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Short-term oral creatine supplementation in professional football players: A randomized placebo-controlled trial

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ABSTRACT

The study aimed to evaluate the effect of a short-term oral creation (Cr) supplementation on body mass and maximal performance in professional soccer players. Using a double blind randomised placebo-controlled trial, 16 male professional soccer players (8 Cr, mean age, 22.5 years; 8 placebo, 22.8 years), highly trained, were tested before (T1) and after (T2) a five days oral Cr (or placebo) supplementation (20 g per day). Body mass (kg) was measured, and peak power (W) was calculated from vertical distance jumped during a vertical jump test. From pre (T1) to post (T2) supplementation, mean body mass increased from 78.1 kg (± 7.2) to 79.8 kg (± 7.7) in the Cr group, and slightly decreased from 77.6 kg (± 5.9) to 77.4 kg (± 6.6) in the placebo group. For peak power, participants in the Cr group increased after Cr supplementation from 4728.7 W (± 607.7) to 4854.4 W (± 581.0), while peak power in the placebo group decreased from 4420.5 W (± 408.9) to 4299.2 W (± 558.7). Signifi cant time (pre vs. post supplementation) by group (Cr vs. placebo) interactions indicated that changes in both body mass and peak power were significantly ($p \leq 0.01$) greater in the Cr group compared with the placebo group. A five days oral Cr supplementation was shown to increases body mass and peak power in professional soccer players. Short term Cr supplementation could be recommended for its ergogenic effect to professional soccer players in order to enhance their peak power and consequently their performance.

Keywords: Creatine, Athletic performance, Football, Randomized controlled trial, Vertical jump test

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INTRODUCTION

Lately, elite athletes have been seeking the latest scientific evidence in sport and exercise physiology in order to persistently develop and apply innovative effective training and diet methods. Beyond both training and diet, professional athletes have had recently a growing interest in the use of advance physiological sports ergogenics for the purpose of enhancing maximally *i.e.* optimally their performance.[1] Ergogenics, being classified into mechanical, psychological, physiologic, pharmacologic and nutritional aids, are techniques or substances designed specifically to augment natural physiological processes, resulting then in the enhancement of energy production and utilization.[2,3]

One of nutritional aids is particularly in vogue among strength and power athletes: creatine supplementation. Creatine (Cr) is a natural dietary constituent that binds phosphate to form creatine phosphate (CP), a high-energy phosphagen which is important for rapid energy production such as in repeated speed and power events.[4]

Concordantly, Cr supplementation, taken mostly orally, is believed to increase the levels of CP during repeated sprints so as to produce more energy and to delay fatigue, improving then performances. Then, with regard to its ergogenic effect, Cr supplementation has been largely taken into consideration and scientific researches have been conducted to explore both mechanisms of action and ergogenic effect on sport performance. Ten to 15 years ago, studies already showed the effect of Cr supplementation on its mechanisms of action, such as an enhancement of CP resynthesis and availability, an increase of body mass, a reduction of muscle acidity, and a delay of fatigue.[5-7]
When it comes to the ergogenic effect of creatine supplementation on sport performance rather than on its mechanisms of action, scientific evidence still remains contradictory.[8] For more than a decade, Cr supplementation has been found to improve aerobic performance as well as anaerobic performance, especially in sports that involve jumping, sprinting or cycling.[9-11] However, there have also been studies in which Cr supplementation has been shown to be ineffective: its use, either during repeated bouts, anaerobic exercises, or for aerobic endeavors, did not lead to any improved performances.[12-14] Despite the controversiality of these findings, professional athletes have been keeping to ingest Cr supplementation in order to enhance their performances: anecdotal reports indicate that Cr supplementation were used by athletes competing in the Olympic Games in Barcelona (1996) and Atlanta (1996), while studies report that American football players, as well as British athletes, swimmers and rugby players, have been using Cr as an ergogenic aid.[15,16] In professional soccer (also called football), the Dutch soccer team has reported the use of Cr supplementation during several World Cups and European Championships, while 37% of professional Italian soccer players reported the use of Cr supplementation.[17] In light of the physical efforts required in professional soccer players, the mechanisms of action of Cr supplementation plead for its use in order to delay fatigue, facilitate recuperation and enhance performances. However, scientific findings on the ergogenic effects of Cr supplementation in professional soccer players are lacking. Then, with regard to the aforementioned considerations, the purpose of this study was to evaluate the effect of a short-term oral Cr supplementation on body mass and maximal performance in professional soccer players.

