Effect of Creatine Loading on Anaerobic Performance and Skeletal Muscle Volume in NCAA Division I Athletes

Tim N. Ziegenfuss, PhD, Michael Rogers, PhD, Lonnie Lowery, PhD, Nicole Mullins, MS, Ronald Mendel, PhD, Jose Antonio, PhD, and Peter Lemon, PhD

From the Human Nutrition Research Laboratory, Kent State University, Kent, Ohio, USA; Rexall Sundown, Boca Raton, Florida, USA; and the School of Kinesiology, University of Western Ontario, London, Ontario, Canada

OBJECTIVE: We measured the effect of 3 d of creatine (Cr) supplementation on repeated sprint performance and thigh muscle volume in elite power athletes.

METHODS: Ten male (mean ± standard deviation of body mass and percentage of fat (81.1 ± 10.5 kg and 9.8 ± 3.5) and ten female (58.4 ± 5.3 kg and 15.0 ± 3.4) athletes were matched for sex and 10-s cycle sprint scores, paired by rank, and randomly assigned to the Cr or placebo (P) group. Subjects completed six maximal 10-s cycle sprints interspersed with 60 s of recovery before and after 3 d of Cr (0.35 g/kg of fat-free mass) or P (maltodextrin) ingestion. Before and after supplementation, 10 contiguous transaxial images of both thighs were obtained with magnetic resonance imaging.

RESULTS: Cr supplementation resulted in statistically significant increases in body mass (0.9 ± 0.1 kg, $P < 0.03$), total work during the first sprint ($P < 0.04$), and peak power during sprints 2 to 6 ($P < 0.10$). As expected, total work and peak power values for males were greater than those for their female counterparts during the initial sprint ($P < 0.02$); however, the reverse was true during the last three sprints ($P < 0.01$). Imaging data showed a 6.6% increase in thigh volume in five of six Cr subjects ($P = 0.05$).

CONCLUSION: These data indicate that 3 d of Cr supplementation can increase thigh muscle volume and may enhance cycle sprint performance in elite power athletes; moreover, this effect is greater in females as sprints are repeated. *Nutrition* 2002;18:397–402. ©Elsevier Science Inc. 2002

KEY WORDS: exercise, creatine loading, dietary supplements, ergogenic aid

INTRODUCTION

Exogenous creatine (Cr) feedings (20 g/d × 5–6 d) can add to the body's total creatine pool,[1,2] and up to 30% of this exists as phosphocreatine (PCr). Performance benefits have included increases in peak isokinetic knee[2] and isometric ankle extension and reductions in fatigue during dynamic and isometric exercise.[3–5]

Interestingly, not all studies have shown a performance improvement with Cr supplementation. For instance, reports using swimming[6] and running[7] showed no benefit with Cr supplementation. Further, an investigation by Cooke et al.[8] found no effect of Cr during a single bout of cycling exercise. The underlying reasons for equivocal results are unclear but may be related to design or statistical issues (e.g., lack of a control group, use of repeated *t* tests with no experimentwise correction, or the use of lengthy rest periods between repeated tests) in some of these studies.

Moreover, there is a dearth of published information on Cr supplementation in elite competitive athletes, particularly those involved in power sports (e.g., wrestling, hockey, basketball, and sprinting). We previously observed increased (14%) resting PCr/ATP (^{31}P magnetic resonance spectroscopy) within 48 to 72 h of Cr supplementation (20 g/d), resulting in ergogenic effects during intense repeated muscle contraction in untrained males.[3,9] Thus, we investigated whether 3 d of Cr supplementation in elite power athletes would affect sprint cycle performance and thigh muscle volume.

