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Creatine supplementation improves the anaerobic performance of elite junior fin swimmers

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The objective of this study was to determine whether creatine supplementation (CrS) could improve mechanical power output, and swimming performance in highly trained junior competitive fin swimmers. Sixteen male fin swimmers (age:15.9±1.6 years) were randomly and evenly assigned to either a creatine (CR, 4×5 g/day creatine monohydrate for 5 days) or placebo group (P, same dose of a dextrose-ascorbic acid placebo) in a double-blind research. Before and after CrS the average power output was determined by a Bosco-test and the swimming time was measured in two maximal 100 m fin swims. After five days of CrS the average power of one minute continuous rebound jumps increased by 20.2%. The lactate concentration was significantly less after 5 minutes restitution at the second measurement in both groups. The swimming time was significantly reduced in both first (pre: 50.69±1.41 s; post: 48.86±1.34 s) and second (pre: 50.39±1.38 s; post: 48.53±1.35 s) sessions of swimming in CR group, but remained almost unchanged in the P group.

The results of this study indicate that five day Cr supplementation enhances the dynamic strength and may increase anaerobic metabolism in the lower extremity muscles, and improves performance in consecutive maximal swims in highly trained adolescent fin swimmers.

Keywords: mechanical power, lower extremity muscles, swimming performance, ergogenic aid, creatine

Dietary creatine supplementation (Cr) is a widely used intervention in exercise science. Numerous studies have demonstrated that Cr results in an elevated total creatine content in skeletal muscle. It has been believed that elevated Cr in the muscle supports the increase of physical performance of trained athletes in several sports and untrained individuals. Numerous studies have been carried out to reveal the effect of short- and long-term Cr supplementation on isometric and dynamic strength (4, 12, 20, 22, 41), on running speed

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(36), swimming perfomance (17, 39), aerob (30), and anaerob endurance variables during running (32), swimming (1, 25, 35), cycling (3, 34, 42) and jumping (6, 13, 38).

Recently several studies have investigated the effect of Cr ingestion on muscle size and strength abilities of elderly people (7, 10, 14). However, there is a lack of literature studying the effect of Cr supplementation on the physical performance of young athletes (11, 25–27).

Most of the studies reported improvement in different variables of physical performance. The short-term Cr ingestion (5–7 days) of a high dose (15–30 g) resulted in significant improvement in strength (2), cycling or running speed (3, 15, 18, 20, 29, 36). Several studies demonstrated that Cr ingestion increased the swimming performance carrying out several lengths and mostly short distances (50–100 m) swimming (1, 17, 21, 25, 33, 35, 39). However, there are also studies reporting no improvement in swimming performance (8, 11, 24, 28).

There are two studies investigating the impact of creatine supplementation in young swimmers (11, 25). Mero et al. (25) studied the combined effect of Cr and sodium bicarbonate on the swimming time of two consecutive 100 m maximum intensity swims. They reported creatine and sodium bicarbonate enhanced performance in consecutive maximal swims. Dawson et al. (11) examined the long-term effects creatine supplementation on the performance of a one time sprint freestyle swimming and performance executed on a swim bench. They found that four weeks of Cr supplementation did not influence the single sprint performance in the pool. By contrast, the total quantity of work increased significantly in a 30 second swim bench workout.

The results of Dawson et al. (11) suggest that there is a difference in force generation and work between swimming in a pool and using a swim bench. The significant improvement in mechanical work in bench swimming indicates that greater work is performed during simulated swimming in swim bench with arm. Although the swimming performance depends upon the arm work predominantly, the role of crawling increases in fin swimming because of the enlarged surface of the foot. Consequently, using fin the swimmers should exert greater force to propel the body. We assumed that if the creatine supplementation increases the dynamic strength and the anaerobic capacity of the lower extremity muscles, it will contribute to the improvement of the maximal swim.

Bosco et al. (5, 6) introduced a new anaerobic test (Bosco test) consisting of vertical rebound jumps carried out with the maximum effort for one minute. Since the vertical jumping height and power output depends on the strength of the antigravity muscles (hip, knee and ankle extensors), they assumed that 5 days of Cr supplementation would increase the anaerobic capacity of these muscles resulting in enhanced average jumping height. They found that the number of jumps did not increase, but the average jumping height increased 7% over 45 s. Significant improvement was observed in the first and second 15 s, but not in the third 15 s. However, the mechanical power output did not change significantly. Also, they reported significant increase in blood lactate level.

