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Acute Effects of Different Creatine Supplementation Methods on Anaerobic Performance

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ORİGİNAL ARTICLE

Abstract

The aim of this study is to compare the acute effects of different creatine loading methods on anaerobic performance in soccer players. Totally 21 healthy male soccer players participated in this study. The study was conducted in a randomized and double-blind study design. Athletes were loaded with creatine on 3 different days. The different creatine supplementation methods were as follows; athletes took creatine supplement 4 times a day for 15 days, 4x5 grams for the first 5 days and 5 g for the following 10 days. In other creatin loading is took 0.3 grams of creatine per kg for 15 days. In other creatin loading is (placebo loading) received the same amount (Maltodextrine) for 15 days. Vertical jump, 10-30 m sprint test and agility test were performed on all subjects. The Shapiro-Wilk test was used for normality distribution of the data. Since parametric test assumptions were met, t-test for dependent groups and one-way analysis of variance test (ANOVA) for repeated measurements were used to compare dependent group differences. Significant differences were found for 10-30 m sprint, vertical jumping, zig zag test ($p<0.05$) after the 1st measurement day creatine supplementation pre-post test values. Also there a significant difference in 10-30 m sprint, vertical jumping values in 1st measurement day and 3rd measurement day (plasebo group) ($p<0.05$). No significant changes in the 2nd measurement day and placebo group were observed in all performance tests following the 15 days experiment ($p>0.05$). According to the results obtained from the study, it was observed that 4x5 grams for the first 5 days and 5 g for the following 10 days loading was more effective on performance outcomes.

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Farklı Kreatin Yükleme Yöntemlerinin Anaerobik Performans Üzerine Akut Etkisi

Öz

Bu çalışmanın amacı, farklı kreatin yükleme yöntemlerinin futbol oyuncularında anaerobik performans üzerindeki akut etkilerini karşılaştırmaktır. Bu çalışmaya toplam 21 sağlıklı erkek futbolcu katılmıştır. Çalışma randomize ve çift kör olarak yürütülmüştür. Sporculara 3 farklı günde kreatin yüklendi. Farklı kreatin takviyesi yöntemleri şu şekildeydi; sporcular 15 gün günde 4 kez, ilk 5 gün 4x5 gram ve sonraki 10 gün 5 gram kreatin takviyesi aldılar. Diğer kreatin yüklemesinde 15 gün boyunca kg başına 0,3 gram kreatin alınmıştır. Bir diğer kreatin yüklemesi gününde (plasebo yükleme) 15 gün boyunca aynı miktarda (Maltodekstrin) alınmıştır. Tüm deneklere dikey sıçrama, 10-30 m sprint testi ve çeviklik testi uygulandı. İstatistiksel işlemler incelenmeden önce verilerin normallik dağılımı için Shapiro-Wilk testi kullanıldı. Parametrik test varsayımları karşılandığından, bağımlı grup farklılıklarının karşılaştırılmasında bağımlı gruplar için t-testi ve tekrarlı ölçümlerde tek yönlü varyans analizi testi (ANOVA) kullanıldı. 1. ölçüm günü kreatin takviyesi sonrası 10-30 m sprint, dikey sıçrama, zig zag testlerinde ön-son değerlerinde anlamlı fark bulundu ($p<0.05$). 10-30 m sprint ve dikey sıçrama değerlerinde 1. ve 3. ölçüm gününde fark bulundu ($p<0.05$). 15 günlük deneyi takiben tüm performans testlerinde 2. ölçüm günü ve plasebo grubunda anlamlı bir değişiklik gözlenmedi ($p>0.05$). Sonuç olarak, ilk 5 gün 4x5 gram ve sonraki 10 gün 5 gram kreatin yüklemesinin performans sonuçları üzerinde daha etkili olduğu gözlemlendi.

