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ORIGINAL ARTICLE

The effects of creatine supplementation on performance and hormonal response in amateur swimmers

Effets d'une supplémentation en créatine sur la performance et la réponse hormonale chez des nageurs amateurs

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KEYWORDS
Swimmers;
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Summary
Objectives. — The purpose of this study was to determine the influence of short-term creatine supplementation on sprint swimming performance (50 and 100 m) and hormonal responses (growth hormone, testosterone and cortisol).
Methods. — Twenty amateur male swimmers ingested creatine monohydrate (CR) or a matched placebo (PL) for 6 days. All subjects performed 6 days, swimming exercise. The subjects were tested for performance and hormonal responses the day before and after this creatine loading.
Results. — The mean swimming time of CR group in 50 m was significantly decreased (Before-period: 53.1 ± 3.73 s, after-period: 50.7 ± 2.84 s). Growth hormone and cortisol were not affected by this creatine loading. But, testosterone concentration was significantly greater in CR compared to PL after supplementation period ($P < 0.05$).
Conclusions. — Our data suggest that short-term creatine supplementation has improved 50 m sprint performance in amateur swimmer and it seems unlikely creatine loading is hormonally mediated.

MOTS CLÉS
Nageurs ;
Supplémentation en

Résumé
Objectifs. — Le but de cette étude était de déterminer l'influence à court terme d'une supplémentation en créatine sur la performance lors de sprints en natation (50 et 100 m) et sur les réponses hormonales (hormone de croissance, testostérone et le cortisol).

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créatine ;
Hormones
anabolisantes

Méthodes. — Vingt nageurs amateurs ont ingéré du monohydrate de créatine (CR) ou un placebo (PL) pendant six jours pendant lesquels ils ont poursuivi leur entraînement de natation. Les performances et les réponses hormonales ont été enregistrées le jour précédent et après cette période de charge orale en créatine.
Résultats. — Le temps de nage moyen du groupe CR sur 50 m était significativement diminué (53,1 ± 3,73 secondes avant charge vs 50,7 ± 2,84 secondes après supplémentation). L'hormone de croissance et le cortisol n'ont pas été affectés par cette charge en créatine. En revanche, la concentration de testostérone était significativement plus élevée dans CR par rapport à PL après la période de supplémentation ($p < 0{,}05$).
Conclusion. — Nos résultats suggèrent qu'une supplémentation de courte durée en créatine a amélioré de manière significative la performance lors de sprints sur 50 m chez des nageurs amateurs sans que l'on puisse imputer de manière objective une médiation hormonale.

1. Introduction

Creatine ergogenic potential is among the subjects of current research interest regarding ergogenic agents. This supplementation is a popular dietary supplement that is used by athletes to increase muscle mass and strength, and improve sports performance [1,2]. It has been well established that increasing dietary availability of creatine serves to increase total creatine and phosphocreatine concentrations in the skeletal muscle [3]. Muscle creatine and phosphocreatine can be increased approximately 25% following high-dose short-term (≈ 20 g d-1 for 5 d) or low-dose long-term (≈ 3 g d-1 for 28 d) creatine supplementation [4,5]. Creatine supplementations positively affect strength, total work performed, peak power and performance [6]. Gotshalk et al. [7] reported that creatine supplementation (0.3 g/kg/d for 7 d) resulted in a significant increase in the amount of work performed during five sets of bench press and jump squats in comparison to the placebo group. Mujika et al. [8] reported that creatine supplementation (20 g/d for 6 d) improved repeated sprint performance (6 × 15 m sprints with 30-s recovery) in jumping ability in soccer players. However, there are conflicting results about improvements in swimming performance after creatine loading in the literature [9—12].

While Selsby et al. [11] demonstrated improvements in the performance of both a single 50 yard and a single 100 yard freestyle sprint in a creatine supplemented group; Mendes et al. [12] found no improvements in the performance of both a 50-m and a 100-m sprint in competitive swimmers following 8 days creatine supplementation. In addition, Havenetidis et al. [13] reported significant improvement in race time (2.1%) in swimmers' performance for creatine group only. Despite this, Burke et al. [9] reported that creatine supplementation (20 g/day-1 for 5 d) did not enhance performance in maximal single effort swim sprints of 25, 50, and 100 m each interspersed with ~ 10 min recovery period. The lack of standardization of exercise protocols, and variations in individual training levels may account for these discrepant results, and suggest that additional studies are needed.