The aim of this study was to examine the effect of short-term Cr supplementation on the alteration of power output assessed during one minute rebound jumps and on the maximum interval swimming performance in young fin swimmers. We hypothesized that young swimmers are sensitive to Cr supplementation and therefore the decrease in power output might be reduced during continuous jumps and the swimming performance might be enhanced.

Materials and Methods

Subjects

Sixteen healthy, young male fin swimmers (age = 15.9±1.6, range: 14–19 years; body weight: 62.4±12.8, range: 46.4–58.0 kg; body height: 172.4±8.8, range: 155–190 cm) participated in this study selected from the Hungarian National Team. The exclusion criteria were abnormal renal function, albuminuria, creatine used before, on medication or taking dietary supplement or under treatment. The subjects followed their usual training during the creatine administration. Subjects were paired and assigned to a creatine (CR) or placebo (P) group with a double-blind research design. None of the subjects experienced negative side effects during the treatment. Each subject provided signed informed consent after receiving a description of the study. The study was approved by the Research Ethical Committee, Semmelweis University, Budapest. The study was carried out in agreement with the Declaration of Helsinki (1964).

Experimental conditions

The study was carried out in a training camp which provided similar conditions for each subject. They lived in double bed-rooms and had their daily meals at the same time and their energy consumption was approximately the same. The training conditions were the same for each subject and the swimming performance test was carried out in the same pool under the same circumstances as during swimming practice.

Creatine supplementation protocol

The CR group was asked to consume 20 g/day creatine–monohydrate for five days. The total daily portion was divided in four 5 g portions mixed with dextrose, ascorbic acid and effervescence intensifiers. The total weight of one portion was 12 g. The subjects were instructed to consume the dissolved mixture in the morning before breakfast, 30 minutes before and after training, and before going to sleep. The placebo group consumed a dextrose-ascorbic acid-flour mixture with an equal portion of the mix added in place of the creatine, making it indistinguishable in flavor, texture, and appearance to the CR group's mixture. The mixture was dissolved in 0.5 litre tap water before use and was given to the subjects before consumption. When asked at the end of the study, the subjects did not realise which kind of supplementation they had received.

Dynamic strength and anaerobe power testing

The testing was carried out one day before the creatine supplementation started (baseline measurement) and one day after ceasing the supplementation. The testing occurred after the completion of a 5-minute warm-up on a cycle ergometer and

5-minute stretching exercises. Having warmed up the goniometer of the testing instrument (MuscleLab – Bosco System, Ergotest Technology A.S., Langensund, Norway), was fixed to the knee joint of the right leg to check the joint angle displacement during continuous rebound jumps. The subjects held a light wooden bar on the shoulder to avoid swinging of the arms. The string of the linear encoder was attached to the wooden bar, which recorded the number of jumps, the vertical displacement, and calculated the velocity and power of each jump. Before the baseline testing the subjects were familiarized with the experimental procedure. Despite the vertical jump test was familiar for the subjects, three days before the first test the participants executed 10 s rebound jumps twice or three times. During the creatine supplementation the swimmers did not practice vertical rebound jumps. To determine the dynamic strength (jumping height) and anaerobe capacity a Bosco test (5) was used. The subjects had to carry out vertical rebound jumps with maximum effort over 60 s. The subjects had to flex the knee during jumping at least 90 degrees, but not more than 110 degrees. The angular displacement of the knee joint was visualized for both subject and experimenter. The subjects were encouraged to carry out the jumps properly and with the highest intensity. If the subject did not execute the first five jumps properly, the test was stopped, and after a five-minute rest the test was repeated. All data were stored in a computer for later analysis. The maximum height of jump was determined in the first five seconds and the average power was calculated for jumps executed during 60 s. Also, we calculated the average power in the first, second, third and fourth 15 s.

Swimming time measurement

After the usual warm up the subjects were instructed to swim 100 m with the highest possible effort in a 50 m long pool. The conditions were similar to usual competition conditions. The swimming time was measured electronically. Having had four minutes of passive rest the 100 m swim was repeated. The subjects were tested one day before and after creatine administration in the morning between eleven and twelve o'clock. The subjects were randomly assigned to four groups containing four swimmers. The swimming time was not displayed for the swimmers until the end of the test.

Blood sampling and lactate measurement

A capillary blood sample was obtained from the ear before, 1 and 5 minutes after the jumping test. The samples were immediately deproteinized in ice-cold percloric acid for subsequent analysis of lactic acid concentration using Lange LP 400 (Hach Lange GmbH.-Berlin, Germany).

