Effect of creatine supplementation on physical performance and regeneration of adolescent fin swimmers

Abstract of PhD Theses

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1. Introduction

The child and adolescent athletes' performance and effectiveness is determind by the correct balanced diet, which provides the necessary nutrients. The role of nutrition in the success of athletes was formulated as follows by Maughan (2002): *„If talented, motivated and well-trained athletes compete,the borderline between victory and defeat narrows. If everything is equal, nutrition can make a difference between victory and failure."* The optimal athlete's diet must be customized, planned, conscious, increased for their needs, according to the requirements and, if necessary, supplement to prevent deficiencies, and / or optimize and support performance growth (Maughan et al 2004).

The international data indicates that there are more and more young athletes under 18 years of age using different supplements for the purpose of performance enhancement (Evans et al 2012). Young athletes are under great pressure to reach higher levels of performance and are looking for alternative tools to reach their goals as soon as possible (Calfee and Fadale 2006). Nutritional supplementation for child and adolescent athletes for performance enhancement is a current and relevant issue that is discussed in several aspects of the present dissertation, and it is also proposing a future study to provide the most accurate information to both professionals and consumers.

The creatine (Cr) is one of the most - and most thoroughly studied sports nutritional supplements. My thesis with Cr supplementation as an ergogenic aid, focuses on the physical performance (study 1.), and on the rehabilitation of tendon damage due to overuse (study 2.) in adolescent fin swimmers.

2. Objectives

2.1. Study 1.: Creatine supplementation improves the anaerobic performance of elite junior fin swimmers.

The aim of our study was to investigate the effects of short-term, high-dose (4x5g / day / 5 days) Cr supplementation on maximum-intensity performance in adolescent fin swimmers.

2.1.1. Hipotheses (H1-2)

H1: Short-term, high-dose Cr supplementation significantly increases the anaerobic performance of adolescent fins.

H2: The short-term, high-dose Cr supplementation results in a significant improvement in the maximum intensity, short-term, repeated swimming performance with adolescent fin swimmers.

2.2. Study 2.: Creatine supplementation supports the rehabilitation of adolescent fin swimmers in tendon overuse injury cases.

The aim of our study was to investigate the effect of oral Cr supplementation on tendon overuse injury rehabilitation of adolescent fin swimmers.

2.2.1. Hipotheses (H1-4)

H1: Oral Cr supplementation significantly reduces the muscle mass loss of the injured limb during relative immobilization following tendon damage due to overuse;

H2: Oral Cr supplementation significantly increases the muscle mass and strength of the injured limb during active rehabilitation following tendon damage due to overuse;

H3: Oral Cr supplementation reduces the intensity of pain due to inflammation;

H4: Oral Cr supplementation the combined effect of all these benefits significantly reduces the total rehabilitation time after injury.

3. Methods

3.1. Study 1.

3.1.1. Participants

Sixteen healthy, young male fin swimmers (n=16; 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). Subjects were paired and assigned to a creatine (CR; n=8) or placebo (PL; n=8) group with a double-blind research design.

3.1.2. Protocol of the study

The study was conducted in a randomized, placebo-controlled, double-blind trial. The study follows the guidelines of the Helsinki Declaration (1964) and the International Sport Nutrition Society (ISSN) resolution adopted in 2007 (Buford et al 2007). The study was approved by the Research Ethics Committee of the Eszterházy Károly College.

3.1.3. 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.

3.1.4. Cr supplementation protocol

The members of the experimental group (CR) received a Cr supplement. The dosing protocol was adapted to the ISSN recommendation adopted in 2007 (Buford et al. 2007). The Cr formula and dose were as

follows: 100% effervescent CrM formula (Scitec USA Inc., Coral Springs, FL, US) for 4x5g Cr / day / 5 days. The control (PL) dosage form contained dextrose, ascorbic acid, effervescent and flavor enhancers.