MATERIALS AND METHODS

Subjects

After Human Subject Review Board approval, 20 (10 males and 10 females) athletes in Division I of the National Collegiate Athletic Association were recruited from the university population to participate in the study. Eight of the 10 male athletes were university wrestlers and the other two were ice-hockey players. The female sample represented a wider range of sports: gymnastics (three), basketball (two), field hockey (two), softball (two), and track (one). For those athletes involved in team sports, care was taken to recruit individuals whose position required brief, intense, repeated activity (e.g., forwards and guards in basketball and midfielders in field hockey) to promote intersubject homogeneity of anaerobic power.[10,11] Subjects were in good health as determined by standard university physical examinations and medical history profiles; none reported the use of tobacco, steroids, diuretics, or oral contraceptives, and all regularly consumed meat in their diets. The female athletes who participated in this study menstruated regularly and were studied at least 7 d before the onset of menses. The nature, purpose, and attendant risks involved in the study were explained carefully to each subject before providing written consent to participate. No monetary compensation was provided.

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Correspondence to: Tim N. Ziegenfuss, PhD, 100 Nixon Hall, Kent State University, Kent, OH 44242, USA. E-mail: tzphd@hotmail.com

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Experimental Design

A double-blind, placebo-controlled, randomized-blocks design was used in this study. Subjects were grouped according to sex, paired by rank according to on 10-s cycle ergometer sprint scores, and randomly assigned to a Cr ($n = 10$) or placebo ($n = 10$) group. Subjects then visited the laboratory on five separate occasions. During the initial visit, subjects reported to the laboratory for the determination of (after an overnight fast) body volume by hydrostatic weighing at residual volume. Determining exact residual volume was unnecessary because the primary purpose of the body composition analysis was to determine the relative Cr dose, so the resulting small error in fat-free mass (FFM) estimation was considered unimportant. As such, constant values were used for residual lung volume (1200 mL for males and 1000 mL for females[12]). Body density was computed as body mass divided by body volume. Body fat was then estimated according to the equation of Brozek et al.[13]; FFM was calculated by subtraction (body mass minus fat mass). Visits 2 and 3 were separated by at least 48 h and used as ranking sessions; after a standardized warm-up (i.e., 5 min of cycling at 25 W), subjects performed a single 10-s cycle ergometer sprint at a load of 10% of their body mass. The average mean power of those two efforts was used to place subjects into ranked pairs that were then randomly assigned to the Cr or P group. Visits 4 and 5 were used for pre-and posttesting, respectively, of anaerobic exercise performance (repeated cycle sprints) and thigh muscle volume (magnetic resonance [MR] imaging). To control extraneous factors that might confound test results (e.g., physiologic variations in energy levels), subjects reported to the laboratory after following standardized procedures (e.g., same time of day [$\pm$1 h], $\geq$8 h postprandial, $\geq$24 h postexercise). A cross-over design was deemed unfeasible based on previous evidence of a protracted ($\geq$5 wk) Cr wash-out period.[9,14]

Supplementation

Using a double-blind procedure, subjects were given a container of powdered grape drink mix containing a 3-d supply of maltodextrin (~20 g as placebo) or Cr monohydrate (American Biorganics, Aurora, OH, USA). Pilot work indicated that these mixtures were unidentifiable by color, texture, or taste. The 3-d dosage regime was adopted because the greatest increase in total intramuscular Cr[1] and PCr/ATP[9] occurs within 48 to 72 h of Cr consumption; moreover, the coingestion of Cr in a high glycemic beverage enhances its uptake into skeletal muscle[15]; also, carbohydrate taken with Cr during training may result in better performance gains than supplementing with Cr alone.[16] The Cr dose was adjusted to FFM because differences in muscle mass affect the absolute size of an individual's Cr pool and might contribute to large individual variations in the amount of creatine retained.[11] Every 2 to 3 h, subjects ingested 0.07 g/kg of FFM of Cr monohydrate or placebo in 500 mL of room-temperature grape drink (with breakfast, lunch, dinner, and two snacks). This amount of Cr was approximately 10 to 20 times that found in a normal mixed diet and was shown to elevate plasma Cr from 14 to 100 μM/L to over 500 μM/L (a value equal to its K_m in rat extensor digitorum longus) and increase total Cr and intramuscular PCr stores by 14% to 30%.[1,11]

Dietary Control

To control for any changes in muscle fluid volumes resulting from alterations in nutrition and hydration status, subjects completed detailed dietary records of all ingested foods and beverages 5 d before initial testing. This included documentation of the quantity of food (estimated by serving sizes and measuring cups), method of preparation, and time of day ingested. Using these records, diet was reproduced as closely as possible during the 5 d that preceded posttesting.