Heart rate measurement

Heart rate was measured instantaneously by using a Polar S810i TM (Polar Electro Oy., Finland) watch. Resting heart rate was measured in the morning before waking up. The heart rate was also measured immediately and 5 minutes after the Bosco test.

Body weight measurement

Body weight was measured by a BIA (Bioelectrical Impedance Analysis) InBody 3.0 multifrequency device (InBody 3.0.-Body Composition Analyser, Biospace. Co. Ltd., Korea, Seoul).

Statistic analysis

The results are expressed as means ± S.D. A two (creatine and placebo groups) × two (pre- and post-test periods) ANOVA was used for Bosco test, blood lactate, body weight, heart rate and swimming time variables. Multiple comparison testing using Tukey post hoc analysis was used, when significant differences were confirmed with ANOVA testing, to assess where differences occurred between means. Unpaired *t*-tests were used to determine potential differences between groups for baseline variables, treatment identification, and training volumes. Statistical significance was tested at $p<0.05$.

Results

Treatment identification and side-effect

Having finished the experimental period the subjects were asked whether they were aware of the treatment they had received. All subjects reported that they were unsure about the treatment. No spontaneous side-effects were reported during the entire duration of the study.

Body weight

The body mass was 1.05 kg (1.7%) greater after the experiment in group CR and 0.37 kg (0.6%) less than before experiment in group P. The differences between the pre- and post-values were significant in both groups (CR: $p=0.007$; P: $p=0.037$).

Bosco test

There was no significant difference between CR and P groups at baseline in any of the test variables. The average power estimated for 60 s increased significantly ($p=0.002$) for CR group but it remained almost unchanged in group P (Fig. 1).

The average power calculated for the first, second, third and fourth 15 second decreased gradually in both groups before and after the experiment. Significant differences were found between pre–post values in group CR, only. The average power was 16.5% ($p=0.006$), 24.1% ($p=0.008$), 18.8% ($p=0.023$) and 22.4% ($p=0.003$) greater after creatine administration, respectively (Fig. 2).

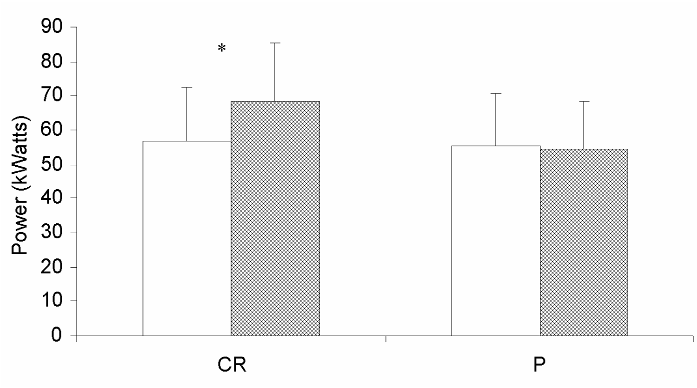

Fig. 1. Mechanical power output (Power; kWatts) calculated for one-minute rebound jumps (Bosco test) at pre (empty columns) and post (filled columns) creatine supplementation in creatine (CR) and placebo (P) group
* denotes a significant difference between pre- and post-supplementation. Values are means and ± S.D.

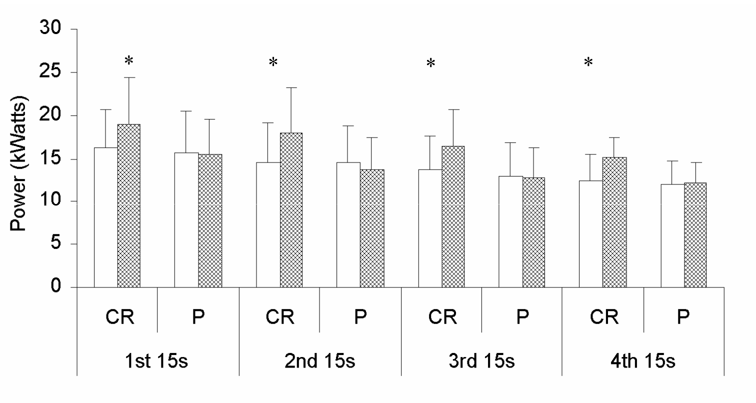

Fig. 2. Mechanical power output (Power; kWatts) calculated for the first, second, third and fourth 15 s, respectively, at pre (open columns) and post (filled columns) creatine supplementation in creatine (CR) and placebo (P) group
* denotes a significant difference between pre- and post-supplementation. Values are means and ± S.D.