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Anahtar kelimeler: Kreatin Yüklemesi, Performans, Futbol

Introduction

Creatine, it has been used as an ergogenic aid that improves training and competition performance by many professional or amateur athletes at different levels, especially in recent years. Creatine is synthesized in the body through the liver, pancreas, kidneys and brain cells (Brosnan and Brosnan, 2007). Approximately 95% is stored in the muscles as phosphocreatine, while 5% is found as free creatine in the brain and testicles. This value varies according to the individual's muscle fiber type, age, gender, training and nutritional status. Adenosine triphosphate (ATP) is the main energy supply for all muscular activities during intense exercise, resynthesize of ATP (phosphorylation from adenosine diphosphate (ADP) to ATP) occurs when the phosphate bond separated by creatine kinase enzyme activity is converted to ATP by binding with ADP. Creatine supplementation increases total creatine level and phosphocreatine stores (Mielgo-Ayuso et al., 2019). It is known that this increase contributes to the increase in performance, especially in high-intensity efforts made in a short and medium time (less than 2 minutes). Also, creatine supplementation also supports the increase of training efficiency by keeping the volume and intensity of the training higher. Creatine supplementation in the range of 20-30 grams for less than 7 days causes some physiological changes. Just minutes after creatine ingestion, increases in the amount of creatine in the muscle and blood begin. After 2-3 hours, it is observed that its value in the blood begins to decrease (Buford et al., 2007). Due to high-intensity exercise and an average daily excretion of 2 grams which is increased stores with short-term supplementation return to their baseline values after 3-4 weeks (Mielgo-Ayuso et al., 2019).

In the literature, there are some studies indicate that athletic performance increases as a result of short-term creatine supplementation. Oliver et al. (2012) evaluated lactate concentrations in consumer cycling exercise by creatine supplementation with glucose in order to accelerate the storage of creatine in muscle in male participants with an average age of 23 years. After the study, after 20 grams x 6 days (4 doses/day x 5 grams + 15 grams glucose) supplementation, a decrease was found in the amount of lactate produced during the consumer cycling exercise applied with a gradual increase in load. Based on this result, it has been indicated that short-term creatine supplementation is beneficial in endurance-type exercises in which the lower extremities are used intensively. In the study of Lifanov et al. (2014) on football players, they found a significant increment in the maximum oxygen values of the creatine supplementation (20 g x 6 days) of soccer players. In the study where Fukuda et al. (2010) evaluated the effects of creatine supplementation on anaerobic capacity for both genders (20 grams x 5 days), they found an increase in the anaerobic running capacity of male participants as a result of supplementation; they did not detect any increase in female participants.

Few studies have been found in the literature reporting that KSKS has no effect. Rawson et al. (2007) reported that creatine supplementation had no positive impact on muscle damage and improvement after supplementation in 22 healthy athletes (0.3 g x body weight x 5 days) aged 19-27 years in their study on muscle damage and recovery after strength exercise. they did not come across. In another study, Aedma et al. (2015) did not indicate any increase in the anaerobic power output of the upper extremity when they applied a supplement of 0.3 grams body weight x 0.3 grams in their study on 20 male wrestlers. Williams et al. (2014) evaluated the speed, explosive power and endurance performances of amateur male football players as a result of 20 grams/7-day CSR, but did not find a significant difference.

Some studies show that long-time creatine supplementation contributes to the formation of muscle hypertrophy (Helms et al., 2014) and to an increase in lean body mass in both sexes in body composition values (Unnithan et al., 2001). When we look at the studies on long term creatine supplementation and high-intensity performance in the literature; Tang et al. (2014) reported that muscle glycogen uses and protein breakdown decreased during endurance exercise (12 grams x 15 days) after long term creatine supplementation. Hamid et al. (2012), in their study on 14 football players, subjected the supplementation (n=7, 7 days 20 g/day + 42 days 5 g/day) and control group to standardized training practice for 7 weeks before the season. Repeated jump test was applied to the groups pre and post the test period. Consequently, it was indicated that creatine supplementation decreased the loss of lower extremity muscle strength during the gradual increase in training applied before the season. Long term creatine supplementation seems to support the increase of athletic performance in studies conducted with a high-intensity exercise model.