MATERIALS AND METHODS

A double-blind randomised placebo-controlled trial was conducted in the present study, involving 16 male professional soccer players (no vegetarians), all free of any musculoskeletal disorders, highly trained, and active at the same club in the Dutch professional league. After baseline measurements, the participants were randomly assigned either to Cr or placebo group, being matched for age and body weight.

All participants have been active in professional soccer for at least four years, training and/or competing at least 45 weeks per year, at least six times a week (10 hours a week or more), and competing weekly one to three times (90 to 270 minutes a week). Following an explanation of the experimental procedures, risks, and benefits, each participant gave his verbal accord to participate in the study and informed consents were signed. During the previous six months, all participants were free of any anabolic or ergogenic supplements or drugs, and they also refrained from any additional nutritional supplementation during the study period. Dietary intake was not monitored, and fluid intake was not measured, but participants were encouraged to adhere as usual to their normal dietary patterns.

Participants reported to the indoor test area with a synthetic surface on two separate occasions for two testing sessions (T1 and T2). Before both testing sessions, participants performed the same standardized warming-up, consisting in 10 minutes on a cycle ergometer (Spintrainer, TechnoGym®, Italy) at 100 to 120 W and 70 to 80 rpm, and were then familiarized with the exercise testing procedure by performing one trial (vertical jumping test). Following the familiarization, and after the measurement of height and body weight (Tanita, BF626W, the Netherlands) to the nearest centimetre and 100 grams, respectively, participants performed the exercise testing procedure *i.e.* vertical jump.

After the first testing session (T1), participants were matched for age and body mass and then randomly assigned to either the Cr or placebo group. This allocation for either Cr or placebo group was blinded to both participants and assessor. Immediately after the first testing session (T1), the Cr group started a daily oral intake of 20 grams of Cr-monohydrate for five consecutive days, while the placebo group ingested a same daily dosage of maltodextrins for five consecutive days.
After the fifth day of Cr or placebo intake, on the sixth day of the protocol, participants underwent the second testing session (T2). Involving the same assessor, both testing sessions were conducted in the morning (8 - 10 am) before the soccer training session, and each participant was assessed at T2 at the same time than at T1, avoiding then any effects related to a change in time testing. During the period of the study protocol, all participants followed the same training and competition program (including a competition match), and were free from training and competition the day before both testing sessions. The study protocol was set in accordance of the medical ethics of Laboratory of Motoria Performance of the University Blaise Pascal, Clermont-Ferrand, France, approved by the technical and

medical staff of the soccer club, and carried out in accordance with the Declaration of Helsinki (2000) of the World Medical Association.

Following the first testing session (T1), participants of the Cr and placebo group were provided a total of 100 grams of Cr-monohydrate (VitaLIFE SPORT PRODUCTS, Echt, the Netherlands) and maltodextrins (both pouder), respectively, divided into five doses of 20 grams, one for each day. With the use of a 5 grams dose spoon, participants were asked to take 5 grams of Cr-monohydrate or maltodextrins four times a day (total of 20 g of Cr-monohydrate or maltodextrins per day) for 5 consecutive days. We asked the participants to take their supplementation with 200-250 ml of water, at regular times during the day, and to avoid any product containing caffeine (coffee of tea) just before or just after the supplementation.[18] The initial dose of five grams was provided within 15 minutes of the conclusion of the first testing session (T1), and was witnessed by one of the investigators. There was no dose required on the morning of the second testing session (T2).