Blood lactate

The blood lactate concentration measured immediately and 5 minutes after completing the Bosco test was elevated 7.5 and 9.1 folds compared to the base line level, respectively, in CR group, and 6.3 and 7.2 folds in P group before creatine administration. In the second test the increase of lactate concentration due to one minute rebound jump was significantly less (6.5 and 7.6 folds compared to the baseline level) after five days creatine in CR group (p=0.042 and p=0.002). No significant decrease was found in the blood lactate level normalized to baseline in P group (Table I).

Table I

Blood lactate (mmol·L^{-1}) at rest and after one and 5 minute rest having finished the Bosco test for the creatine (Cr) and placebo (P) groups pre- and post-supplementation

Variable	CR		P	
	Pre	Post	Pre	Post
Base line	1.46 ± 0.34	1.40 ± 0.29	1.54 ± 0.40	1.35 ± 0.30
1 minute	10.88 ± 2.06	9.04 ± 1.36	9.52 ± 1.18	9.10 ± 1.22
5 minutes	13.19 ± 2.03	10.66 ± 1.97*	11.19 ± 1.59	9.80 ± 1.82

* significant change (P<0.05) in pre–post comparison
Mean (±SD)

Heart rate

The heart rate before and after the anaerobic test showed similar values measured before and after creatine administration. No significant difference was found between the two groups (Table II).

Table II

Heart rate (beat·min^{-1}) at rest and after one and 5 minute rest having finished the Bosco test for the creatine (Cr) and placebo (P) groups pre- and post-supplementation

Variable	CR		P	
	Pre	Post	Pre	Post
Base line	74 ± 8	70 ± 7	74 ± 12	73 ± 11
1 minute	179 ± 7	182 ± 9	179 ± 7	182 ± 11
5 minutes	103 ± 12	96 ± 11	99 ± 14	94 ± 9

Mean (±SD)

Swimming time

The group CR performed the first and second 100 m within a shorter time 3.7% and 3.8%, respectively, comparing pre- and post-experiment means. The differences between the means are significant (p=0.034 and p=0.026). The swimming time did not change significantly in group P in pre–post comparison (Table III).

Table III

First and second 100 m fin swimming time (s) for the creatine (CR) and placebo (P) groups pre- and post-supplementation

100 m fin swim	CR		P	
	Pre	Post	Pre	Post
1st	50.69 ± 1.41	48.86 ± 1.34*	50.13 ± 1.25	50.40 ± 1.28
2nd	50.39 ± 1.38	48.53 ± 1.35*	50.01 ± 1.16	50.14 ± 1.24

* significant change (P<0.05) in pre–post comparison
Mean (±SD)

Discussion

The present study examined the effects of oral Cr supplementation on lactacid anaerobic performance tested by a Bosco test and by 100 m fin swimming time repeated twice with a four-minute rest. The effect was observed on young elite fin swimmers (aged between 14 and 19 years). It is the first study to our knowledge that examined the effect of Cr oral ingestion in such young swimmers with a high daily intensive training and using fins during swimming. We hypothesised that the short-term Cr supplementation might improve anaerobic performance and swimming time for two reasons: [1] young swimmers may be more sensitive to creatine administration to increase creatine phosphate (CrP) store despite the fact that they have been regularly trained intensively; [2] fin swimming requires a significantly greater force exertion of the lower extremity muscles than normal freestyle swimming.

We found that the average mechanical power production calculated for the total period of the one minute rebound jump test and for the separated 15 s intervals was enhanced significantly after creatine administration which may indicate an increased PCr concentration and PCr/ATP ratio (40). However, some studies demonstrated that the elevated total Cr (TCr), free Cr and CrP after Cr supplementation did not affect physical performance (23, 37). In both studies the subjects were adult trained or untrained people, which may explain why the increased skeletal muscle Cr did not result in improvement in physical performance. Snow et al. (37) speculated that 30 g/day Cr supplementation was not enough to increase the total Cr content in the muscle, and as a consequence the anaerobic metabolism in contracting human muscle was unaffected by relatively small increases in TCr content during single, short-duration, high-intensity exercise. This can be one of the explanations why no improvement was found in several studies after Cr supplementation (8, 11, 19, 24, 28, 31). However, difference in individual reactions to Cr loading can cause insufficient alteration in physical performance. Greenhaff et al. (16) showed that some individuals did not demonstrate the expected response to supplementation. Individuals who demonstrated the most favourable reaction to supplementation were those who had the lowest initial muscular Cr stores. These subjects showed enhanced PCr resynthesis during recovery. It is not known whether the level of muscular Cr store is dependent on the training status or age. We may speculate that people in their late teens may have low muscular Cr stores which explains partly why young people can produce lower power output than adults. If our young subjects had low Cr stores, we may suppose that 20 g/day Cr supplementation would enhance muscle Cr content to a greater extent than in adult trained athletes, which may explain the significant improvement in power output during anaerobic work.