Because creatine supplementation rapidly increases body mass and fat-free mass [2,14], it has been hypothesised that creatine induces hypertrophy through endocrine mechanisms [2]. Growth hormone and testosterone seems to be played stimulate muscle protein accretion [15]. Growth hormone stimulates protein synthesis by activating ribosomal initiation factors thereby improving translational efficiency [16]. Alternately, testosterone increases protein synthesis by converting the androgen receptor to a transcription factor and by activating muscle satellite cells, this is important because gene transcription is an initial target for the modulation of protein synthesis [17]. Because of the critical functions of hormones, study has investigated various plans to enhance the exercise-endocrine interaction. Volek et al. [18] tested testosterone and cortisol levels immediately after-exercise (five sets of bench presses and jump squats) in creatine (25 g/d for 7 d) and placebo-supplemented subjects, and found no effect of creatine on endocrine status. Schedel et al. [19], however, found increased growth hormone levels (83%) in response to a 20 g oral creatine bolus. Hence, effects of creatine supplementation on hormonal responses are unclear. The creatine supplementation as coordinated function of metabolically connected nutrients and physiologically active ingredients may be pivotal in enhancing hormonal responses and enhancing performance [15]. Therefore, the purpose of this study was to determine the influence of short-term creatine supplementation on sprint swimming performance and hormonal responses.

2. Method

2.1. Subjects

Twenty healthy amateur male swimmers volunteered to participate in this study. The study was limited to males to reduce variation in hormonal response to the exercise. Following an explanation of all procedures, possible risks, and benefits, each subject gave his informed consent before participation in this study. All the subjects reported that they were free of any anabolic supplements or drugs during the previous year and refrained from creatine supplementation for at least 3 months before the start of this study. The Institutional Review Board of the University approved the research protocol. Subjects had been trained in swimming for, at least, six months, prior to the study, twice per week

Table 1 Diet composition during 7 days of supplementation. Values are given as a percentage. There were no differences in diet composition between groups.

	PL group	CR group
Carbohydrate	64.6 ± 6.4	63.7 ± 4.2
Protein	12.8 ± 4.2	13.6 ± 3.8
Fat	23.5 ± 3.6	23.8 ± 6.8

(mean times were 4 per week). The subjects refrained from any additional nutrition supplementation during this study. All subjects were encouraged to adhere to their normal and similar dietary patterns throughout the study. Table 1 shows the diet composition during supplementation period from dietary records. The subjects had the following characteristics [(mean ± SD)]: CR group: age 21.32 ± 2.74 years; height 173.56 ± 5.34 cm; body mass 68.35 ± 7.35 kg; and PL group: age 20.27 ± 1.54 years; height 174.52 ± 2.85 cm; body mass 68.52 ± 5.41 kg. There were no significant differences between groups in physical characteristics.

2.2. Experimental design

Prior to the study, subjects were randomly assigned to creatine supplementation (CR: 10*n*) or a placebo (PL: 10*n*) group. Testing occurred one day before creatine loading and 6 days after. All tests were conducted at the same time of day (late afternoon). Performance tests at 50 and 100 m of breaststroke were started after the subjects underwent a standard warm-up. All swimming times were recorded by one person and all swimmers started from pool walls. All subjects completed six consecutive days of swimming sprint exercise in 50 and 100 m of breaststroke (Table 2). Subjects performed all trial sessions at maximal velocity of sprint performance. Prior to trial per session, subjects performed 100 m mild swimming for warm-up, and had 3 min of passive rest between exercise sessions. A single-blind procedure was used in the supplementation in this study. During the 6-day supplementation period, the CR group consumed 4 × 5 g of creatine monohydrate per day, which was mixed with apple juice, and PL group consumed 4 × 3 g of wheat flour (mixed with apple juice) per day (20 g) for the same number of days. The supplement was ingested at 10 h 00, 1 h pre and 1 h after exercise sessions, and at 23 h 00.

Table 2 Experimental design.