A vertical jump test in squat position was used to asses jumping performance and in order to determining the effect of Cr supplementation on maximal power.[19] Each participant was asked to place a Velcro ring around the middle finger of his right hand, at its very tip, and to stand with the right shoulder adjacent to the wall. Then, while keeping the feet flat on the floor, he was asked to reach up as high as possible, touching the vertical jump measurement device mounted on the wall with the Velcro ring in order to mark his standing reach height. The participant was then asked to perform a maximal height squat jump, starting in a 90° bent knee preparatory position and with the arms back, to be subsequently thrust forward and upward to contribute to the height of the jump. Three trials of this jump were performed, with one minute and 30 seconds rest in between in order to avoid any fatigue bias. The highest vertical jump was taken into account and standing reach height was subtracted to establish actual vertical distance jumped (h). The vertical distance jumped (h) was used to calculate peak anaerobic power (P) according to the formula of Sayers et al. (1999):[20]

$P(W)=60.7 x h(cm)+45.3 x bodyweight(kg)–2055.$

In addition, peak anaerobic power per kilogram of body weight (W.kg-1) was calculated for all participants, dividing their peak anaerobic power (W) by their body weight (kg).

At T1 and T2, descriptive statistics (means, SDs, ranges) of both Cr and placebo groups were calculated for age, height, body weight, vertical distance jumped and peak anaerobic power (W and W.kg-1). In order to explore statistical difference among groups at the first testing session (T1) *i.e* pre-supplementation, one-way analysis of variance (ANOVA) was performed for age, body weight, vertical distance jumped and peak power.[21] Three separate two-way mixed model ANOVA's (pre- vs. post-supplementation [time] × Cr vs. placebo [group]) were used to analyze body weight, vertical distance jumped and peak power outcomes.[21] Statistical significance was set at $p < 0.05$. All analyses were performed with the statistical analysis software SPSS 16.0 for Windows.

RESULTS

All participants in both Cr and placebo groups appeared to have exhibited 100% compliance (self-reported) with the supplement protocol, and were able to complete the required testing procedures as well as regular training and competition with no side effects reported. Characteristics of both Cr and placebo groups at T1 and T2 are presented in table 1. One-way ANOVA indicated that Cr and placebo groups were statistically equivalent before Cr supplementation (T1) for age (F=1.01;p=0.33), body weight (F=0.02;p=0.90), vertical distance jumped (F=1.91;p=0.19) and peak power (F=1.42;p=0.25), suggesting that participants randomization was successfully established.

Table 1: Characteristics of the participants (mean ± standard deviation) in both creatine and placebo group before (T1) and after (T2) creatine supplementation

		Creatine group	Placebo group
Age (years)		23.2 ± 2.5	25.0 ± 4.5
Height (cm)		183.0 ± 6.1	180.4 ± 8.9
Body weight (kg)	T1	78.1 ± 7.2	77.6 ± 5.9
	T2	79.8 ± 7.7	77.4 ± 6.6
Distance jumped (cm)	T1	53.5 ± 8.5	48.8 ± 4.7
	T2	54.3 ± 7.9	46.9 ± 6.9
Peak power (W)	T1	4728.7 ± 607.7	4420.5 ± 408.9
	T2	4854.4 ± 581.0	4299.2 ± 558.7
Peak power ($W.kg^{-1}$)	T1	60.7 ± 7.5	57.0 ± 3.6
	T2	61.0 ± 6.7	55.5 ± 5.3

Figure 1: Mean body weight before (T1) and after (T2) a five days oral creatine supplementation (20 g per day) in professional soccer players (creatine, n = 8; placebo, n = 8).

