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Effects of creatine supplementation on the performance and body composition of competitive swimmers

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Abstract

The objective of this study was to determine the effect of creatine supplementation on performance and body composition of swimmers. Eighteen swimmers were evaluated in terms of post-performance lactate accumulation, body composition, creatine and creatinine excretion, and serum creatinine concentrations before and after creatine or placebo supplementation. No significant differences were observed in the marks obtained in swimming tests after supplementation, although lactate concentrations were higher in placebo group during this period. In the creatine-supplemented group, urinary creatine, creatinine, and body mass, lean mass and body water were significantly increased, but no significant difference in muscle or bone mass was observed. These results suggest that creatine supplementation cannot be considered to be an ergogenic supplement ensuring improved performance and muscle mass gain in swimmers.

Keywords: Creatine; Exercise; Supplementation; Nutrition; Performance; Swimmers

1. Introduction

Creatine ergogenic potential is among the subjects of current research interest regarding ergogenic agents [1]. The availability of its phosphorylated form (phosphocreatine) has been considered one of the major limitations for muscle performance in short-duration and high-intensity exercises, because depletion of this compound results in the inability to resynthesize adenosine triphosphate (ATP) in necessary amounts [2–6]. This fact suggests that an increase in total creatine concentration in muscle may relieve the depletion of PCr stores during intense exercise, also limiting the reduction in rate of ATP resynthesis through an increase in the rate of ADP phosphorylation [7–10]. Consequently, this increase may be directly related to better performance in short-duration and high-intensity exercise [8,11–17].

Studies involving trained swimmers receiving creatine supplementation have reported controversial results [17–20,21]. The scarcity of published reports concerning swimmers, the lack of standardization of exercise protocols, and variations in individual training levels may account for these descrepant results, and suggest that additional studies are needed.

A secondary effect of creatine supplementation, lean body mass increase, has been noted in several reports [22,23]. Some studies suggest that effect may be due to an increase in muscle protein synthesis [24], whereas others have demonstrated that this phenomenon is a consequence of water accumulation in the intramuscular medium caused by the high osmotic power of creatine [25]. These divergent results justify the importance of new studies to evaluate the effects of this supplementation on body composition in specific manner.

The aim of the present study therefore was to evaluate the effect of acute creatine supplementation on the performance and body composition of competitive swimmers.

2. Methods and materials

2.1. Subjects

The study involved 18 competitive swimmers of the São Caetano do Sul (San Paulo) team, six women and 12 men (Table 1). The athletes were informed about all the stages of the study and signed a Term of Consent according to the

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Table 1
Baseline characteristics of the individuals

Variables	CrG	PlG	*P*
Age (ys)	19.44 (±2.60)	19.78 (±2.33)	0.82
Weight (kg)	68.02 (±13.43)	71.56 (±8.69)	0.47
Height (cm)	174.67 (±6.61)	175.89 (±8.08)	0.60
Time of training (ys)	9.67 (±3.39)	8.44 (±3.43)	0.51

CrG: $n = 9$; PIG: $n = 9$; x: mean / (): standard deviation.

regulations of the Ethics Committee of the Faculty of Pharmaceutical Sciences, University of São Paulo.

2.2. Study protocol

A double-blind, placebo-controlled study was performed. During week 1 of the experiment, all swimmers underwent biochemical evaluations and determination of body composition to obtain baseline data. At the end of week 1, the first performance test was carried out. The athlete group was then divided randomly into two groups receiving either creatine or placebo. After 8 days of supplementation, baseline determinations and performance tests were repeated for comparison between the pre- and post-supplementation periods.

2.3. Supplementation

The creatine group (CrG) received four doses of 5.0 g creatine mixed with 20.0 g carbohydrates per day. The placebo group (PlG) received four doses of 20.0 g carbohydrates per day.

2.4. Performance tests

Performance tests included three types of exercise: 1) single exercise of short duration and high intensity, consisting of a maximal 50-m swim; 2) anaerobic resistance exercise of high intensity and duration of 30–150 seconds, consisting of a maximal 100-m test swim; 3) repetitive exercise, consisting of three series of three 50-m repetitions ($3 \times 3 \times 50$), with 30-second intervals between repetitions and 150-second intervals among the three series.

The investigations took place after week 33 of the training season, during a period of high training volume (~52 km/week). Performance tests were started in the morning when the athletes underwent a standard warm-up and then performed the 50-m swim test. After a 90-minute interval, the 100-m test was performed. Swimmers were instructed to perform each swim test at maximum velocity. In the afternoon, the pre-established warm-up was repeated and repetitive series was started. Each swimmer was tested in his best style competition, according to prior studies [17].