Exercise Test Protocol

Before the first exercise test, each subject was familiarized with sprint cycling via verbal instruction and two practice sessions. After an overnight fast and 24 h after the last supplement dose, each subject performed an exercise protocol designed to repeatedly stress the PCr/ATP system.[5,17–19] This consisted of six 10-s sprints of maximal effort on a friction-loaded cycle ergometer (Monark 864, Varberg, Sweden) modified with toe clips and a racing seat. A frame-mounted optical sensor relayed the passage of 16 equidistant reflective markers on the flywheel perimeter to a microcomputer; those signals were subsequently converted to pedaling frequency and power values by commercially purchased software (Sports Medicine Industries, Inc., St. Cloud, MN, USA). After a standardized warm-up (5 min at 50 rpm $\times$ 0.5 kg and two 30-s periods at 85 and 100 rpm $\times$ 1.5 kg separated by 60-s rest), 5 min of rest, and a brief (2 to 3 s) unloaded acceleration period, subjects pedaled as fast as possible against a load of 0.10 kg/kg of body mass for 10 s (the flywheel strap was positioned over a pulley, making direct instantaneous application of the resistance possible). The load was specifically chosen to generate near-maximal power outputs in these athletes.[20,21] Consistent verbal encouragement and temporal feedback were given during each sprint, but no performance information was provided. Subjects were required to remain seated on the ergometer at all times to prevent the recruitment of other major muscle groups. During each 60-s recovery period, subjects pedaled against a 0.5-kg load at a self-selected pace; at no time did power output exceed 25 W. This active recovery period was chosen to hasten the removal of lactic acid[22,23] and reduce the contribution of anaerobic glycolysis to the energy yield during later sprints.[17,24] The fit of the ergometer (i.e., seat height) was recorded during the initial trial and reproduced during posttesting. A 10-min cool down period followed the final sprint and was used to facilitate venous return and reduce nausea.

Anaerobic Exercise Performance Indices

Two indices of anaerobic exercise performance were measured during each sprint: peak power, the highest power output produced during any second, and total work, the product of the applied resistance and the total distance covered. Previous investigators have used similar repeated cycle sprints of various durations (6 to 30 s) and reported test–retest reliability coefficients of at least 0.93 for peak and total work.[25,26] Peak and total work are expressed relative to each subject's hydrostatically determined FFM, i.e., in watts and joules per kilogram of FFM, respectively, because it was presumed Cr supplementation would alter body mass.

Magnetic Resonance Imaging

MR images were obtained with a 1.5-Tesla Signa whole-body imager (General Electric, Milwaukee, WI, USA). All subjects were positioned supine on the imaging table, with their ankles secured with adhesive tape to minimize motion artifact. Ten 1-cm–thick transaxial images were obtained 120 cm distal to the proximal border of the right femoral head. This standardized distance avoided anatomic interference from the gluteal muscles (superiorly) and the knee joint (inferiorly) and provide clear images with predominant muscle volumes.[27] A 100% interimage gap eliminated cross-talk (interimage interference); contiguous muscle volumes were then obtained by sequential arrangement of the images. A spin-echo sequence with a 500-ms repetition time and 12-ms echo time was used for all acquisitions. The resulting T1-weighted images were obtained on a 256 $\times$ 256 array of pixels within a 400-mm rectangular field of view. Image data were transferred

from 9-mm magnetic tape to an Iris 3020 Silicon Graphics computer (Mountain View, CA, USA) for processing. Separation and quantitation of muscle and non-muscle masses was performed by using software developed at Queens University (Kingston, ON, Canada). Briefly, this involves conversion of the MR images to 256 gray levels and histogram segmentation of the muscle and non-muscle compartments. MR slices were reviewed with an interactive slice editor program that allowed for verification and correction of the segmentation result by superimposing the original gray-level image on the binary segmented image.[28,29] Each image required approximately 3 min to process; thus total processing time was approximately 30 min per subject.