In the literature, there are studies on the use of creatine supplement for short and long use, but which one is more effective could not be found. This study is was made for the purpose of to compare the acute effects of different creatine loading methods on anaerobic performance in soccer players. It is thought that this study will provide the trainers with the opportunity to check the performance outputs of the training/match season they will apply in terms of which creatine loading method can be more effective. It can be recommended that the test results obtained should be evaluated well and transferred to practice, as it will provide positive effects on the performance levels of the athletes.

Material and Methods

Participants

A total of 21 healthy male soccer players (age, 21.20 ± 0.47 years; height, 181.34 ± 2.26 cm; body weight, 70.76 ± 1.75 kg; body mass index, 22.13 ± 0.55 kg/m^2) participate in this study. Athletes who do not smoke, do not have a known history of cardiovascular disease, have no disability, have a

body mass index <30 kg/m^2, do not use any medication, and have no disease/infection status were included in the study. Before the study, each of the subjects was given information about the risks that may be occurred in the study. In the method of the article, "during the current research, it has been acted within the framework of the Higher Education Institutions Scientific Research and Publication Ethics Directive".

Experimental Design

Athletes were loaded with creatine on 3 different days. Subjects came on 3 separate days. Performance tests were carried out during the routine training hours of the soccer players. The tests were carried out in the Arena sports hall and the performance laboratory of the faculty of sports sciences. The study was made in a randomized and double-blind study design. Anthropometric measurements (height, body weight) of all athletes were taken on the test day. Before loading creatine, the athletes were given preliminary information about the study and how to do the test applications. Athletes were asked to drink their supplements dissolved in 200 ml of fruit juice. The different creatine supplementation methods were as follows; athletes took creatine supplement 4 times a day (breakfast, lunch, after dinner and before going to bed) for 15 days, 4x5 grams for the first 5 days and 5 g for the following 10 days. In other creatin loading is took 0.3 grams of creatine per kg for 15 days. In other creatin loading is (placebo loading) received the same amount (Maltodextrine) for 15 days. Vertical jump, 10-30 m sprint test and agility test were performed on all subjects. Performance tests were repeated before and after the loading supplement.

Jump Performance Measurements

Vertical jump performance was evaluated with the Smart Speed mat. Participants were inqured to stand on the mat with their feet fully depressed, placing their hands at hip level, and jumping to the highest point they could jump whenever they wanted, in accordance with the procedure. 2 attempts were given and the best was recorded.

10-30 m Sprint Measurements

The 10-30 meter sprint was measured by Newtest Powertimer (Finland). They warm up for 10 minutes. Photocell gates are installed at the starting line, at distances of 10 m and 30 m. While each football player was waiting beginning line, he tried to cover the distance of 10 m and 30 m by running in the shortest time at a time determined by himself. 2 attempts were given and 5 minutes of rest was given between repetitions and the best value was saved.

Zig-Zag Test Measurements

Before the test, the study was explained to the football players. The zig-zag test was measured by Newtest Powertimer (Finland). In the test area, the direction of going and turning were determined in a zig-zag area formed by a marker funnel at a distance of 4.86 m on the long side, a funnel at a distance of 3.04 m on the short side, and a marker placed in the center. At the starting point, the player took a static standing position with one leg in front and the other in the back, standing linearly, and all the players waited in a forward bending stance for at least 3 seconds before starting to run at the starting point. Soccer players repeated the test 2 times during the 2 minutes rest interval and the best grade was evaluated (Arı and Çolakoğlu, 2017; Mackenize, 2005).