2.5. Parameters evaluated

For urinary creatine [26] and creatinine [27] excretion, 24-hour urine collections were taken at baseline and on day 2 of supplementation.

For serum creatinine concentrations [27], blood was collected at baseline and on day 2 of supplementation. Venous blood samples was centrifuged for separation of plasma and serum, which was stored at −80°C until analysis 1 day later.

To calculate times achieved in swim tests, each score obtained by each swimmer was measured with a chronometer by three trained individuals, and the mean time for each test was calculated.

To determine blood lactate concentrations after exercise [27], fingertip blood samples (25 μL) were collected at the end of the 50-m and 100-m tests and at the end of each 50-m series (trials 3, 6, and 9). These samples was stored at −80°C, and blood lactate concentration was enzymatically analyzed 24 hours after the test using a lactate analyzer YSI 1500 Sport L-Lactate Analyser (Yellow Spring Incorporated, OH, USA).

Weight, height, percentage of lean mass, and percentage of fat were measured 2 days before the beginning of supplementation protocol and on the last day of this supplementation, in the morning after a fast of 8–10 hours. Weight was determined with a platform-type scale and height with a stadiometer. Body composition was determined by methods such as skinfold, electrical bioimpedance, and bone densitometry, all measured during the same morning evaluations. Body hydration was measured with the use of electrical bioimpedance apparatus.

2.6. Standardization

During the 2 weeks of the experiment, training was standardized in terms of intensity and volume for all athletes. Food intake was monitored with 24-hour food records throughout the study. Environmental conditions were also standardized.

2.7. Statistical analysis

The values of the various parameters studied were analyzed by means of the *t* test for unpaired and paired samples according to the case, with the level of significance set at 5%.

3. Results

3.1. Dietary evaluation

There were no statistically significant differences in energy intake or macronutrient distribution before or after supplementation in either CrG or PlG (Table 2).

Table 2
Energy intake during the pre- and post-supplementation periods

Swimmers	Energy intake		Swimmers	Energy intake	
	CrG Pre	CrG Post		PIG Pre	PIG Post
Swimmer 1	3122.5 (±57.63)	3253.4 (±95.12)	Swimmer 1	2256.9 (±46.73)	2365.6 (±52.9)
Swimmer 2	3456.2 (±96.59)	3378.2 (±78.89)	Swimmer 2	2186.3 (±55.48)	2276.8 (±67.52)
Swimmer 3	4960.7 (±1289.21)	2968.5 (±699.68)	Swimmer 3	2569.41 (±102.36)	2751.23 (±89.26)
Swimmer 4	2156.8 (±78.13)	2259.3 (±75.33)	Swimmer 4	3364.52 (±100.57)	3495.68 (±86.31)
Swimmer 5	3789.5 (±163.59)	3698.2 (±84.56)	Swimmer 5	3725.6 (±42.32)	3855.2 (±73.60)
Swimmer 6	3512.7 (±151.26)	3487.6 (±67.54)	Swimmer 6	3977.7 (±265.26)	3589.1 (±133.85)
Swimmer 7	3946.1 (±48.62)	3850.3 (±72.88)	Swimmer 7	4462.2 (±129.5)	4368.1 (±103.61)
Swimmer 8	1896.2 (±68.92)	1922.5 (±81.99)	Swimmer 8	6322.56 (±189.67)	6257.3 (±89.43)
Swimmer 9	1776.2 (±101.56)	1692.3 (±65.28)	Swimmer 9	3569.5 (±64.36)	3752.6 (±58.97)

CrG: $n = 9$; PlG: $n = 9$; x: mean / (±): standard deviation.

3.2. Bioavailability of supplemented creatine

3.2.1. Urinary creatine excretion

On day 2 of supplementation, CrG demonstrated a significant increase in urinary creatine (Table 3). However, it was observed that more than 50% of the supplemented creatine was not excreted but instead was stored.

3.2.2. Serum creatinine concentrations

An increase in blood creatinine concentration was observed after the supplementation period, but no significant differences were observed between CrG and PlG (Table 3).

3.2.3. Urinary creatinine excretion

During the post-supplementation period, CrG showed a significant increase in urinary creatinine excretion, whereas PlG showed no significant changes (Table 3).