Muscle tissue areas for each image were calculated automatically by summing the labeled pixels and multiplying by the pixel surface area (2.93 cm^2). Muscle volumes (cm^3) of each image were calculated by multiplying the muscle tissue area (cm^2) by the slice thickness (1 cm). Midthigh muscle volume was then determined by summing the volumes of all 10 slices. A single-blinded operator determined all muscle areas and volumes. Intraoperator reliability was assessed by comparing duplicate MR images (30 total) from three subjects. The intraclass correlation coefficient between these measurements was computed from a one-way analysis of variance ($R = 0.99$). MR determination of lean tissue areas was shown to have a coefficients of variation of 0.7% to 1.2% for single images and 2.0% to 3.9% for lean tissue volumes.[27,29] Ferrando et al.[27] found that MR-derived images allow the assessment of changes of as little as 3% in muscle volume.

Data Treatment and Analysis

Commercially available software (Statistica, StatSoft Inc, Tulsa, OK, USA) was used to analyze the data. Data are expressed as means ± standard deviation (SD) and standard error (SE), as indicated. Due to intersubject variability and differences between groups after the pretest, a three-way ($2 \times 2 \times 6$, group × sex × sprint) mixed-model analysis of covariance (ANCOVA) with repeated measures on the last factor was used to determined the effects of Cr supplementation on each index of anaerobic exercise performance. Each pretest (sprint) score served as the covariate to analyze group factors. The assumption of ANCOVA procedures were observed and followed. A two-way (2×2, group × time) mixed-model analysis of variance with repeated measures on the last factor was used to determine the effects of Cr supplementation on muscle volume. Post hoc tests included effect size (to assess treatment effect) and Newman–Keuls (to clarify the location of mean differences). A 90% level of confidence ($P \leq 0.10$) was chosen to indicate statistical significance (i.e., predictability) because, in these athletes, the relative cost of a type II error is greater than that of a type I error. However, actual *P* values are reported so that readers can make comparisons with their own choice of critical values.

RESULTS

Physical Characteristics

Notably, these athletes exhibited anaerobic power values (Table I) considerably higher than those previously reported.[30] As expected, the male athletes had higher peak power scores, more body mass and FFM, and less body fat than did their female counterparts ($P < 0.05$).

A statistically significant ($P < 0.03$) increase in body mass was noted in the Cr group (66.7 ± 3.1 to 67.6 ± 3.0 kg), whereas no change was observed in the P group. Without muscle biopsy or MR spectroscopic data, the increase in body mass in the Cr group is consistent with an increase in intramuscular Cr, PCr, and body water.[1,31]

TABLE I.

DESCRIPTIVE CHARACTERISTICS*

Variable	Females ($n = 10$)	Males ($n = 10$)
Age (y)	21.3 ± 1.1	20.5 ± 1.9
Body mass (kg)	58.4 ± 5.3	81.1† ± 10.5
Body fat (%)	15.0 ± 3.4	9.8† ± 3.5
Fat-free mass (kg)	49.6 ± 5.2	72.8† ± 8.4
Peak power (w/kg FFM)	17.7 ± 0.5	18.7† ± 0.4

* Values are presented as mean ± standard deviation.
† Statistically different ($P < 0.05$) from corresponding the female value.