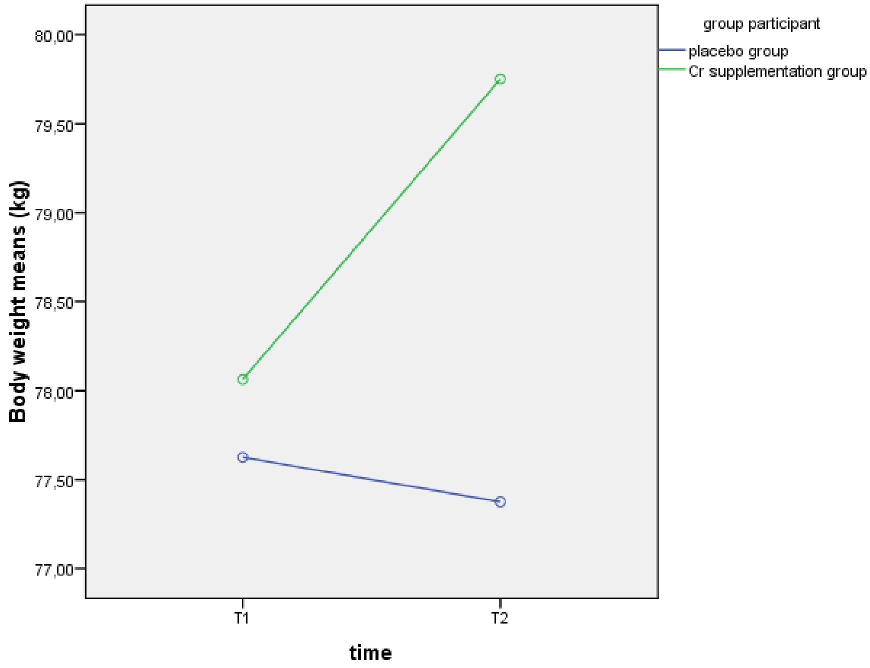
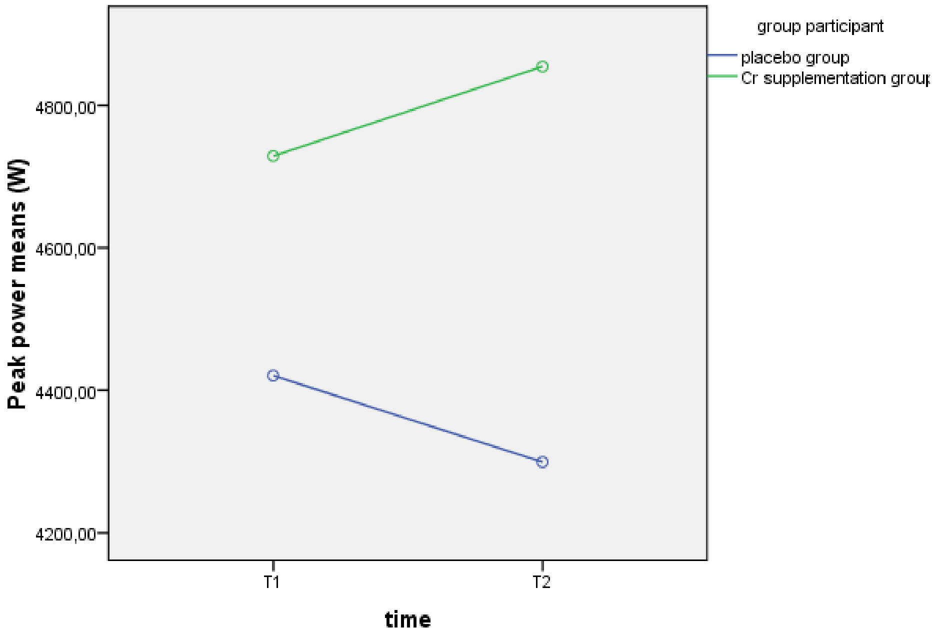


Figure 2: Mean peak power (W) before (T1) and after (T2) a five days oral creatine supplementation (20 g per day) in professional soccer players (creatine, n = 8; placebo, n = 8).



Means and standard deviations of body mass, vertical distance jumped and peak power (W and $W.kg^{-1}$) from both Cr and placebo groups are presented in table1. For mean body mass, two-way repeated measures ANOVA showed significant main effects for pre-post- supplementation (F=6.82;p=0.02) and significant interaction effects between pre-post-supplementation and Cr-placebo (F=12.39;p=0.00), showing that the change in body mass between pre-and post-supplementation was not the same in Cr and placebo group (Figure 1). A significant main effect for Cr-placebo was not found (F=0.17;p=0.69). Concerning vertical distance jumped, statistical analyses did not resulted in significant main effects for time pre-post-supplementation (F=0.64;p=0.44) and Cr-placebo (F=2.98;p=0.11). A nearly significant interaction effect between pre-post-supplementation and group (F=4.41;p=0.054) was found, showing that the change in vertical distance jumped between pre- and post-supplementation was not the same in Cr and placebo group. For mean peak power (W), two-way repeated measures ANOVA showed significant interaction effects between pre-post-supplementation and Cr-placebo (F=8.81;p=0.01), showing that the change in peak power between pre- and post-supplementation was not the same in Cr and placebo group (Figure 2). A significant main effect for time pre-post supplementation (F=0.00;p=0.96) and for Cr-placebo (F=2.57;p=0.13) was not found. Two-way repeated measures ANOVA for mean peak power per kilogram of body weight ($W.kg^{-1}$) did not show any significant main or interaction effects.