Our result can directly be compared to the findings of Bosco et al. (6). They studied adult, elite sprinters and jumpers, and found no significant improvement in power output either for 45 s or for the separated 15 s. The average jumping height increased in the first and second 15 s, but remained almost the same in the third 15 s. In our study average power output increased in the third and fourth 15 s indicating higher level of Cr stores and the possible highest CrP content in the muscle of lower extremity compared to adult sprinters and jumpers tested in Bosco and coworkers' study (6).

In most of the studies the lactate concentration in the blood remained unchanged after Cr supplementation. In our study, we found reduced lactate concentration after Cr administration in the creatine group. The lower lactate level can be attributed to a reduced anaerobic glycolysis per unit work after creatine supplementation (9). If we may suppose that Cr and CrP increased in the muscle and the subjects carried out the test with the same effort, the glycolitic metabolism remained depressed, despite the fact that the power output increased.

We also hypothesised that if the power output increased during the one-minute rebound jump indicating improved dynamic strength, the swim time would decrease. This assumption was based on the fact that fin swimmers have to have greater muscle strength of the lower extremities than normal swimmers, because the surface of the foot is enlarged by the fins. The results confirmed our research hypothesis because the swim time decreased significantly after creatine supplementation in CR group and it remained unchanged in P group. Although muscle Cr and CrP content was not measured in the present study, the increase in body mass in CR group after Cr administration period may suggest that Cr and CrP content might have been enhanced in the muscles of the subjects participating in our study.

Our results contradict the results of Mujika et al. (28) who did not find significant change in the 25, 50, and 100 m swimming time. One of the reasons of the different findings can be attributed to the fact that the mean age of male swimmers in the study of Mujika et al. (28) was 20.5 years which is notably higher than that of our subjects. Our study design was similar to that of Mero et al. (25) which provides a good possibility to compare the findings of the two studies. Their subjects were competitive swimmers with an average age of 18.3 years and received similar Cr loading, but they combined it with sodium bicarbonate ingestion. In contrast to our result they found no improvement in swimming performance, but they reported reduced percentage decline in performance times after creatine supplementation. Similar results were published by Peyrebrune et al. (33) which studied the effect of Cr supplementation on the swim time of repeated 50 yard sprint swim. They found no improvement in the mean times recorded for the single 50 yard sprint, but the percentage decline in performance times was reduced significantly after creatine supplementation. In our study the swim time decreased significantly after Cr supplementation in both the first and second 100 m maximal swims. However, in contrast to the previous studies the performance time did not increase in the second 100 m, what is more, it decreased slightly. The difference between our results and the results of the aforementioned studies can be attributed to a significant increase in dynamic strength revealed in the Bosco test. Also, we may assume that using fin on the legs provides better conditions to push an advantage of the enhanced dynamic force of the lower extremity muscles than in normal freestyle swimming.

The results of our study seem to allow us to accept our hypothesis concerning the enhanced sensitivity of adolescent athletes to increase the Cr store due to Cr supplementation. However, we have only indirect evidence because we did not determine Cr and CrP in the muscles. Further studies are needed to find evidence as to why young swimmers can improve the dynamic strength and swimming performance more pronouncedly than adult athletes.

In conclusion, we tested the hypothesis that 5 days of Cr supplementation may improve the anaerobic power production in one-minute maximum intensity rebound jumps, and 100 m swimming performance in young fin swimmers. These results suggest that short-term Cr supplementation influences average power output (i.e. the average power output increases and the reduction of power output is attenuated during one minute of high intensity muscle work in young competitive fin swimmers). Also, the results indicate that the increased dynamic muscle strength and anaerobic capacity due to Cr supplementation may contribute to the improvement of interval swimming performance in fin swimmers.

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