	Exercise Program	Duration (min)
Day 1	2 × 100 4 × 50 4 × 25	45
Day 2	1 × 100 4 × 50 4 × 25 8 × 12	45
Day 3	2 × 200 4 × 100	45
Day 4	4 × 50 8 × 25 10 × 12	45
Day 5	1 × 100 1 × 50 8 × 25 10 × 12	45
Day 6	1 × 50 10 × 25	20

Table 3 Mean swimming performance times (mean ± SD) in pre and post-supplementation period in the PL and CR groups.

	Group	Pre	Post
50 m (s)	CR	53.1 ± 3.7	50.7 ± 2.8[a]
	PL	53.44 ± 2.76	52 ± 3.78
100 m (s)	CR	122 ± 12.4	119 ± 13.9
	PL	120 ± 10.3	119 ± 10.7

[a] Significant difference ($P < 0.05$) to Pre-test.

2.3. Blood collection and analysis

Blood samples were taken via venipuncture, after 5 min in a supine position, from an antiecubital vein by using a 20-guge needle and Vacutainers system for the determination of serum testosterone, cortisol and growth hormone. Blood samples were obtained pre and after 6 days of supplementation (immediately after swimming tests). All blood samples were taken during a standardized time of day (between 17 h 00 and 18 h 30) for each subject in order to minimize the effects of diurnal hormonal variations. The blood was processed and centrifuged, and the resultant serum was stored at −20 °C until analyzed. Total serum testosterone, cortisol and growth hormone were determined in duplicate by using standard radioimmunoassay procedures and were assayed via Spectria kits (Diagnostic Products, Finland).

2.4. Statistical analysis

Statistical evaluation of the data was accomplished by using a two-way analysis of variance with repeated-measures design. When a significant *F* value was achieved, a Fisher's least significant difference post hoc test was used to locate the pairwise differences between the means. Statistical power calculations ranged from 0.78 to 0.80. The level of significance for this investigation was set at $P < 0.05$. Data are reported as mean ± SEM.

3. Results

3.1. Performance

Mean changes swimming performance times in CR and PL groups are shown in Table 3. Although mean swimming times of CR group in the 50 and 100 m performances decreased, this decrease was statistically significant only in the 50 m ($P = 0.04$).

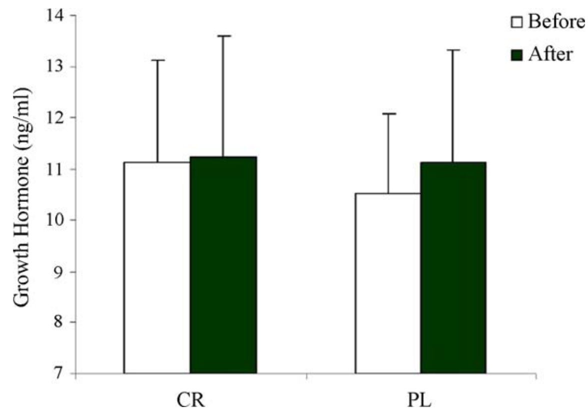

Figure 1 Growth Hormone responses (mean ± SD) before and after supplementation period in the creatine supplementation (CR) and placebo (PL) groups. No significant changes were found in growth hormone responses.

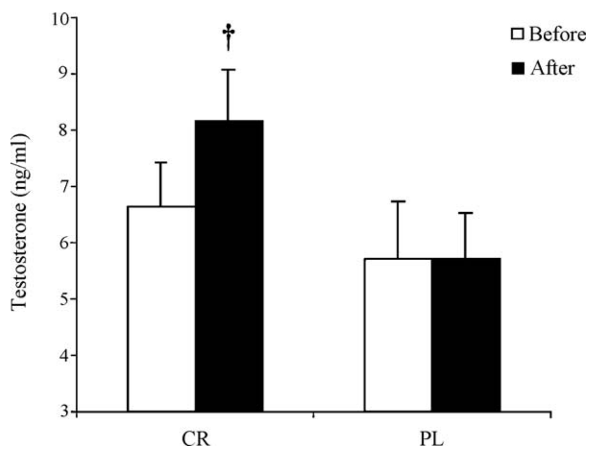

Figure 2 Testosterone responses (mean ± SD) before and after supplementation period in the creatine supplementation (CR) and placebo (PL) groups.
† Significant ($P < 0.05$) greater than placebo value.