DISCUSSION

The aim of this study was to evaluate the effect of a five days oral Cr supplementation on body mass and maximal performance in professional soccer players, using a double-blind randomised placebo-controlled trial. Change in mean body mass from pre- to post-supplementation was + 1.7 kg in the Cr group and – 0.2 kg in the placebo group. Change in peak power from pre- to post-supplementation was + 125.7 W in the Cr group and - 121.3 W in the placebo group. For both body mass and peak power (W), these changes between pre- en post-supplementation were significantly different in Cr group than in the placebo group.

To our knowledge, the present study is the first exploring the effects of five days oral intake of Cr supplementation in professional soccer players, showing that such a short-term Cr supplementation intake has a significant ergogenic effect on body weight and peak anaerobic power. In soccer, in which anaerobic system is the most important energy source, the combination of an optimal body weight (resistance to body contacts) with a high anaerobic power is crucial when it comes to elite performance. In our study, participants were able to jump after Cr supplementation as high as before, despite an increase of 2.2% in their body weight. This increase in body weight after the Cr supplementation did not influence negatively the vertical jump of the participants from the experimental group, resulting in a 2.7% increase in peak anaerobic power. It has been well established that Cr supplementation perturb muscle intracellular volume and increase muscle Cr stores, explaining the gain in body weight and the improvement in performance; however, unequivocal scientific knowledge about these physiological mechanisms is controversial.[8]

Our findings are in line with results from other studies, in which the ergogenic effects of another doses of Cr supplementation (five to 28 days) were explored either on body weight, aerobic or anaerobic performance, in other sport disciplines than soccer, and conducted by recreational or competitive athletes rather than elites or professional ones.[22-24] For more than one decade, Cr supplementation intake has been showed to increase body weight and strength while improvement in aerobic and anaerobic performance was showed in healthy adults and in rowers, rugby and American football players.[22-24] However, these positive findings about the ergogenic effects of Cr supplementation remain controversial as other studies did not showed any improvement in performance after Cr intake.[8,12,13] In our study, we choose to use a daily oral intake of 20 grams of Cr-monohydrate, four times a day for five consecutive days, for two reasons: first because such a short-term supplementation dose was found to have ergogenic effect on velocity and power,[9,11,24] and second because the burden of our research protocol would not substantially interfere with the training and match scheme of our study population, being always an issue when it comes to involve elite athletes in empirical researches.

With regard to the adverse effect of Cr supplementation, reports from empirical researches remain controversial. Most reports on health risks failed to establish any casual relationship between CR intake and side effects such as muscle cramping, muscle injury, gastrointestinal complaints or deterioration of renal functions.[16,25] In the present study, all participants seemed to have tolerated the CR supplementation intake as they did not report any unusual muscle cramping or fatigue, neither gastrointestinal complains during training sessions and competition activities.

Randomised controlled trials (RCT) have been defined as the highest methodological quality design in scientific research and are the most rigorous way of determining whether a cause-effect relation exists between treatment and outcome, generating unbiased, accurate and applicable results.[26] In this study, using a RCT was the most valid method to evaluate the effect of a five days oral Cr supplementation on body mass and maximal performance in professional soccer players, being definitely a strength of our study. Furthermore, appropriated randomization and double-blinding allowed to reduce optimally any bias. One limitation of our study could be the small sample size of both experimental (n = 8) and control (n= 8). However, the difficulty to conduct experimental researches in large groups of elite athletes is well known, especially in professional soccer players. Professional soccer players and their medical or technical staff members are not easily open to empirical research, especially with regard to the competition scheme burden (two or three competition matches a week). With regard to the 16 soccer players involved in our study, we can still be satisfied about this sample size, also with the fact that we did not loose any participants during the experimental procedures.