3.1.5. Bosco-test

The test was performed one day before treatment (Baseline) and one day after treatment. Before the test, as a warm-up, a 5-minute cycle ergometer exercise followed by a 5-minute stretching exercise. After warming up, the test persons performed the Bosco test to determine the maximum dynamic force, anaerobic performance (Bosco et al. 1983), in which they were required to perform a countermovement jump (CMJ) with a maximum intensity of 60s. MuscleLab 4000e (MuscleLab-Bosco System, Ergotest Technology A.S., Langensund, Norway) was used to measure the vertical path of the body from which we calculated mechanical power.

3.1.6. Fin swimming time

After warming up, the subjects performed in a 50m long pool with maximum intensity, 2x100m of surface fin swimming under competitive conditions, with integrated mono fins and snorkels. After the first 100m, after 4 minutes of restitution, the distance was repeated. Swimming times were measured electronically.

3.1.7. Blood sampling and lactate measurement

Capillary blood sample, earloop before Bosco test, at rest (Rest), immediately after test (Tmax), and 5 minutes (R'5) of restitution by enzymatic method, photometrically with Lange LP 400 (Hach Lange GmbH.-Berlin , Germany) determined the lactate level (mmol/L).

3.1.8. Heart rate measurement

At rest (Rest), immediately after the load (Tmax) and in the 5th minute of restitution (R'5) Polar S810iTM (Polar Electro Oy, Finland), the heart rate was measured by 1s sampling.

3.1.9. Direct Segmental Multi-Frequency Bioelectrical Impedance Analysis (DSM-BIA)

DSM-BIA was used to measure body weight (kg) before and after treatment. The InBody230 (InBody230, Biospace Co., Ltd., Seoul, Korea) was used for the measurement.

3.2 Study 2.

3.2.1. Participants

Participants in the study are injured, adolescent, male and female fins (n=18; male=10, female= 8; age=15.1±1.5, range:12-18years; body weight: 60.8±8.9kg, range:50.5-82.5kg; height:1.71±0.06m, range:1.59-1.84m). The subjects were grouped randomly into experimental (CR; n=9, male=5, female=4) or control (PL; n=9, male=5, female=4). Subjects received Cr (CR) or placebo (PL) as part of the conservative treatment of tendinopathy. Estimation of the biological maturity of the subjects in terms of the most commonly used body dimensions, height (TTM) and body weight (TTS), as well as the plastic index (PLX) and decimal age (DCK), as determined by the morphological age (MK) (Mészáros et al. 1990).

3.2.2. Protocol of the study

The study was conducted in a randomized, placebo-controlled, double-blind trial. The study follows the guidelines of the Helsinki Declaration (1964) and the International Sport Nutrition Society (ISSN) resolution adopted in 2017 (Kreider et al 2017). The study was approved by the Research Ethics Committee of the Eszterházy Károly College.

3.2.3. Experimental conditions

The acute phase of tendinopathy treatment was carried out at the homes of the injured participants in line with the specialist requirements. The recovery and maintenance phase of the rehabilitation exercise program was

carried out independently according to the instructions of a physiotherapist. Treatment is based on sound principles but was individualized to suit particular needs. The physiotherapy exercises and methods were used identically in both groups for all subjects.

3.2.4. Cr supplementation protocol

The definition of Cr supplementation was adjusted to reference (Kreider et al 2017), and to our earlier study. We asked the subjects of the CR group to take 20g 100% micronized Cr (Bio-Tech, Inc., Ft. Lauderdale, FL, US) during the first five days (loading phase). The total daily dose was divided into 4x5 g portions. A dose of the total weight was 12g including 5g Cr, 7g dextrose, and 0.075g ascorbic acid. The PL group consumed a dextrose, ascorbic acid, flour mixture, with the taste, texture, and appearance equivalent with the mixture of the CR group. The mixture had to be dissolved in 0.4 liter of water prior to usage. During the remaining 37 days (maintenance phase) the total daily dose was 1x5g Cr or placebo were given daily before breakfast in mixture described above.