3.3. Sports performance

3.3.1. Swimming test scores

No significant differences in scores before and after the supplementation period were observed in either CrG or PlG (Table 4).

3.3.2. Blood lactate concentrations

There was no significant difference in the values before and after supplementation for CrG, whereas a significant increase in blood lactate concentration was observed in PlG in the 100-m test and repetitive series after the supplementation period (Table 5).

3.4. Body composition

After the supplementation period, CrG presented with a statistically significant increase in total body mass (weight), lean body mass (DEXA and BIA), and body water (BIA). However, when the differentiation of lean body mass was determined by bioimpedance associated with DEXA, the only component of LBM that showed a significant increase was BIA (Table 6).

4. Discussion

Approximately 50% of urinary creatine excretion of the supplemented creatine observed in CrG suggests that approximately one half of the supplementation had been stored by this group.According to Williams et al. [28], "fecal losses of creatine are insignificant and, after absorption process, this compound may follow two main metabolic pathways: urinary excretion or muscle storage, once this tissue is responsible for the storage of about 95% of total body creatine" [23]. Increased body weight observed among CrG at day 8 of supplementation also can be an indication that these athletes had stored part of the supplemented creatine; however, this could be conclusively dem-

Table 3
Biochemical parameters indicative of the bioavailability of supplemented creatine

Variable	CrG Pre	CrG Post	PlG Pre	PlG Post
Serum creatinine (mg/dL)	1.01 (±0.12)	1.18 (±0.21)	1.00 (±0.09)	1.10 (±0.12)
Urinary creatine (g/day)	0.026 (±0.0042)	9.34 (±1.71)*ac	0.029 (±0.0036)	0.031 (±0.0043)
Urinary creatinine (g/day)	1.36 (±0.39)	2.71 (±1.04)*ac	1.53 (±0.31)	1.47 (±0.52)

CrG: $n = 9$; PlG: $n = 9$; x: mean / (): standard deviation.
*a Statistically significant difference between CrG pre and CrG post ($P < 0.05$).
*b Statistically significant difference between PlG pre and PlG post ($P < 0.05$).
*c Statistically significant difference between PlG post and CrG post ($P < 0.05$).

Table 4
Marks (S) obtained by the swimmers during the pre- and post-supplementation periods

Tests	CrG Pre	CrG Post	PlG Pre	PlG Post
50 m	29.62 (±3.77)	29.80 (±3.92)	30.62 (±3.94)	30.94 (±4.12)
100 m	69.47 (±18.68)	69.82 (±18.89)	67.17 (±8.40)	68.08 (±8.74)
Sum of series 1	97.75 (±12.04)	98.75 (±11.51)	101.20 (±12.71)	101.71 (±13.29)
Sum of series 2	95.76 (±10.79)	95.73 (±11.17)	99.71 (±12.27)	100.42 (±13.01)
Sum of series 3	94.27 (±10.04)	94.98 (±10.19)	99.14 (±12.35)	99.60 (±13.43)

CrG: $n = 9$; PlG: $n = 9$; x: mean / (): standard deviation; S = seconds.

onstrated only by means of a biopsy, which was not possible in our study.

Increased urinary creatinine excretion in individuals receiving creatine supplementation is a phenomenon frequently reported in literature [28–30]. Creatinine is the compound resulting from the creatine degradation occurring in the intramuscular medium through irreversible cyclization and dehydration reactions [23]. Thus, several investigators have suggested that increased urinary creatinine concentrations may indicate an increase in the intramuscular stores of creatine [14,28,31].

The assumed increase in intramuscular creatine content would have been expected to improve the sports performance of the CrG swimmers. However, this fact was not observed after the supplementation, as also noted in previous studies evaluating the performance of swimmers [17–20]. It is believed that there are some harmful factors associated with creatine supplementation that are capable of exerting an influence as effective as the elevation in intramuscular creatine–phosphate storage. According to Mujika et al. [17], this factor may be the body weight gain that frequently accompanies creatine supplementation. Good hydrodynamics increases the ability of a body to float and helps the swimmer to maintain floating and swimming position by reducing body area and water resistance. Thus, an increase in body weight would result in changes in the mechanics of swimming styles and consequently in a greater energy expenditure during movement [26,32].

Compared to levels before supplementation, PlG presented with significantly higher blood lactate concentrations after supplementation for the 100-m test and repetitive series, whereas CrG maintained baseline values.