3.2. Hormonal responses

Hormonal responses are presented in Figs. 1—3. No significant changes were observed in growth hormone, testosterone and cortisol levels after-supplementation comparing to pre-supplementation in both groups of CR and PL ($P > 0.05$). No significant differences were observed in growth hormone and cortisol levels after-supplementation between CR and PL groups. However, testosterone hormone relatively after-supplementation was greater for CR compared to PL ($P = 0.01$).

4. Discussion

The aim of this study was to investigate the influence of short-term creatine supplementation on sprint swimming performance and hormonal responses. The hypothesis of this study was that creatine supplementation increases performance sprint swimming, and creatine loading may be induced by changes in the hormonal responses [14]. The results indicated that supplementation with 5 g creatine

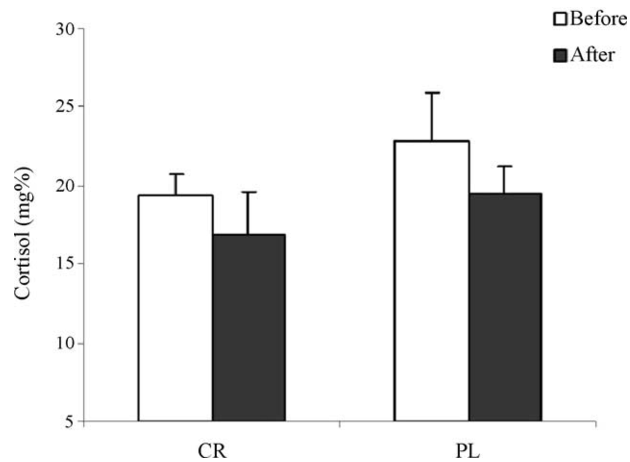

Figure 3 Cortisol responses (mean ± SD) before and after supplementation period in the creatine supplementation (CR) and placebo (PL) groups. No significant changes were found in cortisol responses.

four times a day for 6 days increased sprint swimming performance only in 50 m. Moreover, this performance enhancement of creatine supplementation is unlikely to be hormonally mediated.

Our data showed that short-term creatine supplementation improved swimming performance (50 m) on amateur swimmers. Similar findings were noted by Selsby et al. [11] who demonstrated improvement in the performance of a single 50-yard sprint swim in a creatine supplementation group on collegiate swimmers. The anaerobic energy system contribution to swimming performance can be as high as 80% for a 50-meter sprint [20,21]. Therefore, considering the potential benefits of creatine supplementation on anaerobic exercise performance [22], it would be reasonable to expect that why creatine supplementation has improved performance in 50 m swim.

However, some other studies found no effect of short-term creatine supplementation on single sprint swimming performance [15,16]. A possible explanation for the conflicting finding may relate to the level of the subjects examined. Mendes et al. [16] and Mujika et al. [23] used competitive or elite swimmers as subjects whereas our subjects were amateur. Harris et al. [24] and Greenhaff et al. [25] indicate that the extent of creatine uptake into the muscle is inversely related to an individual's initial muscle creatine content. The higher the initial intramuscular creatine concentration, the more difficult it is to increase stores [6,7]. Therefore, it is possible that our amateur swimmers (low level athletes) had a greater capacity to increase their intramuscular stores of creatine than their elite counterparts [12,23], who may already have creatine levels at their physiological maximum [11]. However, in this study intramuscular stores of creatine were not measured.

The lack of significant effect of creatine supplementation on 100 m sprint swimming performance in this study might be related to subject's performance times. Our amateur subjects completed the 100 m sprint swimming for a long time (110—120 sec). As time of maximal effort determines energy system involvement, it is likely that the subjects in this study used the glycolytic system heavily with greater involvement in the aerobic energy system than ATP-Phosphocreatine system. Hence, this would support our reasoning why creatine supplementation had little effect on 100 m performance.

The results showed tendency towards reduced performance (no statistically significant) in 50 and 100 m in the PL group (Table 3). However, participations of this study were collegiate amateur swimmers; thus, its likely learning effects or improvements in technique and coordination have been effective on performance results.