3.2.5. Tendinopathy treatment plan

All subjects were diagnosed with subacute (the duration of symptoms 4-6 weeks) FHL tendinopathy due to overuse (Mueller-Wohlfahrt et al. 2013). Following the consultation with a medical specialist, in line with the clinical recommendations (Wilson and Best 2005), the entire rehabilitation period was determined for six weeks, which was divided into three phases (acute, recovery, and maintenance). The acute phase consisted of a two-week relative immobilization period, during which the injured body part was fixed with an elastic bandage, and home recovery was prescribed with raising and icing of the damaged leg, and crutches had to be used for walking. Recovery phase: After the acute phase, rehabilitation should emphasize appropriate loading of the tendon and its muscle to provide proper

stimuli for healing. Maintenance phase: The last two weeks, the final phase of rehabilitation, is the most important for restoring maximum performance and minimizing the risk of reinjury.

3.2.6. Segmental Lean Mass (SLM) measurement

DSM-BIA (Bartels et al. 2015) measured SLM (kg) of the injured limb before immobilization, immediately after immobilization, and at weeks 2 and 4 of the subsequent rehabilitation period. For measurement, InBody720 (InBody720, Biospace Co., Ltd., Seoul, Korea) was used (1-1000 kHz; r2 = 0.99 with DXA (Dual-energy X-ray Absorptiometry) (Lim et al. 2009).

3.2.7. Plantar Flexion Torque (PFT) measurement

A custom-made dynamometer measured the ankle plantar flexion isometric peak torque (Mmax; N·m). PFT was measured in the sitting position with the hip and knee joints at 90 degree angles and the ankle in a neutral position. Subjects were verbally encouraged to produce their maximal ankle plantar-flexion strength. Two trials were recorded, consisting of two 2-4 second maximal contractions separated by a 30 second rest period. If the relative difference between these two maximal voluntary contractions (MVC) was within 10%, no additional trials were required. If not, additional trials were proposed as long as two reproducible MVCs were obtained. The maximum value of the two reproducible trials was retained for further analyses. The peak torque was computed.

3.2.8. Numeric Raiting Scale (NRS; 0-10) for pain assessment

NRS was used to evaluate the intensity of pain on a 0-10. scale (McCaffery and Beebe, 1993). 0 = No Pain; 1-3 = Mild Pain; 4–6 = Moderate Pain; 7-10 = Severe Pain. Our team, in collaboration with the adolescent/family (if appropriate), could determine appropriate interventions in response to the Numeric Pain Ratings.

3.2.9. Blood sampling and metabilite measurement

Creatine kinase (CK) was assessed before the immobilization (baseline), and then every 24 hours for four days. Every time, before sampling, subjects sat quietly for 5 minutes. For serum CK, blood was drawn from the antecubital vein into a 10 mL collection tube via a Vacutainer apparatus. The blood samples were allowed to clot at room temperature for 10 minutes and centrifuged for 15 minutes. Serum was separated and frozen at -20°C for subsequent analysis. Total CK was determined by Beckman DU 640 spectrophotometer (Beckman Instruments, Inc., Fullerton, CA, US) in duplicate, at 25°C, using a commercial test kit (Labtest, Sao Paulo, Brazil).

3.3. Identification and side effects of treatment

In both studies at the end of the trial period, we asked the test subjects whether they were able to identify how they were treated. To our question, they could not distinguish between the two formulations, they were uncertain about the treatment. No spontaneous adverse reactions occurred in any person throughout the study.

3.4. Staistical analysis

All statistical computations were run on the measured raw datasets. The Shapiro-Wilk's W test was carried out for each variable for normality. All of the variables were normally distributed. Fisher's exact test was used to compare the homogeneity of the variances. Two-way analysis of variance (ANOVA) was applied for the comparison of the measured data. Repeated measures ANOVA was used to compare values within the groups, and also on the basis of the repeated measures ANOVA results intraclass correlation coefficient-ICC, standard error of measurement-SEM and minimal difference-MD, was calculated for CR and PL, to verify the reliability of the

procedure for study 2, in accordance with Vincent and Weir (2012) and Weir (2005). Tukey HSD post hoc analysis was carried out for the groups when the ANOVA confirmed significant difference. Statistica 7.0 and 12.6 (StatSoft Inc., Tulsa, US) in study 2. software served for statistical analysis. All data in tables, figures, and texts are given as means±SD. A value of $p<0.05$ was considered significant and indicated in the text.

