Garrido, N. D. (2014). Is Long Term Creatine and Glutamine Supplementation Effective in Enhancing Physical Performance of Military Police Officers? Journal of Human Kinetics, 43, 131-138.

Siyah M., Şanlı T. & Turgut E. (2023). Effects of Physical and Cognitive Factors on Reactive Agilıty in Professional Football Players. Turkish Journal of Physiotherapy and Rehabilitation, 34(3), 313-320.

Vargas-Molina, S., García-Sillero, M., Kreider, R. B., Salinas, E., Petro, J. L., Benítez-Porres, J. & Bonilla, D. A. (2022). A Randomized Open-Labeled Study to Examine The Effects of Creatine Monohydrate and Combined Training on Jump and Scoring Performance in Young Basketball Players. Journal of the International Society of Sports Nutrition, 19(1), 529-542.

Volek, J. S., Kraemer, W. J., Bush, J. A., Boetes, M., Incledon, T., Clark, K. L. & Lynch, J. M. (1997). Creatine Supplementation Enhances Muscular Performance During High-Intensity Resistance Exercise. Journal of the American Dietetic Association, 97, 765-770.

Volek, J. S., Ratamess, N. A., Rubin, M. R., Gomez, A. L., French, D. N., McGuigan, M. M., Scheett, T. P., Sharman, M. J., Hakkinen, K. & Kraemer, W. J. (2004). The Effects of Creatine Supplementation on Muscular Performance and Body Composition Responses to Short-Term Resistance Training Overreaching. European Journal of Applied Physiology, 91(5-6), 628-637.

Wilson, J. M., Wilson, S. M., Loenneke, J. P., Wray, M., Norton, L. E., Campbell, B. I., Lowery, R. P. & Stout, J. R. (2012). Effects of Amino Acids and Their Metabolites on Aerobic and Anaerobic Sports. Strength & Conditioning Journal, 34(4), 33-48.

Yáñez-Silva, A., Buzzachera, C. F., Piçarro, I. D. C., Januario, R. S., Ferreira, L. H., McAnulty, S. R., Utter, A. C. & Souza-Junior, T. P. (2017). Effect of Low Dose, Short-Term Creatine Supplementation on Muscle Power Output in Elite Youth Soccer Players. Journal of the International Society of Sports Nutrition, 14(1), 1-8.