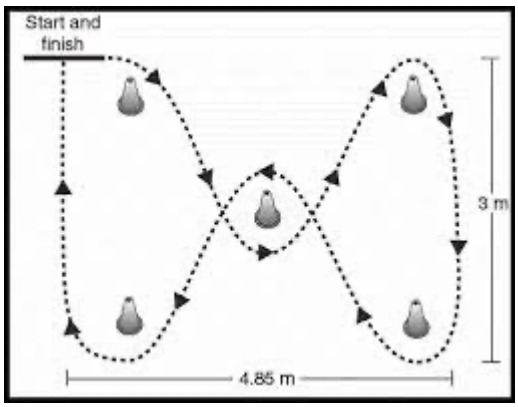

Figure 1. Zig-Zag test

Statistical Analysis

Descriptive statistics have been calculated, the Shapiro-Wilk test was used for normality distribution of the data. Since parametric test assumptions were met, t-test for dependent groups and one-way analysis of variance test (ANOVA) for repeated measurements were used to compare dependent group differences. Post-hoc analysis was used to determine the differences. The statistical significance was set at $p<0.05$. Statistical analyses were performed using the SPSS software, version 24.0.

Ethics of Research

Before the study, each of the subjects was given detailed information about the risks in the study. The study was carried out in Pamukkale University sports hall. In order to carry out the study, the ethics committee approval of Pamukkale University Faculty of Medicine "Non-Invasıve Clinical Research Ethics Committee" was obtained (Date: 28/12/2022, decision no: 10).

Results

The measurement results of the soccer players before and after the creatine intake are presented in Table 1.

Table 1

Pre and Post Experimental Values of After the Creatine Supplementation

Variables		Pre-test	Post-test	t	F
Vertical Jump Test (cm)	1st measurement day	64.40 ± 5.74	66.25 ± 6.51	-6.78*	8.52*
	2nd measurement day	59.31 ± 8.19	61.12 ±9.08	5.41	
	3rd measurement day	58.43 ± 5.02	60.00 ±4.65	5.09	
10 m sprint test (sec)	1st measurement day	1.52 ± 0.08	1.48 ± 0.05	0.58*	2.87*
	2nd measurement day	1.54 ± 0.07	1.51 ± 0.06	0.62	
	3rd measurement day	1.56 ± 0.06	1.52 ± 0.07	0.71	
30 m sprint test (sec)	1st measurement day	4.25 ± 0.13	4.18 ± 0.11	4.27*	4.51*
	2nd measurement day	4.26 ± 0.15	4.22 ± 0.13	4.05	
	3rd measurement day	4.27 ± 0.21	4.23 ± 0.15	4.57	
Zig-zag test (sec)	1st measurement day	5.45 ± 0.26	5.45 ± 0.26	0.19*	3.88
	2nd measurement day	5.58 ± 0.21	5.58 ± 0.21	0.11	
	3rd measurement day	5.50 ± 0.18	5.50 ± 0.18	0.21	

*p<0.05

Significant differences were found for 10-30 m sprint, vertical jumping, zig zag test ($p<0.05$) after the 1st measurement day creatine supplementation pre-post test values. Also there a significant difference in 10-30 m sprint, vertical jumping values in 1st measurement day and 3rd measurement day (plasebo group) ($p<0.05$). No significant changes in the 2nd measurement day and placebo group were observed in all performance tests following the 15 days experiment.

Discussion

The aim of this study is to compare the acute effects of different creatine loading methods on anaerobic performance in soccer players. The main findings from the study were that took creatine supplement 4 times a day for 15 days, 4x5 grams for the first 5 days and 5 g for the following 10 days group' revealed an improvement in sprint, jump and agility values, which are important elements of soccer player performance. There were no significant differences found in other creatine supplementation groups. Studies exploring the effect of acute creatine use on sprint performance differ in the literature. While many studies report that creatine supplementation incrase repeated sprint performance in different exercises (soccer, handball, ice hockey, swimming, cycling) with different training levels (Cox et al., 2002; Lifanov et al., 2014), some studies do not reveal the existence of this support (Delecluse et al., 2003; Gaeeni et al., 2009). Mujika et al. (2000), in their study on 17 high-training football players, loaded 5 g of creatine for 6 days, and at the end of 6 days, the 5 and 15 m sprint times were improvement.