4. Results

4.1. Study 1.

4.1.1. Bosco-test

In the 60s average mechanical power (P; kW), significant ($p <0.002$), 20% power increase was observed at the CR group, while there was no change in the PL group after treatment. Significant difference was found between the two groups after treatment (2X2 ANOVA was used to examine the interactions between the groups; $df_{(between,within)}=1,14$; $F=16.2$; $p<0.001$). The average power calculated for the first, second, third and fourth 15 second decreased gradually in both groups before and after the experiment. In the first 15s of the CR group, significant, 16.5% (1/15s; $p<0.006$), and the second 15s significant 24.1% (2/15s; $p<0.008$) after growth, in the time interval of 31-60s, we also experienced significant 18.8% and 22.4% increase in performance (3 / 15s, $p <0.023$; 4 / 15s, $p <0.003$) after treatment. Significant differences in mechanical performance were found between the two groups at each time interval after treatment ($p <0.000$).

4.1.2. Fin swimming time

By comparing the average of the pre- and post-treatment swimming times separately, a significant difference was found in the CR group. The first 100m was accomplished by 3.7% (-1.83s; $p<0.034$) and the second 100m by 3.8% (-1.86s; $p<0.026$) in a shorter time. In contrast, the PL group swimming

time did not change significantly before and after treatment. We found a significant difference in both the first and second 100m swimming time between the two groups after treatment (1/100m, $p<0.000$; 2/100m, $p<0.000$).

4.1.3 Lactate

The lactate level increase was significantly lower in the CR group compared to the resting rate (Tmax: -17%; $p <0.042$ and R'5: -19%; $p <0.0002$) with improvement in performance after the 5 day supplementation. There was no significant decrease in the blood lactate concentration in the PL group compared to the resting value. There was no significant difference between the two groups after treatment ($p<0.064$).

4.1.4. Heart Rate

Heart rate (stroke / minute) values did not change before and after the Bosco test after Cr supplementation. We found no significant difference between the groups or between the two groups after treatment ($p<0.88$).

4.1.5. Body weight

Significant 1.7% (+ 1.05kg; $p <0.007$) body weight increase in CR group, however a significant 0.6% (-0.37kg; $p <0.037$) decrease was observed in the PL group after treatment. Significant difference was found between the two groups after treatment ($p<0.000$).

4.2. Study 2.

4.2.1. Segmental Lean Mass (SLM)

SLM (kg) significantly decreased ($p <0.01$) in both groups after two weeks of relative immobilization (R2). SLM decreased by 5.6 ± 0.5% (-0.43±0.05 kg) in the CR group, while in the PL group there was a significantly higher 8.9± 0.9% (-0.65±0.09 kg) decrease. The next four weeks of the active rehabilitation program (R4) increased the SLM of the injured leg

in both groups. There was a significant 5.5 ± 0.6% increase in the CR group (+0.4 ± 0.04 kg; p <0.01), as well as a significant but lower 3.8±0.8% increase in the PL group (+0.25±0.06 kg; p<0.01) compared to the values following the immobilization (R2) during the 4 weeks active rehabilitation period. SLM was significantly different from baseline (-0.4 ± 0.04 kg; p <0.01) in the PL group, whereas the CR group reached baseline after 4 weeks of active rehabilitation (R6). Significant difference after both relative immobilization (R2) and second (R4) and fourth (R6) weeks of active rehabilitation between the two groups after treatment (p <0.00).

4.2.2. Plantar Flexion Torque (PFT)

PFT (Mmax; N·m) values were not measurable before immobilization. There was a significant increase in the CR group (R4 10.4±2.9%, p<0.01; R6 16.8±1.7%, p<0.01), while in the PL group, we also found significant but lower growth (R4 7.1±2.3%, p<0.01) ; R6 14.7±2.3%, p <0.01) after active rehabilitation. The percentage change in PFT was significantly different between the experimental groups (CR vs. PL; R2-R6; 28.8±3.1% vs. 22.8±2.8%; p<0.01) after the treatments. There was a significant difference between the two groups in the PFP after two weeks of relative immobilization, followed by four weeks of active rehabilitation (CR vs. PL; R2 = 103.2±10.8 vs. 95.9±5.5; p <0.05; R4 = 113.8 ± 11.1 vs 102.7± 4.6; p <0.01; R6 = 132.8±12.4 vs 117.7±5.2; p<0.01).