Anaerobic Exercise Performance

Despite using a randomized-blocks design, consistent differences were noted between the Cr and P groups in anaerobic performance indices after the pretest, so ANCOVA was used to analyze these data. Conforming to ANCOVA procedures, the homogeneity-of-slopes assumption was not violated; significance values (for the six sprints) ranged from 0.31 to 0.82 (peak power) and from 0.21 to 0.86 (total work). Further, the correlations between each covariate and the dependent variables ranged from 0.76 to 0.88 (peak power) and from 0.78 to 0.89 (total work); all were statistically significant ($P < 0.01$). There were no three-way interactions for any of the variables; therefore, statistically significant two-way interactions were examined. Group × time interactions were found for peak power ($P < 0.10$) and total work ($P < 0.04$). Post hoc analyses (Neuman–Keul) showed that peak power values in the Cr group were significantly greater than those in the P group during sprints 2 through 6 ($P < 0.01$; Fig. 1) and that total work in the Cr group was significantly higher during the first sprint ($P < 0.01$; Fig. 2).

Statistically significant sex X sprint interactions also were noted for peak power ($P = 0.01$) and total work ($P = 0.01$). During sprints 1 and 2, peak power values were significantly higher in the males ($P < 0.02$; Fig. 3) but the reverse was true during sprints 4 through 6 ($P < 0.01$).

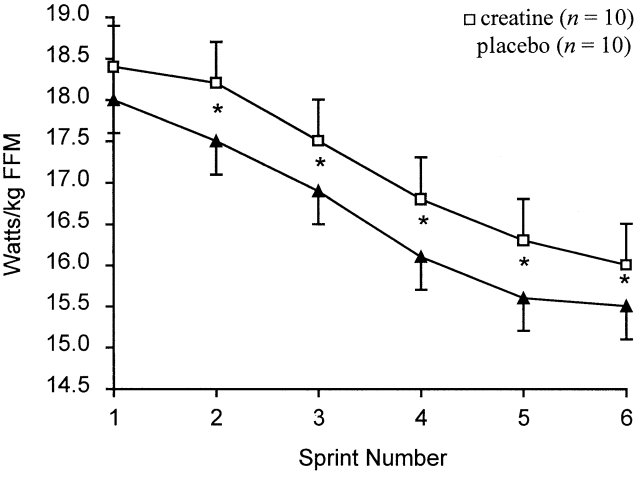

FIG. 1. Mean ± standard error of group × sprint analysis of covariance for peak power (postscores are shown; prescores were used as the covariate). The creatine group achieved greater (*$P < 0.05$) peak scores during sprints 2 to 6. In addition, relative to sprint 1, peak power was significantly lower ($P < 0.01$) during sprints 2 to 6 (placebo group) and sprints 3 to 6 (creatine group). FFM, fat-free mass.

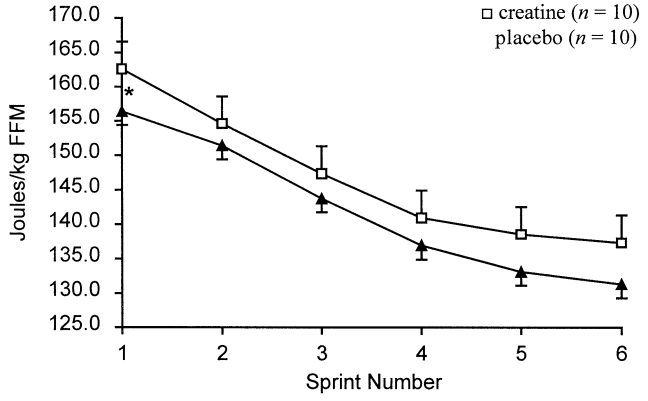

FIG. 2. Mean ± standard error of group × sprint analysis of covariance for total work (postscores are shown; prescores were used as the covariate). The creatine group produced significantly more total work (*$P < 0.01$) during sprint 1 than did the placebo group. In addition, relative to sprint 1, total work was significantly lower ($P < 0.01$) during sprints 2 to 6 in both groups. FFM, fat-free mass.