In athletes, training of creatine stores before strength training or high-intensity training phases contributes to the execution of these phases more efficiently in terms of training results. With the training phase, daily body weight x 0.03 grams supplementation throughout the period supports the preservation of increased creatine stores during intense training. When we look at the studies on long

term creatine supplementation and explosive performance in the literature; Roberts et al. (2016) took a muscle biopsy sample after a strenuous exercise equal to 70% of the maximum oxygen consumption (maxVO_2) and applied a high carbohydrate diet (37.5 kcal x body weight) together with creatine (20 g x 6 days). After the supplementation, after the exercise test at the same workload, a visible increase in creatine and muscle glycogen was detected in the biopsy results, which were examined on the first, third and sixth days, compared to the control group. The results of the study show that creatinine and muscle glycogen stores are renewed more after high-intensity exercise. This situation has reported that creatine is an important supporter for recovery and regeneration of muscle glycogen reserves in athletes after high-intensity training. Claudino et al. (2014), made the supplementation (n=7, 1 week 20 g/day + 3 weeks 5 g/day) and control group standardized training practice for 4 weeks before the season on 14 elite football players. Repeated jump test was applied to measure lower extremity muscle strength before and after the training period in the groups. It was showed that creatine supplementation decreased the loss of lower extremity muscle strength during the gradual increase in training applied before the season. Özkara et al. (2000) found an improvement in sprint performance by loading 0.3 g of creatine a four-day period. In another study conducted on football players, Aksu (2001) reported that 14 elite young football players (16-18 years old) who took 5 g creatine monohydrate and 2 g glucose four times a day for five days, 10 repetitive 15 m maximal sprints with 30 seconds rest between them. compared the values before and after loading. In this study, a significant improvement was found in the 5 and 15 m transition times of the creatine taking group. Schedel et al. (2000), who investigated the biomechanical source of the improvement in sprint performance after creatine loading, stated that there was an increase in the stride frequency of the subjects who took creatine after loading, and this may be due to the shortening of muscle contraction and relaxation times due to high intracellular phosphocreatine. Cox et al. (2002) found an improvement on 20 m sprint performance wihch took to either a creatine (5 g for 6 days) or each group in soccer players. After the measurement, the creatine group performed better. Skare et al. (2012) investigated the effects of 20 gr of creatine on 100m sprint performance of male athletes during 5 days of supplementation and they found increase in sprint performance. In studies in the literature, an improvement in performance values measured after a creatine loading of approximately 15 grams was found. This result is simillar to the results of our study.

An increase in strength in increased muscle creatine stores can be observed as a result of a good training. Variables such as different age groups, gender, muscle fiber distribution, exercise history and training level may differ in terms of usage doses. In the literature, there are studies on the use of creatine supplement for short and long use, but which one is more effective could not be found. In our study, it was observed that the anaerobic performance measurement values of the group taking creatine 4 times a day for 15 days, 4x5 grams for the first 5 days and 5 g for the following 10 days

were better than the other measurement days with creatine intake. There are many methodological differences in the type of supplementation (other substances taken with creatine), time and amount. Athletes should take more than 2 grams creatin per a day to increase resynthesizes ATP during explosive exercise. After using 20 grams (4 doses x 5 grams) for the first 1 week, the formula body weight x 0.03 grams is widely used. No side effects were found.

Conclusion

As a result of the findings, it can be told that 4x5 grams for the first 5 days and 5 g for the following 10 days loading was more effective than other loading protocol on performance outcomes. It is thought that the results of this study will provide the trainers with the opportunity to compare the performance outputs of the training/match season they will apply in terms of for 15 days (4x5 grams for the first 5 days and 5 g for the following 10 days) creatine loading method can be more effective. It can be recommended that the test results obtained should be evaluated well and transferred to practice, as it will provide significant favorable effects on the long-term health and performance levels of the athletes.