With regard to jumping performance measurement and calculation of peak anaerobic power, our choice to use a vertical jump test in our study and to calculate peak anaerobic power according to the formula of Sayers et al. (1999) seems relevant when considering both practical and clinimetric issues. Vertical jump tests have been the most widely used standard by which explosive athletic performance is assessed, either by coaches, strength and conditioning professionals or research scientists.[19,27] Especially in activities where explosive power is closely related with performance achievement such as in soccer, volley-ball and basket-ball, vertical jump tests provide an effective measurement of power as an indirect measure of performance. Besides, vertical jump tests are both efficient and practical, time consuming measurements being an issue of interest when it comes to elite athletes. In addition, the height of a vertical jump and related peak power have been shown to be well correlated with the maximal anaerobic power on a Monark ergometer and with the peak power of the Wingate test as well.[28] From the vertical distance jumped measured through the vertical jump test, the formula of Sayers et al. (1999) was used in order to calculate peak anaerobic power.[20] This formula has been found more accurate and more valid than the formulas of Lewis and Harman et al..[20,29,30] Using the formula of Lewis to calculate peak anaerobic power, post-hoc two-way repeated measures ANOVA analyses revealed the same findings than our primary analyses and showed significant interaction effects between pre-post-supplementation and group ($F=11.86;p=0.00$) but no significant main effect for time *i.e.* pre-post supplementation ($F=0.31;p=0.59$) or for group ($F=1.75;p=0.21$).

CONCLUSIONS

Our double-blind randomised placebo-controlled trial reports that a five days oral Cr supplementation increases both body mass and absolute peak power in professional soccer players. However, relative peak power (per kilogram of body weight) did not increase, suggesting that Cr supplementation could be especially considered in sport disciplines in which body weight do not have such a crucial role in performance achievements. Short-term Cr supplementation could be recommended in professional soccer for its ergogenic effect in order to enhance their performance. However, even if Cr supplementation can be considered as an appealing and legal ergogenic aid for professional soccer players, coaches and healthcare professionals, and the athletes themselves, should consider, before prescribing and using Cr supplementation, several factors such as age, gender, muscular characteristics and position in the field. Meanwhile, further researches should be conducted in order to evaluate the long-term effects of Cr supplementation on health determinants.

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REFERENCES

[1] JM Tokish, MS Kocher, RJ Hawkins. Ergogenic aids: a review of basic science, performance, side effects, and status in sports. *Am J Sports Med*, **2004**, 32(6), 1543-1553.
[2] MH Williams. Ergogenic and ergolytic substances. *Med Sci Sports Exerc*, **1992**, 24(suppl 9), S344-S348.
[3] MH Williams. The use of nutritional ergogenic aids in sports: Is it an ethical issue? *Int J Sport Nutr,* **1994**, 4(2), 120-131.
[4] J Wilmore, D Costill, WL Kenney. *Physiology of sport and exercise*. Human Kinetics, Champaign IL, **2009**.
[5] A Casey, PL Greenhaff. Does dietary creatine supplementation play a role in skeletal muscle metabolism and performance? *Am J Clin Nutr*, **2000**, 72(2), 607S-617S.
[6] GK McConell, J Shinewell, TJ Stephens et al. Creatine supplementation reduces muscle inosine monophospate during endurance exercise in humans. *Med Sci Sports Exerc*, **2005**, 37(12), 2054-2061.
[7] J Stout, J Eckerson, K Ebersole et al. Effect of creatine loading on neuromuscular fatigue threshold. *J App Physiol*, **2000**, 88(1), 109-112.
[8] MG Bemben, HS Lamont. Creatine supplementation and exercise performance: recent findings. *Sports Med*, **2005**, 35(2), 107-125.
[9] O Gutierrez-Sancho, J Moncada-Jimenez, W Salazar-Rojas et al. The effects of creatine supplementation on biochemical, body composition, and performance outcomes in humans: a meta-analysis. *Int J App Sports Sci*, **2006**, 18, 12-27.
[10] BJ Dascombe, M Karunaratna, J Cartoon et al. Nutritional supplementation habits and perceptions of elites athletes within a state-based sporting institute. *J Sci Med Sport*, **2010**, 13(2), 274-280.