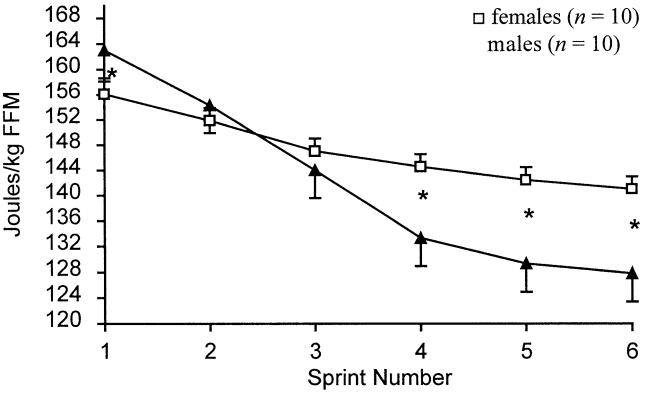

FIG. 4. Mean ± standard error of sex × sprint analysis of covariance for total work (postscores are shown; prescores were used as the covariate). Males outperformed females during the first sprint (*$P < 0.05$); the reverse was true during sprints 4 to 6. In addition, relative to sprint 1, total work was significantly lower ($P < 0.01$) during sprints 2 to 6 in both groups.

The same general trend held for total work values; that is, males outperformed females during sprints 1 and 2 ($P < 0.01$) and females outperformed males during sprints 4 through 6 ($P < 0.01$; Fig. 4).

Muscle Volume

Due to an error during transfer to magnetic tape, data from six subjects (four Cr and two P) were lost during testing. Despite this reduced statistical power, a 6.6% increase in midthigh muscle volume (Fig. 5) was found after Cr supplementation in five of six subjects (3258 ± 427 mL to 3487 ± 386 mL; $P = 0.05$). No effect was noted in the P group (3183 ± 306 mL to 3176 ± 292 mL).

DISCUSSION

The main objective of this study was to determine the effects of acute (i.e., 3 d) Cr supplementation on anaerobic power and thigh muscle volume in a group of elite power athletes. The major findings were: 1) Cr supplementation improved peak power during sprints 2 through 6 and total work during sprint 1, 2) male athletes outperformed (measured as relative power) their female counterparts during initial sprints and the reverse was true during later sprints, and 3) Cr supplementation increased midthigh muscle volume. Our results are intriguing in that the subjects were elite power athletes who competed in various Division I collegiate sports. Finding a performance effect in these subjects is noteworthy considering that their anaerobic power scores were excellent before supplementation. Further, the exercise test was designed to heavily tax the energy systems that Cr supplementation is most likely to affect: the phosphagen system and anaerobic glycolysis and glycogenolysis. Also, this is the first study to show a potentiation in performance after only 3 d of Cr supplementation. These results were not totally unexpected, considering the greatest increase in total Cr and PCr occurs within the first 2 d of supplementation.[1] Our own data using ^{31}P magnetic resonance spectroscopy concurs with this finding as the increase in PCr/ATP after Cr supplementation was essentially complete in 72 h.[9]

Although these data support the findings of Greenhaff et al.,[2,31] Birch et al.,[4] and Vandenberghe et al.,[32] we have concerns regarding those studies. In the study by Greenhaff et al.,[2] subjects performed five sets of 30 maximal isokinetic knee extensions interspersed with 60-s rests. A close look at Figure 1 of that study, however, shows large initial differences between the Cr (six males)