There have been few studies investigating the effects of short-term creatine supplementation on anabolic hormones. For example, Op't Eijnde and Hespel [26] found that creatine supplementation (20 g/day for 5 d) did not alter cortisol and growth hormone levels in a single bout of heavy resistance exercise. In addition, Faraji et al. [27] assessed growth hormone, testosterone and cortisol immediately after sprint running performance (100 and 200 m) in creatine (20 g/d for 6 d) and placebo-supplemented subjects, and found no effect of creatine on growth hormone, testosterone and cortisol hormones status. However, the unchanged growth hormone and cortisol after creatine supplementation is also consistent with their reports. Although testosterone concentration was greater for CR compared to PL, the increased testosterone was not significant in response to the creatine supplementation conditions in CR group. Thus, available data and our finding indicate that creatine supplementation (20 g/d for 6 d), as it is ordinarily practiced by athletes, does not alter exercise responses to anabolic hormones. However, it is possible that creatine supplementation may affect other related protein synthesis likely factors. Deldicque et al. [28] reported that creatine supplementation (21 g/d for 5 d) can facilitated muscle anabolism through increase of IGF-I (30%) and IGF-II (40%) mRNA in muscle. It is difficult to compare our results with previous study results since in our study, supplementation with only creatine was used to determine anabolic hormonal responses; whereas previous studies combined creatine supplementation with other supplementations (e.g., branched chain amino acids, carbohydrates, vitamins, and mineral materials) [21,22], that might has an effect on hormonal responses [10].

Based on the fact that creatine supplementation results in a rapid increase in body mass and fat-free mass [2], it has been hypothesised that creatine induces hypertrophy through endocrine mechanisms. However, we found no significant effects of creatine supplementation on growth hormone and cortisol responses. Therefore, it seems unlikely that increases in body mass and fat-free mass secondary to creatine supplementation are hormonally mediated. Since creatine supplementation increases intracellular water content [29], it could at least partly explain the increase in lean mass.

We studied the impact of creatine supplementation in amateur male swimmers with normal experimental design on performance and hormonal responses. Thus, various experimental designs and method in swimmers of different levels (elite) or in the other gender may eventually result in different hormonal reactions. In addition, future studies, should address the effect creatine supplementation on other subjects in various methods of exercise.

Creatine supplementation is used by athletes to increase muscle mass and strength, and especially improve sports performance. The present results suggest that under the experimental conditions using short-term creatine supplementation, amateur swimmers' performance increased only in 50 m. According to our data when combined with the findings of Faraji et al. [27], it seems unlikely that performance improvement to creatine supplementation is hormonally mediated and systemic changes have been ruled out via hormonal alterations.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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References

[1] Kreider RB. Effects of creatine supplementation on performance and training adaptations. Mol Cell Biochem 2003;244:89—94.
[2] Rawson ES, Persky AM. Mechanisms of muscular adaptations to creatine supplementation. Int Sport Med J 2007;8:43—53.
[3] Navratil T, Kohlikova E, Petr M, Heyrovsky M, Pelclova D, Pristoupilova KI, et al. Contribution to, 16 Explanation of the effect of supplemented creatine in human metabolism. Food Chem 2009;112:500—6.
[4] Burke DG, Chilibeck PD, Parise G, Candow DG, Mahoney D, Tarnopolsky M. Effect of creatine and weight training on muscle creatine and performance in vegetarians. Med Sci Sports Exer 2003;35:1946—55.
[5] Rawson ES, Clarkson PM, Price TB. Differential response of muscle phosphocreatine to creatine supplementation in young and old subjects. Acta Physiol Scand 2002;174:57—65.
[6] Hopwood MJ, Graham K, Kieron BR. Creatine supplementation and swim performance. J Sports Sci Med 2006;5:10—24.
[7] Gotshalk L, Kraemer WJ, Mendonca MA, Vingren GL, Kenny AM, Barry SA, et al. Creatine supplementation improves muscular performance in older women. Eur J Appl Physiol 2008;102:223—31.
[8] Mujika I, Padilla S, Ibanez J, Izquierdo M, Gorotiaga E. Creatine supplementation and sprint performance in soccer players. Med Sci Sports Exer 2000;32:518—25.
[9] Burke LM, Pyne DB, Telford RD. Effect of oral creatine supplementation on single effort sprint performance in elite swimmers. Int J Sport Nut 1996;6:222—33.
[10] Hoffman JR, Ratamess NA, Ross R, Shanklin M, Kang J, Faigenbaum AD. Effect of pre-exercise energy supplement on the acute hormonal responses to resistance exercise. J Strength Cond Res 2008;22:874—82.
[11] Selsby JT, Beckett KD, Kern M, Devor SD. Swim performance following creatine supplementation in division III athletes. J Strength Cond Res 2003;17:421—4.
[12] Mendes R, Pires I, Oliveira A, Tirapegui J. Effects of creatine supplementation on the performance and body composition of competitive swimmers. J Nut Biochem 2004;15:473—8.
[13] Havenetidis K, Cooke C, King R, Denison T. Repeated creatine supplementation and swimming performance. Abstracts of the 1st Annual Congress of the European College of Sport Science 1996:566—7.