[11] M Izquiero, J Ibanez, JJ Gonzales-Badillo et al. Effects of creatine supplementation on muscle power, endurance, and sprint performance. *Med Sci Sports Exerc,* **2002**, 34(2), 332-343.
[12] M Mac Kenna, J Morton, SE Selig et al. Creatine supplementation increases muscle total creatine but not maximal intermittent exercise performance. *J App Physiol,* **1999**, 87(6):2244-2252.
[13] M Deutekom, JGM Beltman, CJ de Ruiter, et al. No acute effects of short-term creatine supplementation on muscle properties and sprint performance. *Eur J App Physiol,* **2000**, 82(3), 223-229.
[14] PD Chilibeck, C Magnus, M Anderson. Effect of in-season creatine supplementation on body composition and performance in rugby union football players. *App Physiol Nutr Metab,* **2007**, 32(6), 1052-1056.
[15] ER Eichner. Ergogenic aids. *Physician Sportsmed,* **1997**, 25, 70-80.
[16] JR Poortmans, M Francaux. Adverse effects of creatine supplementation: fact or fiction. *Sports Med,* **2000**, 30(3), 155-170.
[17] E Taioli. Use of permitted drugs in Italian professional soccer players. *Br J Sports Med,* **2007**, 41(7), 439-441.
[18] MA Tarnopolsky. Caffeine and creatine use in sport. *Ann Nutr Metab,* **2010**, 57(suppl 2), 1-8.
[19] EL Fox, DK Mathews. *The Physiological Basis of Physical Education and Athletics*, 3rd Ed. Philadelphia: Saunders College, **1981**, 619-621.
[20] SP Sayers, DV Harackiewicz, EA Harman et al. Cross-validation of three jump power equations. *Med Sci Sports Exerc*, **1999**, 31(4), 572-577.
[21] LG Portney, MP Watkins. *Foundations of clinical research: Applications to practice*. New Jersey: Prentice-Hall, **2007**.
[22] JD Branch. Effect of creatine supplementation on body composition and performance: a meta-analysis. *Int J Sport Nutr Exerc Metab,* **2003**, 13(2), 198-226.
[23] J Rico-Sanz, MT Mendez Marco. Creatine enhances oxygen uptake and performance during alternating intensity exercise. *Med Sport in Sport Exerc,* **2000**, 32(2), 379-385.
[24] I Mujika, S Padilla, J Ibañez et al. Creatine supplementation and sprint performance in soccer players. *Med Sport Sport Exerc,* **2000**, 32(2), 518-525.
[25] B Gualano, C Ugrinowitsch, RB Novaes et al. Effects of creatine supplementation on renal function: a randomized, double-blind, placebo-controlled clinical trial. *Eur J Appl Physiol,* **2008**, 103(1), 33-40.
[26] J Grossman, FJ Mackenzie. The Randomized controlled Trial Gold standard, or merely standard? *Persp Biol Med*, **2005**, 48(4), 516-534.
[27] P Klavora. Vertical-jump tests: a critical review. *Strength Conditioning J,* **2000**, 22(5), 70-75.
[28] H Vandewalle, G Peres, J Heller et al. Force/velocity relationship and maximal power on a cycle ergometer. Correlation with the height of a vertical jump. *Eur J Appl Physiol,* **1987**, 56(6), 650-656.
[29] C Hertogh, O Hue. Jump evaluation of elite volleyball players using two methods: jump power equations and force platform. *J Sports Med Phys Fitness,* **2002**, 42(3), 300-303.
[30] AJ Lara, J Abian, LM Alegre et al. Assessment of power output in jump tests for applicants to a sports science degree. *J Sports Med Phys Fitness,* **2006**, 46(3), 419-424.