The increased blood lactate concentration observed among PlG suggests that, even though training had been standardized throughout the experimental period, PlG probably experienced an accumulation of training load, demonstrating a greater effort in the same task proposed in the pre- and post-supplementation periods.

According to Barbanti [33], this fact can be confirmed by the so-called overcompensation theory. This theory states that the energy reserves spent during the process of muscle contraction are rebuilt or replaced only during the recovery period. This replacement, in turn, does not occur at a proportion identical to that of the condition preceding exercise, but develops beyond this condition, an event known as the overcompensation process [33].

In cases in which long-term objectives are proposed, the strategy used is to reduce the recovery periods between one training session and the other to achieve the period of overcompensation only at specific times, such as the end of a season or of a specific championship. Thus, with an anticipated interruption of the recovery periods, the training sessions become increasingly exhausting for the athlete even though they are identical to the previous sessions in terms of intensity and volume.

The swimmers assessed in the present study were working within this training strategy, exactly in the phase during which the recovery periods are shorter than those considered ideal for full replacement of the energy spent during training. This may have been responsible for the accumulation of training load even though the intensity and volume of training were standardized during the 2 weeks of the experiment.

The important fact in this case is that although PlG

Table 5
Blood lactate concentrations (mmol/dL) during the pre- and post-supplementation periods

Test	CrG Pre	CrG Post	PlG Pre	PlG Post
50 m	2.59 (±1.35)	3.49 (±1.02)	2.76 (±0.98)	3.22 (±0.82)
100 m	4.16 (±1.37)	4.97 (±0.64)	4.70 (±1.47)	6.25 (±2.17)*[abc]
End of series 1	4.42 (±1.05)	4.30 (±0.80)	5.30 (±2.36)	5.29 (±1.22)
End of series 2	6.35 (±1.14)	6.69 (±1.41)	7.43 (±2.18)	8.64 (±2.42)
End of series 3	7.99 (±2.34)	8.89 (±1.73)	8.51 (±3.33)	11.54 (±3.45)*[bc]

CrG: $n = 9$; PlG: $n = 9$, x: mean / (): standard deviation.
*[a] Statistically significant difference between CrG pre and CrG post ($P < 0.05$).
*[b] Statistically significant difference between PlG pre and PlG post ($P < 0.05$).
*[c] Statistically significant difference between PlG post and CrG post ($P < 0.05$).

Table 6
Changes in body composition in the post-supplementation period (BIA)

Variable	CrG	PlG
σ Weight (kg)	1.34	−0.09*
σ Lean mass (BIA) (kg)	1.5	−0.75*
σ Body water (BIA) (L)	1.38	−0.55*
σ Muscle mass (BIA) (kg)	0.06	−0.2

CrG: $n = 9$; PlG: $n = 9$; σ: Delta: Post value − Pre value.
* Statistically significant difference between σCrG and σPlG ($P < 0.05$).

accumulated more lactic acid in their blood because of an accumulation of training load or some other factor, CrG were able to overcome this factor, maintaining similar blood lactate concentrations before and after supplementation. However, as mentioned earlier, there was no differences between CrG and PlG performances before and after supplementation, which supports the hypothesis of the existence of a harmful factor, such as weight gain, that would prevent better performance in CrG.

After supplementation, CrG presented a statistically significant increase in total body mass, lean mass and body water, although no significant differences were observed with respect to bone or muscle mass.

The present study demonstrated that acute creatine supplementation induces an increase in body water without increasing muscle mass, supporting the hypothesis of water retention. Several investigators have suggested that an increase in the intramuscular content of creatine may induce water inflow to the intracellular medium, increase the water content of the latter, and consequently increase body mass [34–36].

It is important to emphasize that cell hydration plays a relevant role in the nitrogen balance [37], possibly modulating protein synthesis in some tissues [38]. Berneis et al. [39] and Parise et al. [37] suggest that creatine may reduce the cellular water balance and proteolysis. Therefore, on a long-term basis, the increase in cell hydration may stimulate protein synthesis or reduce protein degradation, possibly increasing muscle mass [34,35,39,40].

Thus, these affirmations suggest that if the greater hydration observed in the present study could be maintained by continued supplementation at lower doses, changes in muscle mass might be observed on a long-term basis. However, this is simply a hypothesis that should be tested in future studies.

In conclusion, the present results suggest that, under the experimental conditions used, acute creatine supplementation did not increase swimmers performance and muscle mass, a fact emphasizing the need to re-evaluate the high consumption of this compound by swimmers in general.

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