[14] Rahimi R, Faraji H, Sheikholeslami-Vatani D, Qaderi M. Creatine supplementation alters the hormonal response to resistance exercise. Kinesiology 2010;421:28—35.

[15] Kraemer WJ, HatWeld DL, Spiering BA, Jakob L, Vingren MS, Fragala JH, et al. Effects of a multi-nutrient supplement on exercise performance and hormonal responses to resistance exercise. Eur J Appl Physiol 2007;101:637—46.

[16] Bush JA, Kimball SR, O'Connor PM, Suryawan A, Orellana RA, Nguyen HV, et al. Translational control of protein synthesis in muscle and liver of growth hormone-treated pigs. Endocrinol 2003;144:1273—83.

[17] Olsen S, Aagaard P, Kadi F, Goran T, Julien V, Olesen L, et al. Creatine supplementation augments the increase in satellite cell and myonuclei number in human skeletal muscle induced by strength training. J Physiol 2006;573:525—34.

[18] Volek JS, Boetes M, Bush JA. Response of testosterone and cortisol concentrations to high-intensity resistance exercise following creatine supplementation. J Strength Cond Res 1997;11:182—7.

[19] Schedel JM, Tanaka H, Kiyonaga A, Tanaa H, Kiyonaga A, Shindo M, et al. Acute creatine loading enhances human growth hormone secretion. J Sport Med Phys Fit 2000;40:336—42.

[20] Holmer I. Energetics and mechanical work in swimming. In: Hollander AP, Huijing PA, Groot G, editors. Biomechanics and medicine in swimming. Champaign, Illinois: Human Kinetics Publishers; 1983. p. 154—64.

[21] Toussaint HM, Hollander AP. Energetics of competitive swimming. Sports Med 1994;18:384—405.

[22] Terjung RL, Clarkson P, Eichner ER, Greenhaff PL, Hespel PJ, Israel RG, et al. The American College of Sports Medicine Roundtable: the physiological and health effects of oral creatine supplementation. Med Sci Sports Exer 2000;32:706—17.

[23] Mujika I, Chatard JC, Lacoste L, Geyssant A. Creatine supplementation does not improve sprint performance in competitive swimmers. Med Sci Sports Exer 1996;28:1435—41.

[24] Harris RC, Soderlund K, Hultman E. Elevation of creatine in resting and exercised muscle of normal subjects by creatine supplementation. Clin Sci 1992;83:367—74.

[25] Greenhaff PL, Bodin K, Soderlund K, Hultman E. Effect of oral creatine supplementation on skeletal muscle phosphocreatine resynthesis. Amer J Physiolo 1994;226:725—30.

[26] Op't Eijnde B, Hespel P. Short-term creatine supplementation does not alter the hormonal response to resistance training. Med Sci Sports Exer 2001;33:449—53.

[27] Faraji H, Arazi H, Sheikholeslami-Vatani D, Hakimi M. The effects of creatine supplementation on sprint running performance and selected hormonal responses. South African J Res Sport Phy Ed Rec 2010;32(2):31—9.

[28] Deldicque L, Louis M, Theisen D, Dehoux M, Thissen JP, Rennie MJ, et al. Increased IGF mRNA in human skeletal muscle after creatine supplementation. Med Sci Sports Exer 2005;37:731—6.

[29] Kilduff LP, Georgiades E, James N, Minnion RH, Mitchell M, Kingsmore D, et al. The effects of creatine supplementation on cardiovascular, metabolic, and thermoregulatory responses during exercise in the heat in endurance trained humans. Int J Sport Nut Exer Met 2004;14:443—60.