Ethics Committee Permission Information

Ethics review board: Pamukkale University Faculty of Medicine 'Non-Invasive Clinical Research Ethics Committee'

Date of ethics evaluation document: 27.12.2022 decision no: 19

Issue number of the ethics evaluation document: 020-308640

Statement of Researchers' Contribution Rates

The entire study was executed by the only author of the study.

Conflicts of Interest

The authors state no conflicts of interest.

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References

Aedma, M., Timpmann, S., Lätt, E., & Ööpik, V. (2015). Short-term creatine supplementation has no impact on upper-body anaerobic power in trained wrestlers. *Journal of the International Society of Sports Nutrition*, *12*, 45. doi:10.1186/s12970-015-0107-6.

Aksu, Ç. A., (2001). *Kreatin yükleme uygulamasının futbol performans parametreleri üzerine olan etkisi*. Doktora tezi, Ege Üniversitesi Sağlık Bilimleri Enstitüsü, İzmir.

Ari, Y., & Çolakoğlu, F. F. (2017). The effect of 12-week plyometric training program on anaerobic power, speed, flexibility and agility for adolescent football players. *European Journal of Physical Education and Sport Science*, *3*(5), 44-64. doi:10.5281/zenodo.572401.

Aspenes, S. T., & Karlsen, T. (2012). Exercise-training intervention studies in competitive swimming. *Sports Medicine*, *42*(6), 527-543. 10.2165/11630760-000000000-00000

Brosnan, J. T., & Brosnan, M. E. (2007). Creatine: endogenous metabolite, dietary, and therapeutic supplement. *Annual Review Nutrition*, *27*, 241-61. doi: 10.1146/annurev.nutr.27.061406.093621.

Buford, T. W., Kreider, R. B., Stout, J. R., Greenwood, M., Campbell, B., Spano, M., et al. (2007). Position Stand: creatine supplementation and exercise. *Journal of the International Society of Sports Nutrition*, *30*(4), 6. doi:10.1186/1550-2783-4-6.

Claudino, J. G., Mezêncio, B., Amaral, S., Zanetti, V., Benatti, F., Roschel, H., Gualano, B., Amadio, A. C., & Serrão, J.C. (2014). Creatine monohydrate supplementation on lower-limb muscle power in Brazilian elite soccer players. *Journal of the International Society of Sports Nutrition*, *18*(11), 32. doi:10.1186/1550-2783-11-32.

Cox, G., Mujika, I., Tumilty, D. & Burke, L., (2002). Acute creatine supplementation and performance during a field test simulating match play in elite female soccer players. *International Journal of Sports Exercise*, *12*, 33-46. 10.1123/ijsnem.12.1.33

Delecluse, C., Diels, R. & Goris, M., (2003). Effect of creatine supplementation on intermittent sprint running performance in highly trained athlets. *The Journal of Strength Conditioning Research*, *17*, 446-454.

Fukuda, D. H., Smith, A. E., Kendall, K. L., Dwyer, T. R., Kerksick, C. M., Beck, T. W., Cramer, J. T., & Stout, J. R. (2010). The effects of creatine loading and gender on anaerobic running capacity. *The Journal of Strength Conditioning Research*, *24*(7), 1826-33. doi: 10.1519/JSC.0b013e3181e06d0e.

Gaeeni, A. A., Alidosteghahfarokhi, A. & Aabolhasani, M. (2009). The effects of short term creatine supplementation in sprint performance and muscular strength in wrestlers. *Journal of Sport Biosciences*, *1,* 77-92. 10.5829/idosi.mejsr.2012.12.3.611421

Hamid, M., Rahnama, N., Moghadasi, M. & Ranjbar, K. (2012). Effect of creatine supplementation on sprint and skill performance in young soccer players. *Middle-East Journal of Scientific Research*, *12*(3): 397-401. Doi: 10.5829/idosi.mejsr.2012.12.3.64214

Helms, E. R., Alan, A. A., & Peter, J. F. (2014). Evidence-based recommendations for natural bodybuilding contest preparation: nutrition and supplementation. *Journal of the International Society of Sports Nutrition*, *11*(20), 2-20. doi:10.1186/1550-2783-11-20.