4.2.3. Numeric Rating Scale (NRS)

Pain intensity was measured on a scale of 0 to 10 (NRS) before immobilization (baseline) and acute (R2), recovery (R4), and maintenance (R6) phases of rehabilitation. The pain intensity was significantly lower two weeks after relative immobilization (Baseline-R2; decreased by 64.4±9.6%; p<0.01), then the recovery phase of active rehabilitation (Baseline-R4; decreased by 93.1±8.2%, p<0.01), and its maintenance phase (Baseline-R6;

98.4 ± 4.8% decreased; p<0.01) in the CR group. The result of the PL group was the same, but the decrease in the intensity of pain showed a slower tendency in the experimental periods (Baseline-R2; 57.7±9.4%; Baseline-R4; decreased by 72.4±8%; Baseline-R6; decreased by 88.8±9.6%; p<0.01). There was a significant difference between the groups in the percentage change in active rehabilitation (p<0.001). We experienced a significantly faster reduction in the CR group compared to the PL group during active rehabilitation (CR vs PL; R2-R6, 94.4±16.7% vs 75±20.4%; p<0.02).

4.2.4. Creatine-kinase (CK)

CK increased significantly (p <0.01) by 3.2 ± 1.7% in the first 24 hours and then significantly (p <0.01) decreased by 10.1 ± 7.1% over the next three days in the CR group. The CK increased significantly (p <0.01) by 12.9 ± 5.3% in the first two days and decreased significantly (p <0.00) by 9.3 ± 3.1% over the next two days in the PL group. Significant relative differences between the experimental groups (CR vs. PL; 24-48 hours, -0.1 ± 1.7% vs. 6.0 ± 3.1%; p <0.01) were found 48 hours after the start of the study. No significant difference in CK (U / L) was observed between the two groups before starting treatment (CR vs PL; Baseline = 444.2 ± 184.3 vs. 428.9 ± 146.8), as well as 24 (456.4 ± 184.7 vs. 453.8 ± 149.9), 72 (445.7 ± 181.3 vs. 464.8 ± 155.3), and 96 hours (410.3 ± 192.2 vs. 437.0 ± 149.3) after initiation of treatment (p <0.08).

5. Conclusions

The results of our first study were examined in the light of the literature. As a conclusion, we say that anaerobic performance is significantly increased by the administration of 20g Cr 5 times/day, significantly improving the maximum intensity of sprint swimming time. The adolescent fin swimmers organization can work more efficiently and economically in this way.

After discussing the results of our second study, we say as a conclusion that the oral Cr supplementation, combined with therapeutic strategy, effectively supports the rehabilitation of tendon overuse damage of adolescent fin swimmers.

If we provide adequate precautions and supervision, the Cr supplementation is also acceptable for children and adolescent athletes, to complement and support their training, improve training adaptation and reduce the risk of injury. In line with the latest ISSN resolution, we recommend that Cr be used by athletes under 18 years of age, who participate in serious, high-level, supervised training, follow a balanced diet and know and adhere to the recommended dosage of Cr. Our results can be used directly to optimize the performance of our domestic adolescent fin swimmers, and to further improve effectiveness.

We think, that the Cr supplementation should be used by young athletes receiving intensive training. Potentially overused young athletes are optimal and a personalized plan should be part of their sport-specific nutrition strategy, actively supporting and complementing the conservative methods and therapies used in regeneration and rehabilitation.

6. Publications

Original articles published in the topic of the PhD Thesis

Juhasz I, Gyore I, Csende Z, Racz L, Tihanyi J. (2009) Creatine supplementation improves the anaerobic performance of elite junior fin swimmers. Acta Physiol Hun, 96: 325-36.

Juhasz I, Kopkane Plachy J, Hajdu P, Szalay G, Kopper B, Tihanyi J. (2018) Creatine Supplementation Supports the Rehabilitation of Adolescent Fin Swimmers in Tendon Overuse Injury Cases. J Sports Sci Med, 17: 279-88.

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