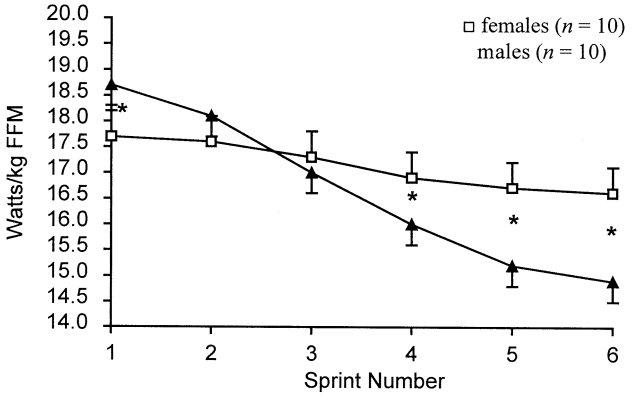

FIG. 3. Mean ± standard error of sex × sprint analysis of covariance for peak power (postscores are shown; prescores were used as the covariate). Males outperformed females during the first sprint (*$P < 0.05$); the reverse was true during sprints 4 to 6. In addition, relative to sprint 1, peak power was significantly lower ($P < 0.01$) during sprints 2 to 6 in males and sprints 3 to 6 in females. FFM, fat-free mass.

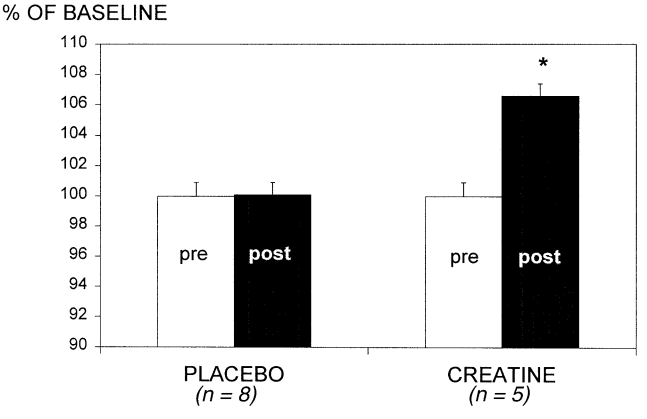

FIG. 5. Change in midthigh muscle volumes as a percentage of baseline values. A significant (*$P = 0.05$) increase in muscle volume was noted in the creatine group, whereas no change was found in the placebo group.

and P (three males, and three females) groups. Similarly in the study by Birch et al.,[4] during each of three 30-s cycle sprints interspersed with 4 min of recovery, the post scores in the Cr group were less than the pre scores of the P group. These two studies underscore the need to match subjects according to pretest scores before random group assignment or consider alternative statistical procedures (e.g., ANCOVA). In the present study a randomized-blocks design was used to reduce initial group differences, an often overlooked procedure that can reduce the chances of obtaining spurious results. Further, in both of the aforementioned studies, repeated *t* tests were used to assess differences of between-group means. Although this approach is appropriate with only two groups, making multiple comparisons (with no experimentwise correction, e.g., Bonferroni) will inflate the actual α-level, potentially resulting in a type I error. Balsom et al.[33] compared cycle performance during five 6-s sprints interspersed with 30 s of recovery, followed (40 s later) by a single 10-s bout. Unfortunately, repeated *t* tests were used to analyze the data and, even more importantly, no control group was used. Clearly, given the potential for placebo effects in supplement studies, inclusion of a P group is critical. Also, Vandenberghe et al.[32] reported ergogenic effects after 6 d of Cr ($0.5 \text{ g} \times \text{kg}^{-1} \times \text{d}^{-1}$), but not after Cr and caffeine ingestion. Despite the elegant measurements in this study, the period for wash-out (3 wk) between each experimental condition (Cr, P, and Cr + caffeine) may have been inadequate, making interpretation of the results difficult. As previously mentioned, data from our laboratory[9,14] indicated that a 5 week wash-out between treatments may even be inadequate in some individuals, particularly those who consume meat on a regular basis. Logically, it is possible that once an individual "loads" with Cr, intramuscular levels of Cr and PCr might be maintained simply by consuming adequate meat (e.g., beef, pork, salmon, and tuna all contain between 4 to 5 g Cr/kg). Interestingly, Hultman et al.[34] suggested that, after using the classic Cr-loading procedure (4×5 g/d for 5 d), lower doses at the approximate endogenous rate of Cr degradation (2 g/d) can maintain elevated muscle Cr stores for weeks.