Lifanov, D., Khadyeva, M. N., Rahmatullina, L., Demenev, S. V., & Ibragimov, R. R. (2014). Effect of creatine supplementation on physical performance are related to the AMPD1 and PPARG genes polymorphisms in football players. *Ross Fiziol Zh Im I M Sechenova*, *100*(6), 767-76. PMID: 25665401.

Mackenzie, B. (2005). *101 Performance evaluation tests*. Electric Word plc, London.

Mielgo-Ayuso, J., Calleja-Gonzalez, J., Marques-Jimenez, D. et al. (2019). Effects of creatine supplementation on athletic performance in soccer players: A systematic review and meta-analysis. *Nutrients, 11*(4), 757, https://doi.org/10.3390/nu11040757

Mujika, T., Padilla, S., Ibanez, J., Izquierdo, M., & Gorostiaga, E., (2000). Creatine supplementation and sprint performace in soccer players. *Medicine Science and Sports Exercise*, *32*, 518-525. 10.1097/00005768-200002000-00039

Oliver, J. M., Joubert, D. P., Martin, S. E., & Crouse, S. F. (2012). Oral creatine supplementation's decrease of blood lactate during exhaustive, incremental cycling. *International Journal of Sport Nutrition and Exercise Metabolism*, *23*(3). 252-8. doi:10.1123/ijsnem.23.3.252.

Özkara, A., Güner, R., Kunduracıoğlu, B., & Günay, M., (2000). Creatin yüklemenin düz ve slalaom koşularında sprint performansı üzerine etkileri. *Hacettepe Üniversitesi Spor Bilimleri Dergisi*, *11*, 56-63.

Rawson, E. S., Conti, M. P., & Miles, M. P. (2007). Creatine supplementation does not reduce muscle damage or enhance recovery from resistance exercise. *The Journal of Strength Conditioning Research*, *21*(4), 1208-13. doi:10.1519/R-21076.1.

Roberts, P. A., Fox, J., Peirce, N., Jones, S. W., Casey, A., & Greenhaff, P. L. (2016). Creatine ingestion augments dietary carbohydrate mediated muscle glycogen supercompensation during the initial 24 h of recovery following prolonged exhaustive exercise in humans. *Amino Acids*, *48*(8), 1831-42. doi:10.1007/s00726-016-2252-x.

Schedel, J. M., Terrier, P., & Schutz, Y., (2000). The biomechanic origin of sprint performance enhancement after one-week creatine supplementation. *The Japanese Journal of Physiology*, *50*, 273-276. 10.2170/jjphysiol.50.273

Skare, O. C., Skadberg, Q., & Wisnes, A. R. (2012). Creatine supplementation improves sprint performance in male sprinters. *Scandinavian of Medicine and Science in Sports*, *11*(2), 96-102. https://doi.org/10.1034/j.1600-0838.2001.011002096.x

Tang, F. C., Chan, C. C., & Kuo, P. L. (2014). Contribution of creatine to protein homeostasis in athletes after endurance and sprint running. *European Journal of Nutrition*, *53*(1), 61-71. doi:10.1007/s00394-013-0498-6.

Unnithan, V. B., Veehof, S. H., Vella, C. A., & Kern, M. (2001). Is there a physiologic basis for creatine use in children and adolescents? *The Journal of Strength Conditioning Research, 15*(4), 524. doi:10.1519/00124278-200111000-00021.

Williams, J., Abt, G., & Kilding, A. E. (2014). Effects of creatine monohydrate supplementation on simulated soccer performance. *International Journal of Sports Physiology and Performance*, *9*(3), 503-10. doi:10.1123/ijspp.2013-0407.

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