The present findings contradict the investigation by Cooke et al.[8] who reported no effect of Cr supplementation on power output during high-intensity cycle exercise. However, unlike the present exercise test (multiple sprints, short rest periods), those investigators allowed a 20-min rest period between the two successive 15-s sprints. Snow et al.[35] found no ergogenic effect (20-s maximal sprint on a cycle ergometer) of 5 d of Cr supplementation (30 Cr/d + 30 g dextrose) despite a 9.5% increase in total Cr content of the vastus lateralis. Perhaps this increase, although significant, was not sufficient to produce an increase in sprint performance. Further, the subjects in those studies were untrained, unlike those in the current study. Untrained subjects will experience an improved performance simply from neural adaptation. This neural adaptation may have masked any possible ergogenic effect.

Although the mechanisms governing the ergogenic effect of Cr are not entirely understood, several theories have been proposed. Greenhaff et al.[31] used electrically evoked contractions of the knee extensors and serial (0, 20, 60, and 120 s) biopsies and found improvements in PCr resynthesis during recovery after 5 d of Cr supplementation. Perhaps an increase in functional cross-bridges occurs due to greater ATP availability. Bessman et al.[36] suggested that interactions between Cr and PCr can increase protein synthesis and influence muscle hypertrophy, but clearly, given the short period of supplementation in this study, a morphologic explanation is highly unlikely. Perhaps, as has been suggested for caffeine, Cr has multifactorial ergogenic effects affecting tissues other than skeletal muscle (e.g., nervous). This area deserves future consideration.

An unexpected finding in the present study was that female power scores, expressed relative to FFM, were higher than male scores during the last three sprints. This is in contrast with the study by Earnest et al.[37] who found that anaerobic performance improved approximately two-fold better in men than in women as measured by the Wingate test. Although there is little evidence supporting a difference in Cr levels between males and females,[11] the rate of PCr degradation is greater in type II fibers[38] and the rate of PCr resynthesis is faster in type I fibers.[39] Although the fiber type distribution of these athletes is unknown, if males had a greater preponderance of fast twitch fibers in their quadriceps, the aforementioned factors could help explain the present results. A second possibility is that, because eight of the 10 men participated in a sport where upper body power predominates (e.g. wrestling) and the women participated in multiple sprint sports requiring lower body power, the exercise test used to assess the effects of Cr supplementation favored females from the start. It is also possible that females were in better shape (relatively speaking) during the study.

Similarly, the lack of an improvement in fatigue index after Cr ingestion was surprising. Vandenberghe et al.[32] reported a similar finding during repeated isokinetic knee extensions and suggested that Cr supplementation does not delay fatigue during continued high-intensity exercise but rather enhances recovery during rest periods. This explanation is consistent with these and previous studies showing ergogenic effects after repeated[4,5] but not after single[8] exercise efforts. Further, Bogdanis et al.[19] showed that PCr resynthesis is a two-phase process with rapid and slow components, both of which are directly influenced by muscle blood flow. Therefore, it is plausible that the (active) low-intensity recovery periods enhanced oxygen availability and increased muscle pH, resulting in similar rates of fatigue in each supplement group.

Interestingly, the MR data showed a statistically significant 6.6% increase in midthigh muscle volume after Cr supplementation. The important question is, what accounts for the increase in muscle volume: water, protein, or some combination of both? Using multifrequency bioimpedance analysis to assess changes in body fluid compartments after Cr supplementation, prior data[14] suggested that approximately 90% of the weight gain associated with the initial days of Cr supplementation can be accounted for by increases in total body water, and that much of this increase is contained within the intracellular compartment, at least when Cr is coingested with a high glycemic index beverage.

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